Recommendations of the Expert Panel to Define Removal Rates for Street and Storm Drain Cleaning Practices

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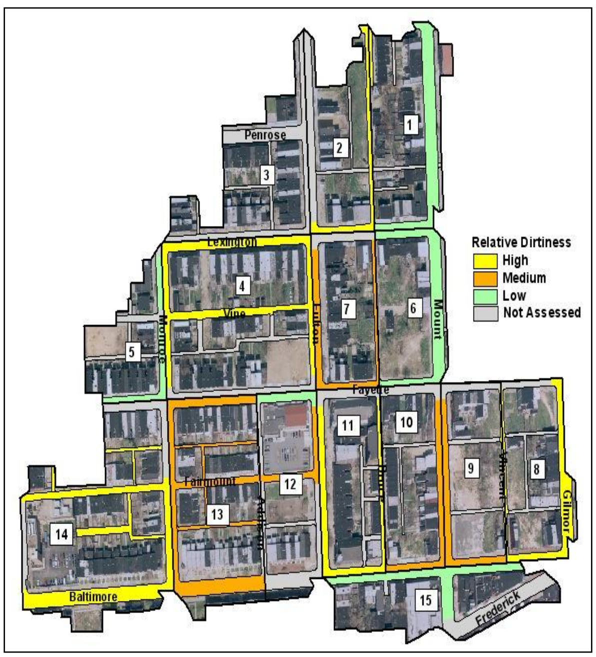
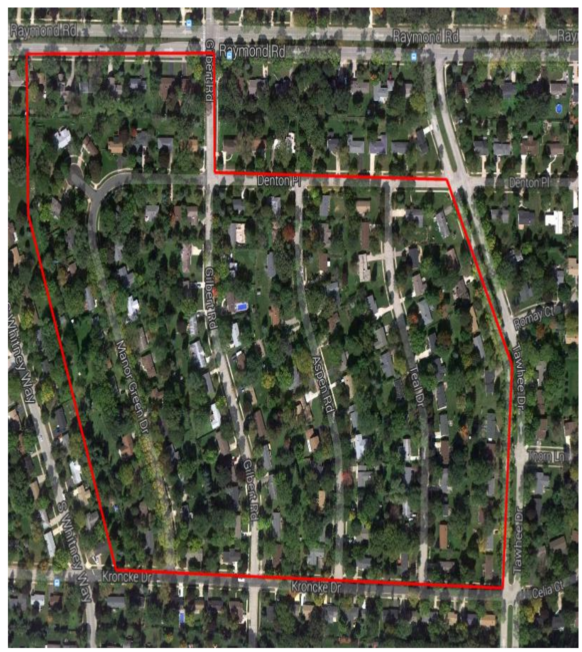
FINAL REPORT

Approved by CBP Management Board





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The following is a list of common acronyms used throughout the text:

ADT	Average Daily Traffic Volume
BMP(s)	Best Management Practice(s)
CBP or CBPO	Chesapeake Bay Program Office
CBWM	Chesapeake Bay Watershed Model
EMC	Event Mean Concentration
HUC	Hydrologic Unit Code
MS4	Municipal Separate Storm Sewer System
NEIEN	National Environmental Information Exchange Network
NPDES	National Pollutant Discharge Elimination System
Rv	Runoff Coefficient
SOP	Standard Operating Procedure
STAC	Scientific and Technical Advisory Committee
TMDL	Total Maximum Daily Load
TN or N	Total Nitrogen
TOC	Total Organic Carbon
TP or P	Total Phosphorus
TSS	Total Suspended Solids
USWG	Urban Stormwater Work Group
WinSLAMM	Source Loading and Management Model for Windows
WIP	Watershed Implementation Plan
WQGIT	Water Quality Goal Implementation Team

Summary of Panel Recommendations

An expert panel was formed in 2013 to re-evaluate how sediment and nutrient removal credits are calculated for street and storm drain cleaning, which is an existing BMP approved by the CBP partnership.

While street cleaning is a common municipal practice across the Chesapeake Bay watershed, it is not widely credited at the present time for pollutant reduction, given that most communities either do not sweep frequently enough or use ineffective sweeper technology.

The panel reviewed new research conducted over the last ten years on (a) nutrient and sediment loading from streets, roads and highways (b) the particle size distribution and nutrient, carbon and toxic enrichment of urban street dirt and sweeper waste, and (c) ten recent research studies that evaluated the effect of different street sweeping scenarios on different street types across the country. Based on this review, the panel concluded:

- Road runoff has moderately higher nitrogen concentrations than other forms of impervious cover, and may merit its own land use in Phase 6 of the Chesapeake Bay Watershed Model (CBWM).

- The accumulation rate, particle size distribution and pollutant content of street solids follows a relatively consistent and uniform pattern across the nation. These relationships provide a strong empirical basis for modeling how solids are transported from the street to the storm drain.

- Street cleaning may be an excellent strategy to reduce the toxic inputs from urban portions of the Chesapeake Bay watershed, given the high level of toxic contaminants found in both street solids and sweeper wastes.

- The water quality impact associated with street cleaning will always be modest, even when it occurs frequently. Mechanical broom sweepers have little or no water quality benefit. Advanced sweeping technologies, however, show much higher sediment reduction potential.

- Street parking and other operating factors can sharply reduce sweeper pick-up efficiency.

- The adjacent tree canopy influences the organic and nutrient loads on the street on a seasonal basis, but the management implications for this phenomenon are unclear. Future panels should revisit this concept as more monitoring data becomes available.

- The ten sweeper studies published since 2006 have produced a lot of quantitative data on the sediments and nutrients that are picked up by sweepers, but none were able to measure a detectable water quality change within storm drains that can be attributed to upland street cleaning. One key reason is the high variability that often occurs in street runoff can outweigh a measurable signal due to street cleaning. To date, researchers have been unable to collect enough paired stormwater samples to detect a statistically significant difference due to treatment. Consequently, most researchers now rely on simulation or mass balance models to quantify the impact of street cleaning.

The panel agreed that modeling was the best available approach to derive sediment and nutrient reduction rates associated with street cleaning, given the dearth of studies that showed measurable water quality change in receiving waters. The panel elected to use the Source Loading and Management Model for Windows (WinSLAMM), and supervised the work of a consultant to develop a Chesapeake Bay application of the model. The model was selected because it has (a) a module to assess sediment reduction for a wide range of street cleaning scenarios, (b) been calibrated to empirical data on street solid build-up and wash-off and (c) been used to estimate pollution reduction credits for street cleaning for TMDLs in two states.

The panel used the model output from the Chesapeake Bay version of WinSLAMM to develop its protocol for calculating sediment and nutrient reductions associated with different street cleaning scenarios. The model was used to simulate the expected annual sediment reduction for 960 different street cleaning scenarios, which included 3 different lengths for winter shutdown, 4 types of streets, 2 sweeper technologies, 10 different cleaning frequencies, and 4 combinations of street parking conditions and controls.

Pollutant Reductions Associated with Different Street Cleaning Practices

Practice #	Description [1]	Approx Passes/Yr [2]	TSS Removal (%)	TN Removal (%)	TP Removal (%)
SCP-1	AST- 2 PW	~100	21	4	10
SCP-2	AST- 1 PW	~50	16	3	8
SCP-3	AST- 1 P2W	~25	11	2	5
SCP-4	AST- 1 P4W	~10	6	1	3
SCP-5	AST- 1 P8W	~6	4	0.7	2
SCP-6	AST- 1 P12W	~4	2	0	1
SCP-7	AST- S1 or S2	~15	7	1	4
SCP-8	AST- S3 or S4	~20	10	2	5
SCP-9	MBT- 2PW	~100	0.7	0	0
SCP-10	MBT- 1 PW	~50	0.5	0	0
SCP-11	MBT- 1 P4W	~10	0.1	0	0

AST: Advanced Sweeping Technology MBT: Mechanical Broom Technology
[1] See Table 15 for the codes used to define street cleaning frequency
[2] Depending on the length of the winter shutdown, the number of passes/yr may be 10 to 15% lower than shown

A spreadsheet tool was used to define percent nutrient removal rates by applying a nutrient enrichment ratio to the mass of sediments removed per acre in each street cleaning scenario, and subtracting the resulting nutrient load from the unit area nutrient load for impervious cover calculated by the Chesapeake Bay watershed model.

For the sake of simplicity, the panel elected to consolidate the model results to show removal rates for eleven different street cleaning practices, primarily involving the use of different street cleaning technology at different frequencies, as shown in the preceding table.

In general, one impervious acre is equivalent to one curb-lane mile swept for streets. The street sweeping credit is an annual practice, so communities need to submit the total number of curb lane miles swept under the appropriate street cleaning scenario.

The panel recommended that MS4 communities report their annual street cleaning effort in the annual MS4 reports they submit to their state stormwater agency. Localities may also need to maintain records to substantiate their local street cleaning effort (e.g., length of routes swept, frequency, sweeper technology and parking conditions/controls, etc.).

In addition, the panel recommended a strong verification program to document local street cleaning effort over time and provide additional data on sweeper waste characteristics.

The panel also recommended a second sediment and nutrient removal credit for solids that are directly removed from catch basins, within storm drain pipes or are captured at stormwater outfalls. The sediment credit is based on the dry weight of the mass of solids captured and removed, whereas the nutrient reduction is determined by multiplying the mass of solids by a default nutrient enrichment factor.

The storm drain credit rewards innovative efforts to manage sediment and organic matter that reaches the storm drain system and therefore has a much higher chance of being transported downstream to the Bay.

The panel established three qualifying conditions to ensure that the storm drain cleaning efforts have a strong water quality focus.

1. To maximize load reduction, efforts should be targeted to catch basins that trap the greatest organic matter loads, streets with the greatest overhead tree canopy and/or outfalls that generate higher sediment or debris loads.

2. The load removed must be verified using a field protocol to measure the mass or volume of solids collected within the storm drain pipe system. This may also entail periodic sub-sampling of the carbon/nutrient content of the solids that are captured.

3. Material must be properly disposed so that it cannot migrate back into the watershed

The panel agreed that the two existing methods for calculating pollutant reduction for street cleaning should be phased out. The existing "qualifying lane miles method" in Appendix A should be replaced by the more versatile credit proposed by this expert panel as soon as possible. The existing "mass loading method" for street cleaning may continue to be used until 2017, but should be completely phased out when the Phase 6 Chesapeake Bay Watershed Model becomes operational in 2018.

The panel also recommended a long term research strategy to provide managers with the better data to improve the effectiveness of future street and storm drain cleaning programs. In addition, the panel outlined several priorities to improve the capacity of communities to implement programs that can maximize pollutant reduction to local waterways and the Chesapeake Bay.

Section 1: Charge and Membership of Expert Panel

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In 2011, an expert panel recommended sediment and nutrient removal rates for intensive street sweeping in 2011, largely based on the research and literature review provided by Law et al (2008). However, the recommendations were made prior to the adoption of a uniform BMP review protocol, as outlined by the Water Quality Goal Implementation Team (WQGIT, 2014). In particular, the four page memo produced by the 2011 panel did not contain recommendations on how to report, track and verify the practice for credit in the Chesapeake Bay Watershed Model (CBWM), nor did it document the full body of research used to derive the recommended rates.

In addition, many localities requested that the panel broaden its scope to include more activities that remove sediments and vegetative debris from the storm drain system, such as catch basin cleanouts, municipal leaf collection, and the use of nets and screens to capture urban detritus at the outfalls of storm drain pipes. At the same time, researchers have tested the performance of a new generation of street cleaners, and have measured the nutrient content of sediment and detritus at various points of the street and storm drain system. Several protocols for defining nutrient and sediment removal rates for these practices were developed in response to several TMDLs in northeastern states which may be transferable to the Chesapeake Bay watershed.

A wide range of local and state stakeholders agreed at a session of the 2012 Bay-wide stormwater retreat that the expert panel should be re-convened and the BMP expanded in scope to address the above cited issues, and provide more options for localities to get verifiable credits for more active management of their street and storm drain network.

The initial charge of the panel was to review all of the available science on the nutrient and sediment removal performance associated with the regular cleaning of municipal street and storm drain infrastructure:

1. Street cleaning, with an emphasis on new developments in sweeper technology and operation.
2. Targeted catch basin cleaning to prevent nutrient and sediment deposits from migrating further down the storm drain system.
3. Municipal biomass (leaves, grass clippings etc) collection programs to keep detritus out of the street and storm drain system.
4. The use of nets, screens and other devices to capture urban detritus from stormwater outfalls prior to its delivery to receiving waters.

The panel was specifically requested to assess:

- The technical assumptions underlying the 2011 expert panel memo, along with its supporting research and literature review (Law et al, 2008).
- New street cleaning research from 2007 to the present, including USGS studies in MA, WI and elsewhere.
- The potential for credits for street cleaning frequencies that were less than that recommended by the original panel (i.e., 26 times per year).
- The technical support for pollutant reduction protocols developed in other regions of the country.
- Studies measuring the nutrient content of sediment and leaf detritus at various points in the urban landscape.
- Specific operational definitions for each of the four management practices defined earlier and the qualifying conditions under which a locality can receive a nutrient and/or sediment reduction credit.
- Appropriate procedures and units for reporting, tracking, and verification of the practice.

Beyond this specific charge, the panel was asked to:

- Evaluate whether the current procedures for simulating the wash-off of sediments and nutrients from impervious cover in the CBWM accurately reflect how sediments and vegetative detritus move through the storm drain system, and whether or not future versions of the CBWM may need a land use or land cover that better represents street and highway conditions.

- Take an adaptive management approach to refine the accuracy of its removal rate protocol, including any recommendations for further monitoring research that would fill critical management gaps.

- Critically analyze any unintended consequences associated with the nutrient management credit and any potential for double or over-counting of the credit.

While conducting its review, the panel followed the procedures outlined in the BMP review protocol, as amended (WQGIT, 2014). The process begins with BMP expert panels that evaluate existing research and make initial recommendations on removal rates. These, in turn, are reviewed by the Urban Stormwater Workgroup, and other Chesapeake Bay Program (CBP) committees, to ensure they are accurate and consistent with the Chesapeake Bay Watershed Model (CBWM) and the Scenario Builder tool.

Appendix C describes this report's conformity with the BMP review protocol (WQGIT, 2014). Minutes from the Panel's conference calls are provided as Appendix D.

Section 2: Key Definitions

This analysis of street and storm drain cleaning practices draws on complex terminology used by the scientific and practitioner communities. To assist the reader, the panel agreed to the following definitions to maintain consistency throughout the report.

Street Sweeping vs. Street Cleaning: Both terms are used interchangeably in the literature to describe the use of sweepers to pick up solids off the street surface. In the context of this report, street sweeping is used to denote the more historic approach to the practice (i.e., use of mechanical broom sweepers to improve street aesthetics and safety). The term "street cleaning" refers to the use of advanced sweeper technologies to improve water quality.

Solids Terminology:

- *Street Dirt*: the total mineral fraction of street solids of all grain sizes (clay to gravel), expressed in lbs/curb mile
- *Street Detritus*: the total organic fraction of street solids, typically comprised of leaves, grass clippings, pollen and other biomass
- *Street Solids*: The total mass of street dirt and detritus, as measured on the street surface, catch basin or sweeper hopper
- *Gross Solids:* Total mass of non-organic solids larger than gravel size, which represents trash and litter, and may be subject to a trash TMDL.

Solids Particle Size:

Although some differences exist among the cutoff thresholds in the literature, the following general definition was adopted.

- *Coarse-Grained Solids*: All particles greater than 1000 microns in diameter
- *Medium-Grained Solids*: All particles from 75 microns to 1000 microns in diameter
- *Fine-Grained Solids*: All particles less than 75 microns in diameter.

Street Sweeper Technology

- *Mechanical Broom Sweepers (MBS)*: Sweeper is equipped with water tanks, sprayers, brooms, and a vacuum system pump that gathers street debris
- *Regenerative-Air Sweepers (RAS):* Sweeper is equipped with a sweeping head which creates suction and uses forced air to transfer street debris into the hopper.

- *Vacuum Assisted Sweepers (VAS):* Sweeper is equipped with a high power vacuum to suction debris from street surface.

Note: For purposes of this report, the RAS and VAS sweepers both qualify as Advanced Sweeper Technologies (AST) and achieve higher pollutant removal rates, whereas MBS sweepers do not, and do not provide any pollutant removal.

Yields/Rates:

- *Street Solids Yield*: the mass, dry weight, of street solids, measured on the street before or after sweeping, expressed in terms of lbs/curb mile.

- *Sweeper Waste Yield*: the mass, dry weight, of street solids collected by a street sweeper, expressed in terms of tons.

- *Pick-up Efficiency:* The fraction of the available solids on the street that is effectively removed by a street sweeper, expressed as a percent, which varies based on sweeper technology.

- *Nutrient Enrichment Ratio*: Extractable nutrients found in either street solids or sweeper wastes, originally measured in mg/kg or lbs/ton, but converted to a percentage and applied to the effective sediment reduction rate to estimate nutrient reduction for different street cleaning scenarios.

- *Effective Sediment Reduction Rate:* the percent reduction in the unit area sediment loading rate associated with a qualifying street cleaning practices, as predicted by the WinSLAMM model. The sediment percent removal is then applied to the unit area sediment load for impervious cover derived by CBWM to determine the mass reduced.

Catch Basin Terminology

- *Catch Basin***:** A type of storm drain inlet that contains a sump. Typically a catch basin is constructed using a pre-cast concrete barrel installed vertically, with a cast-iron grated lid at the street surface.

- *Curb-cut Inlets:* A cut in the curb that allows stormwater runoff to enter into the inlet through bypassing the inlet grate.

- *Drop Inlet:* A type of storm drain inlet that does not contain a sump.

- *Deep Sump Hooded Catch Basin*: A type of catch basin that contains a sump that is at least 4 feet deep and a hood.

- *Hood:* A 90^{o} elbow installed at the outlet of a catch basin to reduce floatable material from the discharge.

- *Inlet:* a structure located below the ground surface with a grated lid at street level that drains road or parking lot runoff. Inlets are typically constructed adjacent to a road curb, and is covered by a cast iron grated lid with multiple openings (each opening no more than 2-inch square). The runoff is directed to drain pipes, then via an outfall to surface waters. May also be referred to as a storm drain.

- *Storm Drain Manhole*: A bend structure connecting stormwater drainage pipes that contains a solid cast-iron cover at street level.

- *Sump:* A trap located below the outlet invert of a catch basin. The purpose of the sump is to collect solids in stormwater runoff.

Other Key Terms:

- *Average Daily Traffic (ADT):* a measure of the traffic volume on a street, road or highway, expressed in vehicles per day. ADT is often used to classify streets, and distinguish between urban versus rural roads.

- *C:N:* The elemental ratio of carbon to nitrogen in vegetation and street detritus. The lower the ratio, the more N is potentially available. Freshly fallen leaves have a C:N ratio of about 60, but this drops to about 40 as they decompose (i.e., leaf compost), and fall to about 15 for grass clippings.

Section 3: Background on Street Cleaning in the Bay Watershed

3.1 Prevalence of Street Cleaning in the Chesapeake Bay

Our best understanding about local street cleaning programs comes from a detailed survey of 36 municipalities, most of which were located in the Chesapeake Bay Watershed (CWP, 2006b). This section summarizes the survey's key findings. It should be noted that local street and storm drain cleaning practices may have changed in the decade since the survey was conducted.

The first finding was that nearly all communities operate some kind of street sweeping program. The survey indicated that aesthetics and public demand were the main drivers for local street sweeping programs, with only one community citing nutrient removal as a major objective. Some of the key factors that determine which streets are swept include high traffic volume, residential demand, commercial areas, central business districts and proximity to environmentally sensitive areas (Table 1).

Table 1. Factors to select streets for enrollment in street sweeping program and sweeping frequency (n=20). Expressed as % of communities**.** CWP, 2006b

	Traffic volume	Land use	Target commercial areas	Residential demand	Proximity to ESA [1]	Loading rates
Street selection	45%	5%	45%	40%	10%	5%
Frequency	30%	5%	35%	35%	10%	5%

[1]. ESA = environmentally sensitive area

Municipal sweeping programs vary widely in their size and scope. The survey found communities sweep at least 70% of their public streets at least once a year, and that 85% of communities swept a subset of their streets more frequently. The proportion of streets that are swept ranged from 6% to 100% of all publicly-owned streets. Some communities sweep streets in early spring to remove sand and other material that were applied during winter snow removal operations. By contrast, fewer communities target sweeping efforts in the fall to pickup leaf detritus from their streets.

Less than 25% of the communities surveyed cleaned their streets frequently enough to qualify for the pollutant removal credits approved by CBP in 2011 (and then for only a smaller subset of their overall street network). Figure 1 summarizes the variability in sweeping frequency by communities that clean their streets more than once a year.

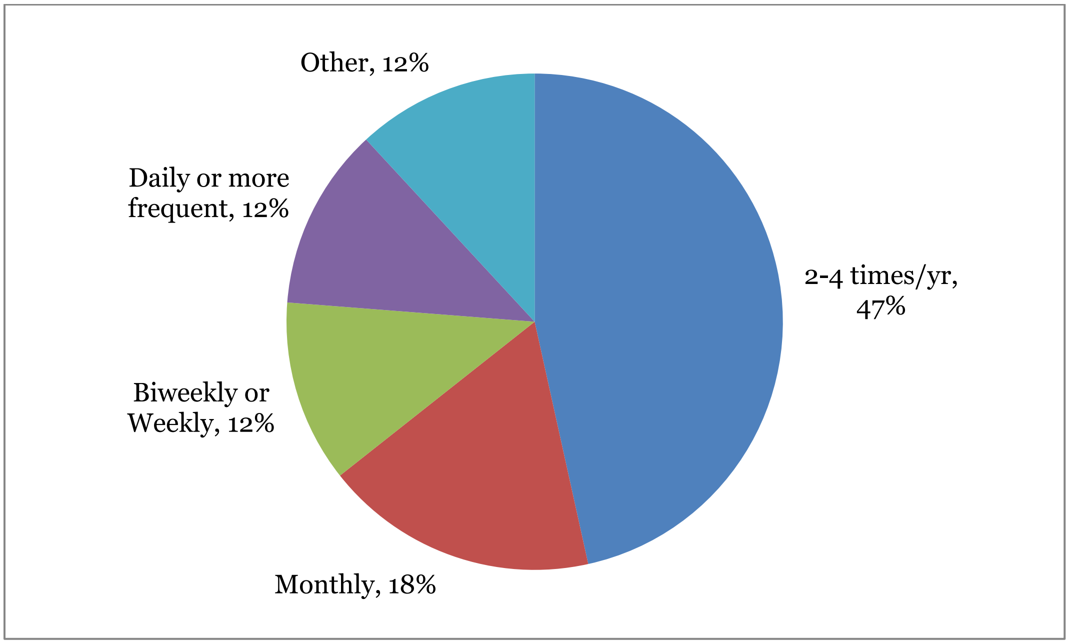

Figure 1. Percentage of communities that sweep more than once per year and the associated sweeping frequency (n=17) Source: CWP, 2006b

Street sweeper technology can have a strong influence on sediment pick-up efficiency. Newer vacuum-assisted sweepers or regenerative air sweepers have higher pickup efficiency than older mechanical broom sweepers. However, as of 2006, only 27% of the municipalities reported that they employed advanced street cleaning technology (Figure 2).

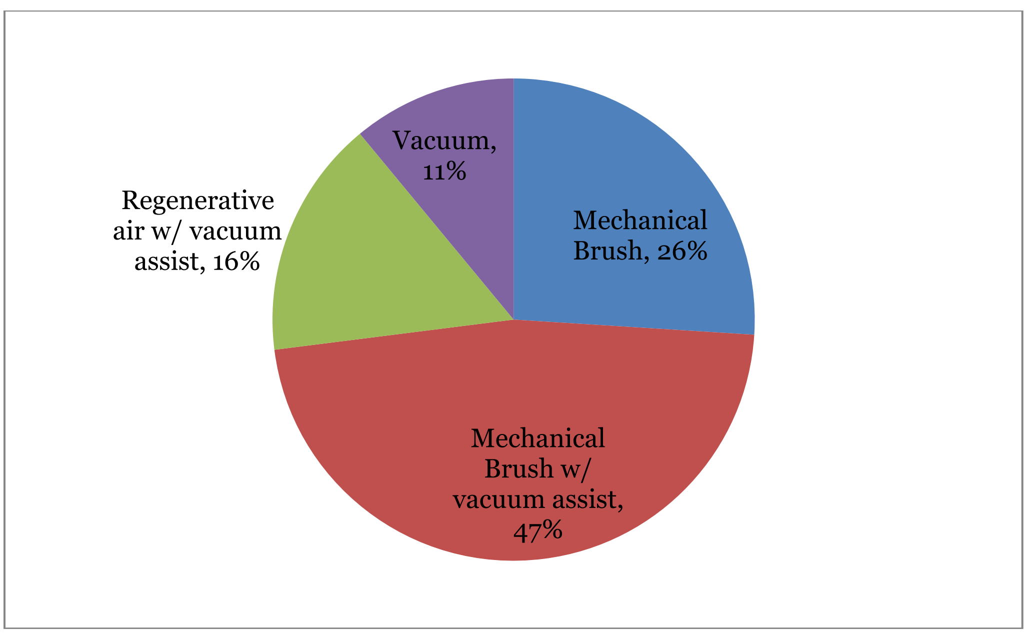

Figure 2. Most common street cleaning technology used by Chesapeake Bay communities (n=19) Source: CWP, 2006b

3.2 Catch Basin Cleanouts

The CWP survey also looked at how frequently communities clean out their storm drains (CWP, 2006b). The key finding was that only 40% of communities clean out storm drains on a regular schedule, with the remainder cleaning them only in response to public complaints or actual flooding problems. Overall, communities conduct storm drain cleanouts very infrequently -- 94% of communities clean them out less frequently than once a year (Table 2). Improving water quality was not cited as the primary objective of local storm drain cleanout programs.

Table 2. Storm drain cleanout frequency in the Chesapeake Bay (n=19)

Frequency	Percent
Seldom, if ever	23.5
Once every 3-4 years	29.4
Every 2 years	23.5
Annual	5.9
Twice a year	0
Other	17.6

3.3 Past CBP Street Cleaning Removal Credits

Appendix A summarizes the two methods for crediting street cleaning developed by the 2011 expert panel. The first method is termed the **mass loading approach**, and calculates sediment and nutrient removal based on the mass of street solids picked up by the sweeper fleet, with an adjustment for particle size. The second method is termed the **qualifying lane miles approach,** and calculates the load reduced based on the aggregate acres of road that are swept in a community that meet the qualifying conditions.

Both methods only apply to streets that are swept biweekly (26 times per year) or more frequently. For that reason, relatively few communities in the Bay watershed have reported the street sweeping credit in recent years. The 2011 expert panel did not include any procedures to verify local street cleaning efforts that are reported for credit. Consequently, there has been some confusion about how to report and track annual street cleaning efforts.

This is evident in the street cleaning implementation data that are submitted by the Bay states to the Chesapeake Bay Program each year (Table 3). Jurisdictions can report street cleaning effort in units of either acres swept or pounds collected, or both. To date, five states have reported street cleaning in their annual progress submissions since 2009, although reporting is not consistent or of uniform quality.

Table 3. Summary of Street Cleaning Implementation, 2009-2013, as reported and credited in annual progress runs (acres and lbs)

YEAR	DC	DE	PA	WV	VA
2009	1 ac			218,000 lbs	632 ac
2010	1,631 ac			227,000 lbs	
2011	1,540 ac		619 ac		75,385,792 lbs
2012	1,539 ac		413 ac		
2013	1,526 ac	79,541 lbs	3,240,489 lbs	190,000 lbs	218,677 lbs
2014	1,531 ac	413,367 lbs	3,367,040 lbs	700,000 lbs	426,671 lbs

3.4 How the CBWM Simulates Loads From Streets

The Phase 5.3.2 Chesapeake Bay Watershed Model simulates two types of urban land: pervious and impervious cover. These two cover types are used to simulate the full range of urban land use categories (industrial, commercial, residential, institutional and transport). This means that different street types (e.g., highways, arterials, residential streets) are lumped in with other impervious surfaces (e.g., driveways, sidewalks, rooftops, parking lots), and are currently represented as a single impervious layer. As a result, streets and roads do not load differently and are not counted separately in the current version of the CBWM. Table 4 portrays the average annual nutrient and sediment loadings associated with urban impervious cover in the current model.

Table 4. Loading Rates Associated with Urban Impervious Cover in the Chesapeake Bay Watershed Model, Version 5.3.2.

Acres in Watershed [1]	1,269,030
Average TN Load [2]	15.5 lbs/ac/yr
Average TP Load [2]	1.93 lbs/ac/yr
Average TSS Load [2]	0.65 t/ac/yr
Key Inputs	Air Deposition, Build-up/Wash-off, No Groundwater Interaction, No Direct Interaction with Pervious Cover

[1] Acres, as reported in most recent CBWM version 5.3.2
[2] Average values, as reported in Tetra Tech (2014), although actual values are regionally variable across the watershed.

It should be noted that not all of the sediment load generated from urban impervious cover actually reaches the Chesapeake Bay. The sediment loads at the edge of pavement are adjusted downward by a sediment delivery factor in the current version of the CBWM. For a more thorough discussion of the sediment delivery factor, please consult the discussion in SR EP (2014).

Section 4: Review of the Available Science on Street Cleaning

The expert panel reviewed more than 100 research papers during its deliberations. The major focus was on studies published after the last literature review used by the previous expert panel (CWP, 2006b). The national review focused on research that investigated:

(a) Nutrient and sediment loading from streets, roads and highways.

(b) The particle size distribution of urban street solids and sweeper wastes, as well as their nutrient, carbon and toxic content.

(c) The effect of different street sweeping scenarios on different street types across the country.

4.1 Nutrient and Sediment Concentrations in Road Runoff

The panel first investigated whether the nutrient and sediment concentrations in road runoff were different compared to other urban land uses or types of impervious cover. The panel relied on a recent re-analysis of the National Stormwater Quality Database (NSQD, Pitt, 2014) provided by Tetra Tech (2014). Over the last decade, the NSQD has roughly doubled in size, and now includes more than 8,000 storm event samples.

Some of the key findings from the analysis are shown in Figure 3, which compares the TN concentrations in stormwater runoff measured for different types of impervious cover. The mean TN concentration for transport land uses, which includes roads, streets and highways, was 3.11 mg/l, as compared to 1.98 mg/l for all other urban runoff samples. The higher TN concentration for transport land uses was considered statistically significant, based on Wilcoxon rank sum testing (Tetra Tech, 2014). The presumed explanation for the higher TN concentrations at transport land uses appears be related to vehicle emissions.

By contrast, the same analysis showed that TSS and TP concentrations from transport land uses were not statistically different from other urban land uses or impervious cover types. This is evident in the box and whiskers plot shown in Figure 4, which compares TP event mean concentrations for transport versus other urban land uses. As can be seen, median TP concentration among the different urban land uses are very similar.

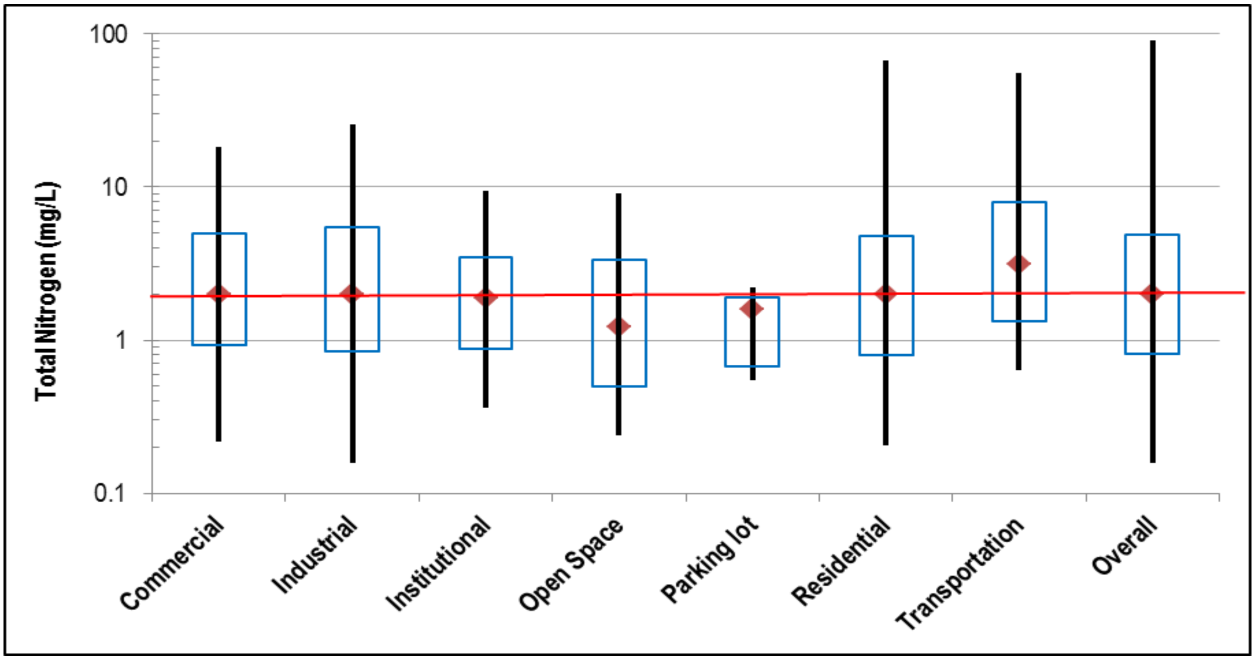

Figure 3. TN Event Mean Concentration for Various Urban Land Uses
Source: Tetra Tech, Inc, 2014.

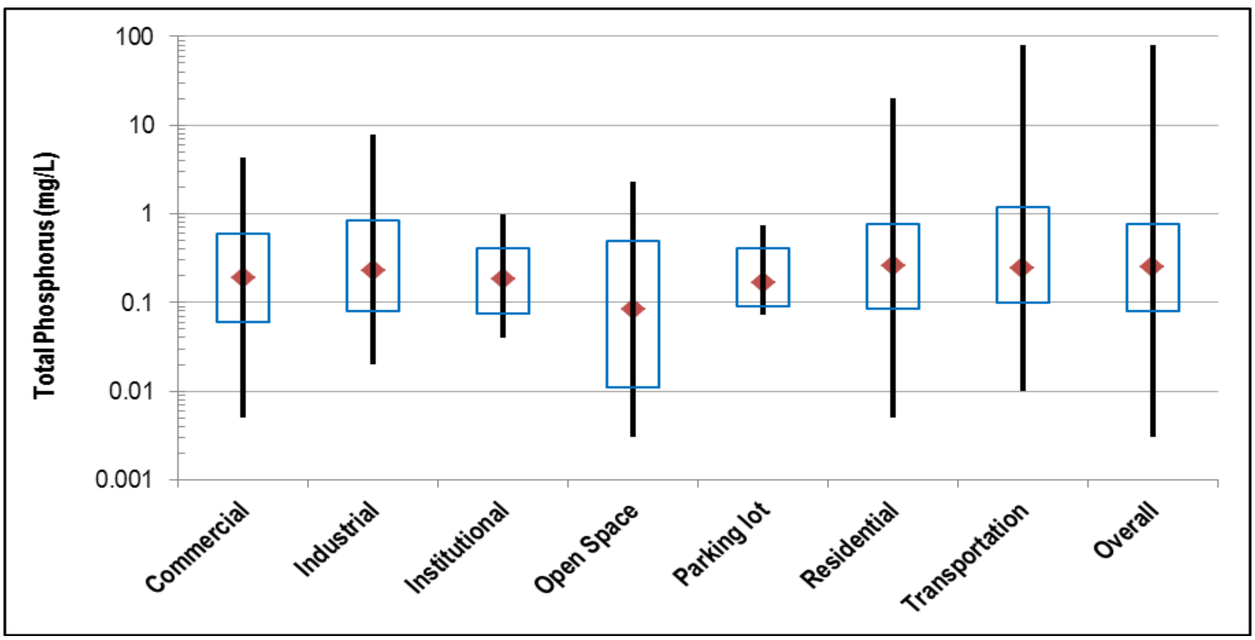

Figure 4 TP Event Mean Concentration for Various Urban Land Uses
Source: Tetra Tech, Inc 2014.

Another key finding was that the average daily traffic volume (ADT) for a street had a moderate influence on event mean concentrations (EMCs) of nutrients and sediment in stormwater runoff. Table 5 explores the general relationship of between stormwater EMCs as a function of ADT.

The most pronounced relationship is for TN, which steadily climbs as ADT increases. The relationships for TSS and TP were more mixed, with higher concentrations observed at both low and high ADT streets. Often, low ADT streets lack a curb and gutter to demarcate the road pavement, and instead have turf or vegetated shoulders, which may become a potential source of solids and organic detritus.

Table 5. Median Stormwater EMCs for Sediment and Nutrients as a Function of ADT

ADT	TSS (mg/l)	TN (mg/l)	TP (mg/l)
High	129	3.48	0.34
Medium	119	2.46	0.21
Low	126	2.17	0.36
Overall	**64**	**2.0**	**0.25**

Source: Tetra Tech, 2014
Overall value refers to all urban land use stormwater samples

4.2 Characterization of Urban Street Solids

Street solids are a complex mix of both mineral sediments and organic detritus that exhibit particle sizes ranging from extremely coarse-grained (larger than 1000 microns) to very-fine grained silts and clays (less than 60 microns). Street solids tend to be carbon and nutrient rich, and are frequently contaminated with petroleum hydrocarbons, trace metals and other pollutants.

Table 6. Comparison of measured street solids yield around the country (Lbs/curb mile--dry weight)

Median Yield	Location	Citation	Note
650 *	Baltimore, MD	Law et al 2008	Ultra Urban
1100 *	Baltimore, MD	Law et al 2008	Ultra Urban/US
350	Seattle, WA	SPU et al 2009	Industrial/RAS
240	Seattle, WA	SPU et al 2009	Resid./RAS
160	Seattle. WA	SPU et al 2009	Resid/RAS
1100	Seattle¸WA	SPU et al 2009	Industrial/US
1010	Seattle. WA	SPU et al 2009	Resid/US
790	Seattle. WA	SPU et al 2009	Resid/US
602	Cambridge, MA	Sorenson, 2013	Multi-fam. resid
467	Cambridge, MA	Sorenson, 2013	Commercial
672	Madison, WI	Selbig et al, 2007	Resid/US
455	Madison, WI	Selbig et al 2007	Resid/US
488	Madison, WI	Selbig et al 2007	Resid/US
408*	Champaign, IL	Bender et al 1984	US
391*	Nationwide	Sartor/Boyd 1972	US
705	Bellevue, WA	Pitt and Bissonette, 1984	
Grand Mean: 600 Range: 160-1100			

* indicates a mean value
[1] One curb mile is roughly equivalent to one acre of impervious cover
US = Unswept, RAS= Regenerative Air Sweeper, Resid = Residential

Several recent studies have measured street solids yield (in pounds per curb mile), which is a useful index of solids accumulation on the street surface. Table 6 compares seven studies that have measured street solid yields from around the country. Some variability would certainly be expected, given the inherent difference in street types, land use and climates among the studies. Surprisingly, street solid yield is fairly consistent across the country, with most studies clustering around 400 to 800 lbs/curb mile.

The research indicates that some road types may have higher sediment accumulation rates than others (e.g., residential, industrial, freeway, medians versus curbs), but there have not been enough studies to produce reliable comparative statistics. Some researchers have suggested that residential streets may have higher nutrient concentrations, particularly if they have a significant tree canopy (Ray, 1997, Baker et al, 2014).

In general, curbs and gutters create a trap that retains sediment and organic particles where they can be effectively swept. Streets without curb and gutters do not have a trap at the pavement edge, and the adjacent pervious area may actually become a net source of sediment when they are dislodged by contact with a sweeper brush (Smith, 2002).

The panel compared data on the particle size distribution for street dirt across the country, which is presented in Table 7. Once again, the distribution in particle size was surprisingly consistent across the country, with about two-thirds of particles classified as medium-grained (63 to 1000 microns), about 10% as fine-grained (less than 62 microns) and about 20% as coarse-grained.

Table 7. Comparison of General Particle Size Distribution of Street Solids [1]

GRAND MEAN of 9 Studies [2]	**Coarse**	**Medium**	**Fine**
	19.9	**65.3**	**9.2**

[1] numbers do not add up to 100% due to rounding
[2] See Table A-1 for a full comparison of the nine studies, their citation and particle size cut-off thresholds.

The particle size distribution of street dirt has several important implications related to street cleaning. First, particle size influences the mobility of street solids during runoff events and whether they will reach the storm drain system or not. Coarse-grained particles are more difficult to entrain in stormwater runoff and may take a long time to reach the storm drain system. Second, particle size has a strong influence on the pickup efficiency of street sweepers. In general, sweepers are most effective at picking up coarse-grained particles from the street, and are much less effective at removing fine-grained particles (Selbig and Bannerman, 2007).

Lastly, particle size is also strongly related to the degree of nutrient enrichment for street solids. The conventional wisdom is that many of the nutrients are associated with fine-grained street solids (Vaze and Chiew, 2004) as well as the organic fraction of the most coarse-grained particles (Waschbusch et al, 1999, Pitt, 1985 and Sorenson, 2013, and Tables 8 and 9). Medium-grained particles, which comprise the greatest fraction of street solids, had the lowest level of nutrient enrichment.

Table 8. TP enrichment in street solids by particle size (mg/kg)

STUDY	COARSE	MEDIUM	FINE
Pitt 1985	1015	600	785
Sorenson, 2013	400	400	800
Sorenson, 2013	800	500	900

Table 9. Percent of pollutants, by mass, in Madison, WI street solids
Source: Waschbusch et al, 1999

	< 63 micron	63-250 micron	> 250 micron	Leaves
Sediment	2.5	15.5	74	8
Total P	5	15	50	30

4. 3 The Organic Fraction of Street Solids

Another key issue relates to the organic fraction of urban street solids. Some recent research suggests that leaf detritus and other organic matter inputs can play an important role in street nutrient loads. Street solids tend to have a relatively high organic carbon content, particularly in the fine and coarse grained fractions (SPU, 2009, Sorenson, 2013). On average, organic carbon comprises about 5 to 12% of the mass of street solids, but this can be even higher following leaf drop (Sorenson, 2013, Kalinosky, 2013, Selbig, 2014).

The panel reviewed recent literature on the interaction between leaf detritus, street solids and nutrient dynamics in urban watersheds. Fall leaf drop provides a potentially large "gutter subsidy" in terms of the mass of organic carbon available for wash-off (Kaushal and Belt, 2012, Duan and Kaushal 2013), and to a lesser degree, pollen and green fall during the growing season.

Initially, the C:N ratio of freshly fallen leaves is about 60 or so (Heckman and Kluchinski, 1996). The ratio drops to about 40 as leaves age and decompose, and can be as low as 15 for decomposing grass clippings (Newcomber et al, 2012). Nutrients, especially phosphorus, rapidly leach from fallen leaves and grass clippings after being immersed in water for a few days. Wallace (2008) found grass clippings leached more phosphorus than leaves.

The initial grain size of leaf detritus is more than 1000 microns, but becomes progressively finer grained throughout the year due to physical and mechanical fragmentation and decomposition. Street detritus deposits are not very mobile until intense storms or melt events provide enough energy to move them into the storm drain, although the deposits become progressively finer throughout the year.

Leaf decomposition rates are much faster on pavement than on adjacent natural areas (Hobbie et al, 2013) possibly because of increased moisture in the gutter environment. Decomposition rates are rapid for leaves on pavement with 80% loss of initial leaf mass within one year (Hobbie et al, 2013). Baker et al (2014) observed that rapid nutrient leaching occurred in the first few days after leaf drop, particularly for phosphorus.

4.4 Nutrient Enrichment of Street Solids and Sweeper Waste

This section summarizes recent research on nutrient enrichment of street solids and sweeper waste. To aid comparison, published values that were reported as mg/kg were converted to a simple percentage applied to mass of solids/sediment (dry weight). Table 10 compares nutrient enrichment values from across the country. The degree of nutrient enrichment measured for street solids among the 12 studies was very similar. It should also be noted that the mean nutrient enrichment levels reported in Table 10 are slightly lower than values used by the last expert panel report (which were derived from a single study -- the ultra-urban Baltimore streets monitored by DiBlasi, 2008).

Based on the analysis, the fraction of street solids that are enriched by phosphorus ranges from 0.04 to 0.08 percent. By contrast, about 0.14 to 0.25 percent of street solids are enriched with total nitrogen. A slightly higher TN enrichment factor may be appropriate for catch basin and/or BMP sediments, based on the data presented in Table B-4 in Appendix B. Other researchers have also measured the nutrient enrichment associated with leaves and coarse organic matter, which is profiled in Table 11.

Table 10: Nutrient Enrichment of Street Solids

Solid Type	Value	% P	% N	Reference/Notes
Street Solids	Mean	0.10	0.25	CBP EP Report (2011)
Street Solids	Mean	0.05	0.20	Mean 4 Studies (Table B-2)
Street Solids	Mean	0.07	0.14	Baker et al (2014)
Street Solids, Fine	Mean	0.08	---	Sorenson (2013)
Sweeper Waste	Mean	0.04	0.15	Mean of 4 Studies (Table B-3)
Mid-Point of Data	--	**0.07**	**0.20**	Estimated

Table 11: Nutrient Enrichment of Coarse Organic Matter

Type	Value	% P	% N	Reference/Notes
Coarse Organic Matter	Mean	0.17	1.6	Baker et al 2014
Municipal Leaf Litter	Mean	0.10	0.94	Heckman and Kluchunski, 1996
Leaves	Mean	0.06	0.80	Rushton, 2006
Leaves	Mean	0.19	1.25	Ostrofsky, 1997
Leaves	Mean	0.08	0.96	Stack et al 2013
Mid-Point of Data	--	**0.12**	**1.11**	Calculated

The degree of nitrogen enrichment is about five times higher for organic matter than for street solids. On the other hand, the phosphorus enrichment of organic matter is only slightly higher than that measured for street solids. In general, these higher nutrient enrichment values can be applied to practices that trap organic matter during certain times of the year (e.g., fall leaf drop).

4.5 Trace Metals and Toxics Found in Street Solids and Sweeper Wastes

Street dirt and sweeper waste are typically contaminated by trace metals, polycyclic aromatic hydrocarbons, petroleum hydrocarbons, pesticides and other potential toxicants. Table 12 summarizes the trace metal content measured in sweeper wastes, which are roughly twice as high as those observed in urban soils.

Table 12. Trace Metal Content of Street Sweeper Waste (mg/kg)

Study	STATE	Copper	Lead	Zinc
Sorenson, 2013	MA	72	62	146
Sorenson, 2013	MA	47	111	169
SPU, 2009	WA	49	103	189
CSD, 2011a	CA	92	23	136
CSD, 2011b	CA	157	204	210
Walch, 2006	DE	64	81	208
MEAN		**80**	**97**	**176**
Urban Soils (Pouyat et al, 2007)		35	89	91

Table 13. Other Toxics Found in Street Sweeper Waste or Street Dirt (mg/kg, unless specified otherwise)

Toxic Contaminant	Sediment Concentration
Petroleum Hydrocarbons	Diesel range: 200 to 400 mg/kg Motor Oil/Oil Grease: 2,200 to 5,500 mg/kg
Polychlorinated Biphenyls (PCB's)	0.2 to 0.4 mg/kg
Polycyclic Aromatic Hydrocarbons (PAH)	Total: 2,798 ug/kg, Carcinogenic: 314 ug/kg
Pthalates	1,000 to 5,000 ug/kg
Pesticides	Pyrethroid pesticides present
Chloride	980 mg/kg
Mercury	0.13 mg/kg
Based on 3 West Coast Studies of street dirt and/or sweeper waste contamination, plus one Delaware Study	

Several west coast studies have also established that sweeper wastes are highly contaminated with petroleum hydrocarbon and polycyclic aromatic hydrocarbons (SPU, 2009, CSD, 2010). These compounds are hydrophobic and are strongly associated with the organic fractions of street solids (Bathl et al, 2012, Nowell et al 2013). Street solids are also enriched with mercury, PCBs, pthalates and pyrethoid pesticides, as well as very high chloride levels due to winter road salt applications (Table 13).

Given the high level of toxic contaminants found in street solids and sweeper wastes, street cleaning may be an excellent strategy to reduce the toxic inputs from urban portions of the Chesapeake Bay watershed.

4.6 Summary Review of Recent Street Cleaning Research

The panel focused its effort on street cleaning research conducted after the 2006 literature review that was the primary resource used by the last expert panel (CWP, 2006a). Ten key studies that were published after 2006 are profiled in the ensuing section.

Overall, the new studies produced quantitative data on the sediments and nutrients that are picked up by sweepers, but none measured a detectable change in sediment or nutrient concentrations within the storm drain system or receiving waters. Once again, the study designs were not robust enough to collect enough stormwater samples to show a statistically significant difference before and after treatment. Instead, most of the recent studies relied on simulation models to predict the impact of different street cleaning scenarios on pollutant removal, although the empirical data collected during monitoring was used to calibrate or validate their models.

2005 National Literature Review: This review was conducted by the Center for Watershed Protection on behalf of the CBP Urban Stormwater Workgroup (CWP,2006a). It included more than a dozen research studies, many from the Nationwide Urban Runoff Project (NURP) in the early 1980's. Most of the studies relied on older mechanical broom technology and showed street cleaning had a small impact in reducing stormwater pollutants, with a few studies showing no detectable impact. Given the differences in street types, sweeping frequency and technology between the studies, an overall removal rate could not be calculated. Instead, CWP developed a conceptual mass balance model to derive a conservative pollutant removal rate.

Based on the model results, CWP estimated that TSS removal could range from 16 to 32%, depending on the type of sweeper technology and frequency in which it used. CWP estimated that nutrient reduction for street sweeping was lower, ranging between 4 to 9% for TN and TP, respectively.

Baltimore, Maryland: This monitoring study evaluated the impact of street cleaning in paired, ultra-urban catchments in the city of Baltimore (Law et al, 2008). The streets experienced high street solid loadings rates, and pre-treatment monitoring of the storm drains indicated stormwater pollutant EMCs that were about twice as high as the national average (Pitt et al, 2004). The before and after study design evaluated whether vacuum-assisted sweeping at frequent intervals (twice a week) would influence pollutant event mean concentrations during storm events. More than 50 pre- and post-treatment stormwater samples were collected over a two-year period.

Despite this effort, Law concluded that "an insufficient number of stormwater samples were collected to statistically determine the effectiveness of street sweeping in paired urban catchments". In addition, the study sampled the particle size distribution and nutrient content of street solids, and assessed the nutrient concentrations from the mass of solids removed during storm drain cleanouts. The Baltimore data on stormwater quality, street solids and catch basin sediments were used by the last expert panel to formulate their recommended pollutant removal rate for street cleaning.

Madison, Wisconsin: This four-year, paired subwatershed study evaluated the effectiveness of weekly cleaning using three different sweeping technologies in residential streets (Selbig and Bannerman, 2007). In addition to stormwater monitoring, the team analyzed the particle size distribution and nutrient content of street solids. The study found street solid loading was highest in the early spring, a result of the remnant sand applications during the winter months. Street solid pick-up efficiencies ranged between 50 to 80% for the two advanced sweeper options tested, but were negligible for mechanical broom sweepers.

The study could not find a detectable impact of sweeping on stormwater EMCs for sediment or nutrients, but concluded the high variability observed in their stormwater runoff may have masked the real impact. The Wisconsin DNR has shifted to the use of stormwater models to predict the impact of different street cleaning scenario for phosphorus TMDLs. Many of the functions and parameters in their model are informed by data collected from this study, and the model was calibrated to the time series of street solid loading data.

Seattle, Washington: This study was conducted by the City of Seattle to respond to a MS4 stormwater permit condition that required them to evaluate the pollutant removal capability of their current street and storm drain cleaning programs (SPU, 2009). This study monitored street solid yield, sweeper mass yield, sweeper pick-up efficiency and catch basin accumulation in residential and industrial streets. The study evaluated the effect of regenerative air sweepers that swept city streets every other week. The study measured regenerative air sweeper street solid pick up efficiencies on the order of 50 to 90%.

The study design expressly avoided stormwater quality sampling, given the inherent variability of pollutant concentrations in the urban landscape. The authors did collect extensive data on the particle size distribution and pollutant content in street solids and sweeper wastes. The study assumed that the pollutants in street solids that are picked up by sweepers are effectively removed from downstream water bodies (i.e., 100% delivery of all street dirt particles to the storm drain), but provided no evidence to confirm this hypothesis. Based on this assumption, the authors concluded street cleaning every two weeks produced solid reductions in the range of 40 to 60%, and could also reduce toxics and metals by an unspecified degree.

San Diego, California: Like Seattle, this study was conducted in response to a MS4 permit condition, as well as to comply with trace metal TMDLs for local waterways. They looked at how effective three sweeper types were in influencing measured street solids and sweeper waste yields on residential and commercial streets and arterial highways (CSD, 2010, 2011). They also measured the particle size distribution and pollutant content of street solids and sweeper waste, including a number of trace metals and toxic contaminants.

The authors concluded that street cleaning was an effective means of reducing pollutants discharged in stormwater runoff, but did not provide much documentation to support their conclusion. Although there were mixed results due to street conditions, vacuum-assisted sweepers had the highest pick-up efficiency, mechanical broom sweepers the least, with regenerative air sweepers in the middle. The study also tested the effect of high intensity cleaning (every 3 to 4 days), and whether paved medians should be swept. The major difference was noted for the most intense cleaning frequency (two times/week) compared to weekly cleaning. Paved medians were found to have high rates of street solid accumulation, which made them a priority target for street cleaning.

Cambridge, Massachusetts: This USGS study measured pick up efficiency for three different street sweepers operating on multi-family and commercial streets for street solids and phosphorus (Sorenson, 2013). The study was conducted to provide management data to respond to a phosphorus TMDL for the Lower Charles River. The study design did not include sampling of pollutants in stormwater runoff, but measured changes in street solid accumulation rates over time. Data acquired during the study were used to calibrate a WinSLAMM model of typical street conditions in the Boston area, along with other Boston area sweeping research (Smith, 2002, Zarriello, et al 2002, Breault et al, 2005).

Based on the model, Sorenson (2013) predicted total solids removal of approximately 3 to 19%, total particulate solids removal of 4.2 to 32% and total phosphorus removal of 1.4 to 9%, over a range of sweeping frequencies from 3 times per week to once a month. Regenerative air and vacuum-assisted sweepers were found to have higher removal rates than mechanical broom sweepers.

Prior Lake, Minnesota: This study looked at the interaction of three different sweeping frequencies and adjacent tree canopy in several residential streets in the Twin Cities area (Baker et al, 2014). The study departed from earlier research in that they sampled the nutrient content of both solids and organic matter that were picked up by a regenerative air sweeper, regardless of particle size. The team observed seasonal spikes in the accumulation of solids and nutrients over the two year study period, with a peak in the fall that coincided with fall of deciduous leaves.

Although no stormwater samples were collected, the authors found higher nutrient loads were associated with the organic fraction of the sweeper waste, for all particle sizes. They also reported a strong link between the phosphorus load picked up by sweepers and the degree of adjacent tree canopy for residential streets. Based on their results, the team concluded that an increased intensity of street cleaning that coincides with the peak of fall leaf drop may be a potential strategy to reduce lake eutrophication. Further research on the effectiveness of seasonal street cleaning is now underway.

State of Florida: This study investigated the nutrient content in street sweeper wastes, catch basin debris and pond sediments from residential, commercial and highway land uses (Berretta et al, 2011). The project collected more than 450 sediment samples from across the state, which contributed to a much greater understanding of the degree of nutrient enrichment in both sweeper waste and BMP sediments.

Easton, Maryland: While this study did not look at street cleaning per se, it did evaluate the performance of a leaf net filter to capture and remove organic matter and sediments that would have been otherwise discharged to the Tred Avon River (Stack et al 2013). The net filters were located at the terminus of the storm drain system and were found to be effective in capturing organic debris. The dry-weight nutrient content of the organic matter captured in the nets was measured and found to be a significant source of N and P discharged from the outfall. Stack noted that this nutrient input would not have been detected through conventional stormwater monitoring equipment.

4.7 Summary of Storm Drain Cleaning Research

This section reviews the limited research available to examine the pollutant removal benefits associated with storm drain and/or catch basin cleanouts. As with street cleaning, much of the research has focused on the nutrient content of the sediment and organic matter trapped in the storm drain, but few studies have discerned a statistical improvement in stormwater quality, either due to the presence of catch basins, or based on regular cleanouts.

Mineart and Singh (1994) evaluated the effect of monthly catch basin cleaning in California, and reported potential reductions of 3 to 12% of sediment and trace metals (nutrients were not investigated). Pitt and Bissonnett (1984) reported that twice a year cleanouts of catch basins in Bellevue, Washington could reduce total solids in urban runoff by 10 to 25% and reduce nutrients and organic matter by 5 to 10%.

The results of recent research are more equivocal. For example, UNH SC (2012) investigated the performance of a deep sump catch basin receiving runoff from a nine-acre parking lot in Durham, NH. The study evaluated how the catch basin reduced sediment and nutrient concentrations as they passed through the practice. While they detected about a 10% reduction in TSS loads due to the deep sump catch basin, they did not find any statistical difference in nitrate or total phosphorus concentrations during monitored storm events.

MWCOG (1993) monitored the effectiveness of oil grease separators, a type of drain inlet with special sediment trapping chambers, in removing sediments, nutrients and metals from urban runoff. The Maryland study demonstrated that sediments and attached pollutants trapped within the chambers were frequently re-suspended and effective pollutant removal required very frequent cleanouts. The study also reported that sediments trapped in the inlets were highly enriched with nutrients, trace metals and hydrocarbons.

High nutrient content for catch basin sediments are frequently reported elsewhere in the literature (see Table 20 and Table B-4 for a comparative review of nutrient levels in traditional catch basin sediments).

Law et al (2008) presented data on the composition and nutrient content of sediments cleaned out from catch basins without sumps, as measured in Baltimore County, MD. The study noted that coarse-grained sediments and organic matter predominated in the catch basins sampled. Law et al (2008) reported that most of the nitrogen was associated with the sediment particles, whereas organic matter (leaves) were an important source of phosphorus in catch basin sediments. Coarse-grained material comprised more than 85% of catch basin solids (trash represented ~10% of the material cleaned out from the inlets). The nutrient enrichment data derived from Law et al (2008) was used to define the 2011 CBP storm drain cleaning credit (CSN, 2011).

SPU (2009) examined the interaction between street cleaning and catch basin cleanouts in the same subwatershed. The study team monitored sediment accumulation in catch basins located on residential and industrial streets, some of which were cleaned and some that were not. They found that frequent street cleaning by advanced cleaning technology did not change the solids accumulation rate in the test catch basins, which is not surprising given the low solids reduction reported for both practices. SPU (2009) did not assign a pollutant removal rate for catch basin cleaning for local TMDLs.

Smith (2002) evaluated the performance of a catch basin to remove suspended sediment and nutrients along an interstate highway in Boston that was also swept by mechanical broom sweepers. Smith (2002) found that 85 percent of the material trapped in the catch basin was coarse-grained (i.e., >0.25 mm in diameter). Fine-grained material was seldom deposited in the catch basin because its retention time was too short for gravity to separate particles (the median retention time was seven minutes during the median storm). Smith (2002) also reported that the suspended sediment concentrations discharged from the catch basins did not substantially change before and after they were cleaned out each year.

Smith (2010) investigated the performance of six deep sump catch basins with different hood configurations in reducing gross solids, oil and grease and total petroleum hydrocarbons along an interstate highway in Boston, Massachusetts. The median efficiency of the deep sump basin catch basins for trapping gross solids was 44% over the six month study. Smith (2010) noted that the gross solids accumulation rate for deep sump catch basins ranged from 6 to 69 lbs/curb mile. The gross solids that were trapped were predominately natural organic matter (~75%), followed by plastic materials (~20%) and cigarette butts (~5%). The catch basins did not appear effective at removing oil and grease or petroleum hydrocarbons from urban runoff.

Two other studies showed little pollutant removal benefit associated with catch basin cleaning. Irgang et al (2001) sampled stormwater quality during 11 storm events in catch basins located in a residential roadway network, and could not find a statistical improvement in stormwater quality between sites where catch basins had been cleaned or not cleaned. The study team qualified their finding by noting that their study was of short duration and subject to significant variability in pollutant concentrations. Dammel et al (2001) also found that catch basin cleanouts did not improve stormwater quality in successive storm events in Southern California, although once again it was a short term study.

Based on the foregoing data, the expert panel concluded that there was insufficient data to support assigning a positive sediment or nutrient removal rate for catch basins, regardless of sump or hood configuration, due to their minimal hydraulic residence time. The panel took a more conservative approach that nutrient removal credit was only warranted when the mass of nutrient-rich catch basin sediments was measured and physically removed from the storm drain system.

4.8 Key Panel Conclusions About Recent Street Cleaning Research

Based on its research review, the panel came to several conclusions about pollutant loads from roads and the effect of street cleaning in reducing them.

1. Road runoff has moderately higher nitrogen concentrations than other forms of impervious cover, and merits its own land use in the next generation of the Chesapeake Bay Watershed Model.

2. The accumulation rate, particle size distribution and pollutant content of street solids follows a relatively consistent and uniform pattern across the nation. These relationships provide a strong empirical basis for modeling how solids are transported from the street to the storm drain.

3. High level of toxic contaminants are consistently found in street solids and sweeper wastes. The panel concluded that street cleaning may be an excellent strategy to reduce the toxic inputs from urban portions of the Chesapeake Bay watershed, given the high level of toxic contaminants found in street solids and sweeper wastes.

4. The effect of street sweeping will always be modest, even when it is done frequently.

The primary reason is that storms are also efficient at cleaning the street and moving smaller particles into the storm drain system.

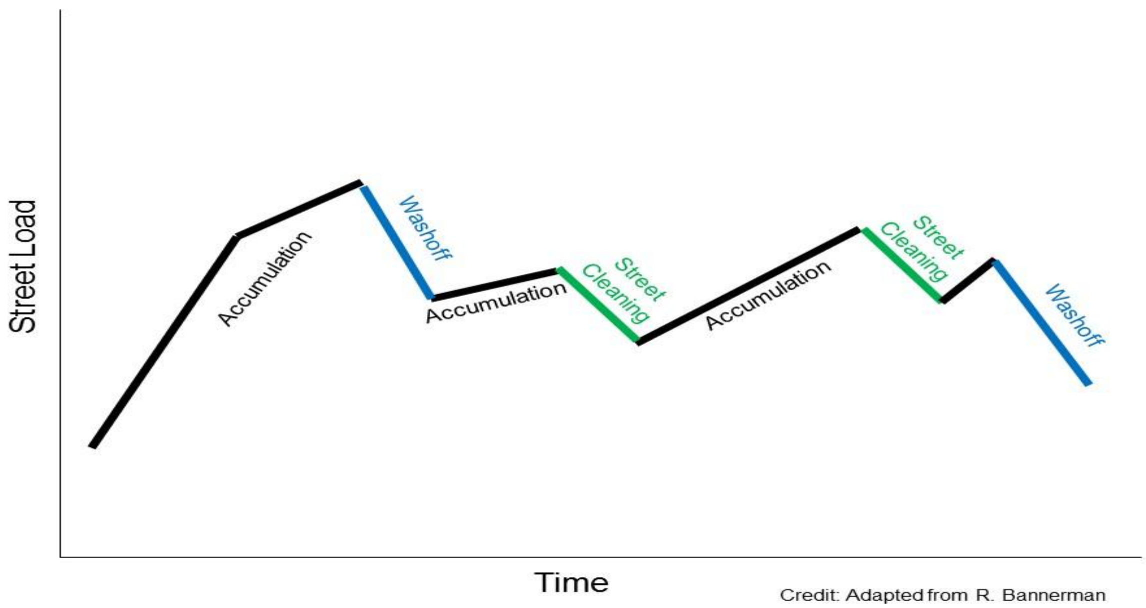

Figure 5. The Relationship Between Solids Accumulation, Street Cleaning and Wash-off During Rain Events.

On average, storm events occur every 4 to 5 days in the Bay watershed, which creates the "sawtooth" pattern in street solid accumulation shown in Figure 5. On dry days, solids build up on the street surface, only to be washed off during storm events, unless a sweeper happens to come sooner. Given that sweeping usually occurs on a fixed schedule, it is not uncommon to sweep streets that were recently "cleaned" by prior rain events.

5. Mechanical broom sweepers have little or no nutrient reduction benefit

This conclusion surprises many, particularly when they see large street solid loads that are picked up mechanical broom sweepers. Researchers have found that mechanical broom sweepers are effective in picking up coarse-grained particles, but have a low overall sediment pick-up efficiency. Mechanical broom sweepers leave behind fine-grained particles on the street that are subject to future wash-off (CWP,2006a, Selbig and Bannerman, 2007, CSD, 2010, and Sorenson, 2013). The panel concluded that mechanical broom sweepers can play a role in removing gross solids, trash and litter from street surfaces.

Figure 6 shows the sediment pick-up efficiency for three kinds of sweepers as a function of particle size on the street. Street sweepers tend to be effective at picking up coarse-grained particles, but actually increase the percentage of fine particles on the street after they pass.

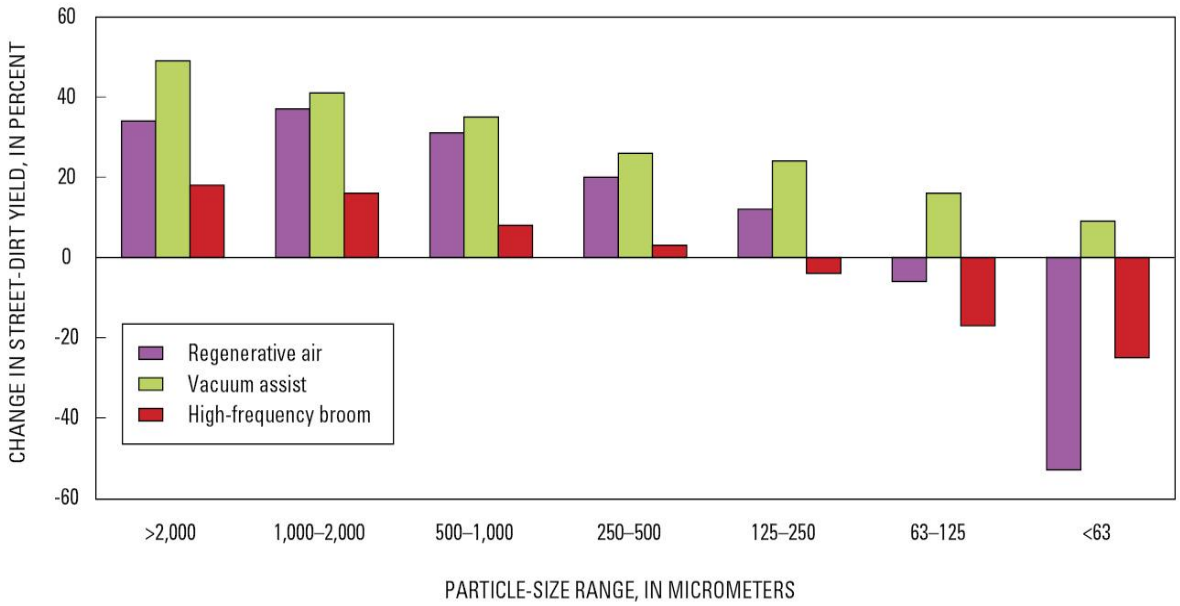

Figure 6 Comparative pick up efficiency of three types of sweepers (Selbig and Bannerman, 2007).

Mechanical broom sweeper actually dislodge fine particles that were trapped in the nooks and crannies of the street surface, making them available for future wash-off. Consequently, mechanical sweepers have very limited capability to reduce sediment concentrations discharged to the storm drain system. This finding is illustrated in Figure 7 which shows the weekly average sediment loading for two streets --one swept by a mechanical broom sweeper versus a control street that was not swept at all. There was no statistical difference between the two street treatments, suggesting that the broom sweeper was largely ineffective.

In addition, the panel could find no other credible monitoring or modeling studies that showed mechanical broom sweepers could reduce sediment loads by more than 10%, even at the most frequent sweeping intervals. Several studies indicated that broom sweeper had a zero or negative efficiency (Selbig and Bannerman, 2007, Sorenson, 2013, Smith, 2002, Waschbush, 1999).

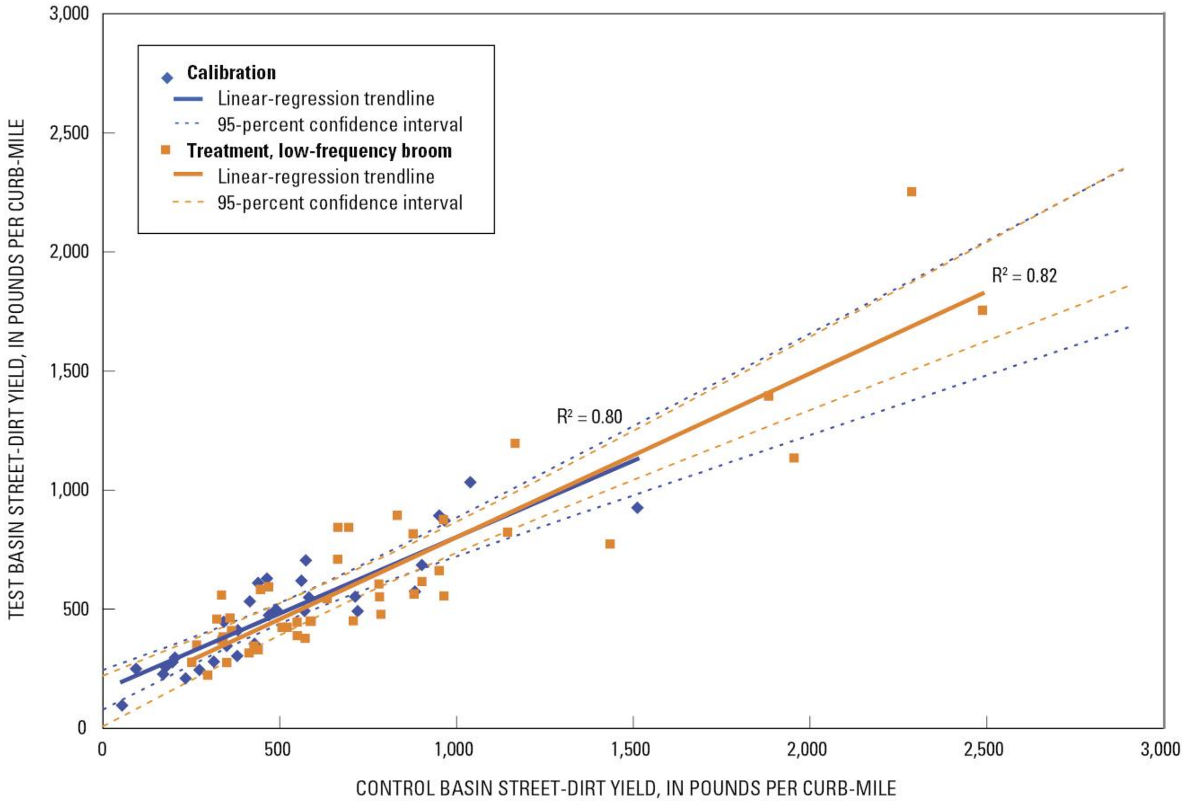

Figure 7. Response in weekly average street dirt load for control street (un-swept) and a street cleaned with mechanical broom sweeper in Madison, WI (Source: Selbig and Bannerman, 2007).

6. Other street cleaning technologies show much higher sediment reduction potential.

Two other street cleaning technologies show much more promise in picking up solids from the street surface -- regenerative air sweepers and vacuum assisted sweepers. Research has consistently shown that these technologies have pickup efficiencies in the 50 to 90% range, and most importantly, have the capability to pick up all particle size fractions from the street surface (Selbig and Bannerman, 2007, Law et al 2008, SPU, 2009, CSD, 2010 and 2011, and Sorenson, 2013).

An example of the high pick-up efficiency achieved by these sweeper technologies is provided in Figure 8 which shows how a regenerative air sweeper was able to sharply reduce weekly street dirt loads, compared to a control street that was not swept (note the sharp contrast with Figure 7).

The panel noted that high street dirt pick-up efficiency does not automatically equate to downstream reductions in sediment loads, since many of the coarse-grained sediments may never reach the storm drain inlet, or if so, may be re-deposited in the urban stream corridor.

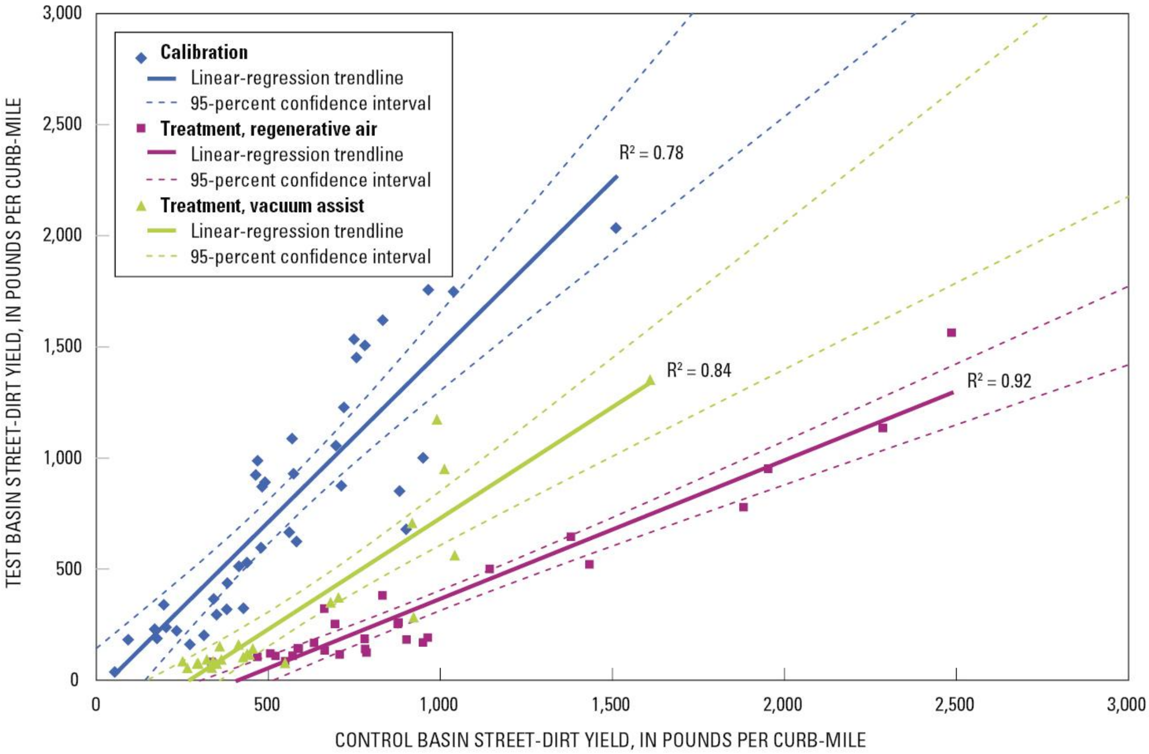

Figure 8 Comparison of Street Dirt Load for Control Street and Street Swept by Regenerative Air Sweeper (Selbig and Bannerman, 2007)

The panel found a handful of monitoring studies that compared sediment pick-up efficiency between the two advanced street cleaning technologies -- regenerative air and vacuum assisted sweepers. Selbig and Bannerman (2007) showed that regenerative air sweepers had high sediment pick-up efficiencies that were generally comparable to those achieved by vacuum-assisted sweepers. Their finding was reinforced by three other street cleaning monitoring studies (Sorenson, 2013, SPU, 2009 and CSD, 2010). Consequently, the expert panel concluded that both qualify as Advanced Sweeper Technologies (AST) and thereby can earn higher pollutant removal rates than traditional mechanical broom sweepers.

7. Street parking and other operator factors can sharply diminish sweeper pick-up efficiency.

Sweeping practitioners frequently note that real world factors such as the number of parked vehicles along a street can sharply reduce sweeper pick-up efficiency (Pitt, 1979). The main reason is that parked cars limit sweeper access to the curb and gutter where many of the particles are located. Pitt has developed relationships to quantify how parking reduces sweeper pick-up efficiency (Appendix B in Tetra Tech, Inc, 2015) which have been subsequently incorporated into the street cleaning module of the WinSLAMM model.

Other practitioners have noted that pickup efficiency can be influenced by the skills of sweeper operators (e.g., how close they get to the curb, how quickly they can avoid cars and the speed at which they operate the sweeper --Brinkman and Tobin, 2001 and CWP, 2006a). Experienced operators also know which portions of the routes they sweep are the dirtiest and require extra attention.

The panel acknowledges the importance of the human factor, but could find little direct monitoring evidence on the topic. The single study that monitored the influence of sweeper speed found that sweepers operated at 3 to 6 mph had the same street dirt yield as those operated at 6 to 12 mph (CSD, 2011).

8. The adjacent tree canopy influences the organic and nutrient loads on the street on a seasonal basis, but the management implications for this phenomenon are unclear.

As noted in Section 4.3, a significant fraction of street dirt consists of organic matter, much of which is derived from fall leaf drop, green fall and pollen deposition. Several recent studies indicate that adjacent tree canopy may exert a strong seasonal influence on TP and TN loads in the street (Baker et al 2014, Ray, 1997, Kalinosky, 2013).

A good example of the influence of tree canopy on nitrogen recovery in sweeper waste is shown in Figure 9. This Minnesota study found the highest N recovery in the late fall, with a second and smaller peak occurring in the late spring (Kalinosky, 2013). Figure 10 shows a similar pattern between tree canopy and phosphorus recovery in stormwater runoff (Selbig, 2014).

The potential nutrient loading from tree canopy is not fully known. Using data provided by Nowak (2014), the average nutrient load associated with leaf drop in the City of Baltimore was estimated to be 28.8 lbs/ac/yr and 2.95 lbs/ac/yr of N and P, respectively. The unresolved issue at this time, however, is how much of the leaf drop actually gets to the curb, moves into storm drains and ultimately reaches the stream corridor.

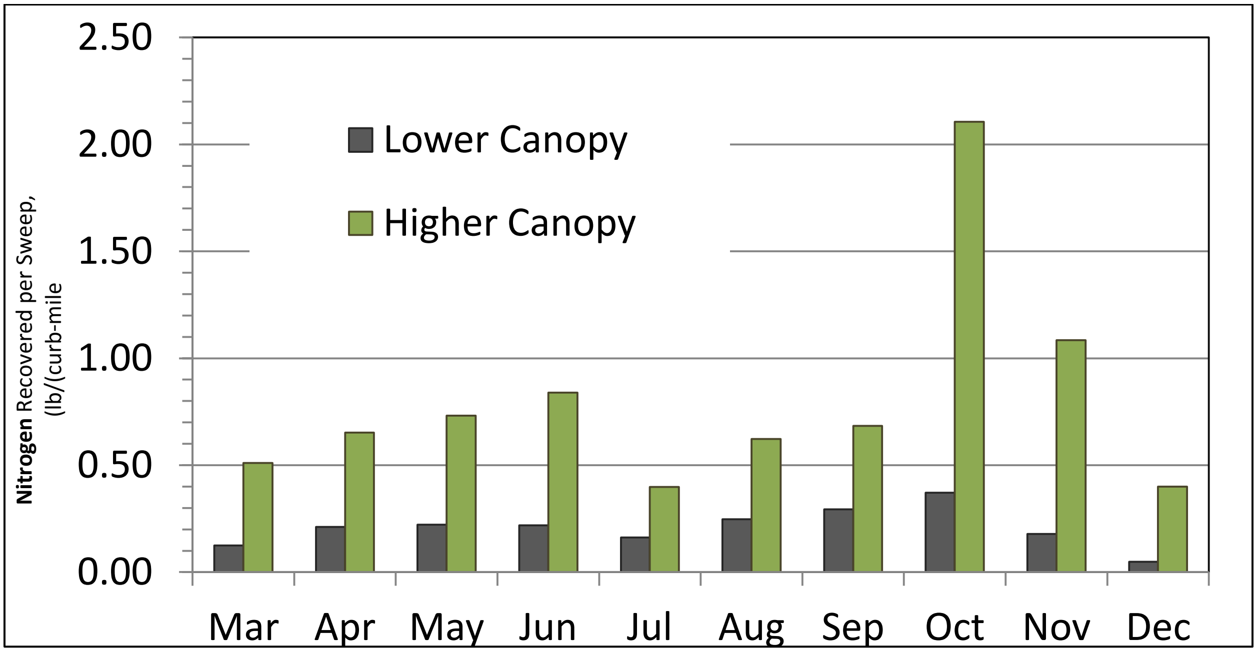

Figure 9: Effect of Street Tree Canopy on N Levels in Sweeper Waste (Kalinosky, 2014).

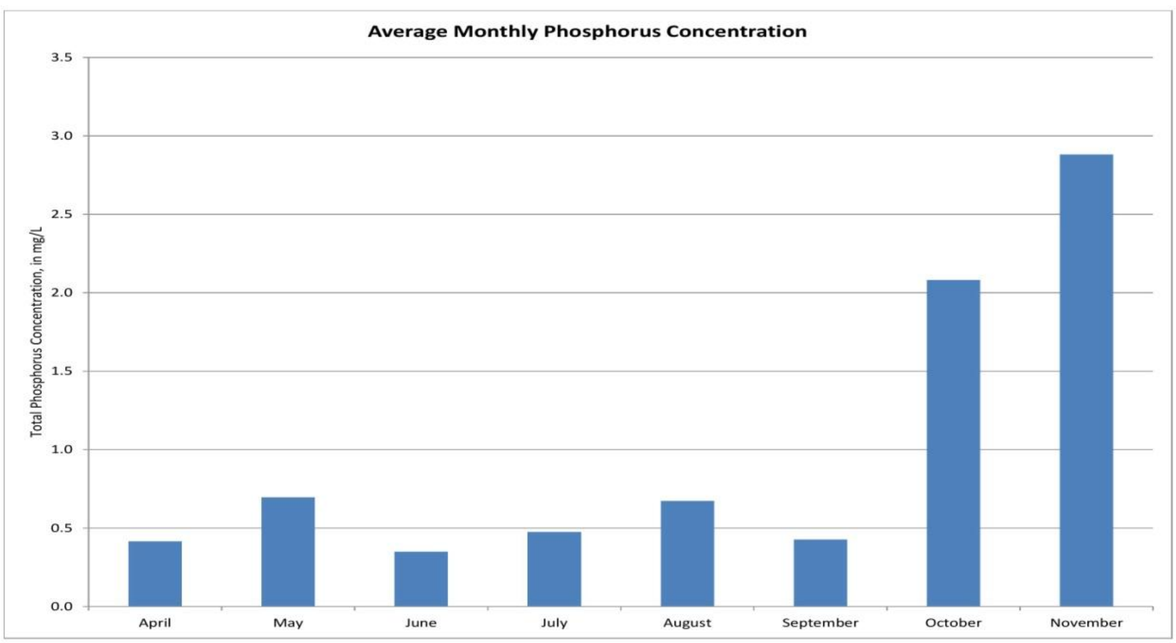

Figure 10. Seasonal changes in average monthly total phosphorus concentration measured from four residential basins in Madison, WI (USGS Wisconsin Water Science Center, unpublished data).

The panel concluded that our understanding of the fate, transport and processing of leaf litter in urban watersheds is still emerging, and there were insufficient data to quantify its significance as a nutrient source. In addition, the panel could find no monitoring data to establish whether more intensive street cleaning coinciding with fall leaf drop might have a definitive water quality impact.

The panel agreed that further research on this urban nutrient management strategy should be a top priority and should have a major influence on the next generation of street cleaning programs. A CBP Scientific and Technical Advisory (STAC) research synthesis report on the sources of urban nutrients arrived at a similar conclusion about the potential importance of leaf drop (Sample et al, 2015).

9. No monitoring studies have shown a detectable water quality change within storm drains that can be attributed to upland street sweeping, and it is doubtful whether future monitoring efforts will be any more successful. Given the limitations of monitoring, the panel concurred that empirically-based simulation models were needed to derive street cleaning estimates.

There are several reasons why it has been so difficult to quantify the impact of street cleaning through stormwater monitoring. To start, the presumed effect of street cleaning is expected to be rather low given the "sawtooth" pattern in how solids build up and then wash-off street surfaces (Figure 5). Such small differences are hard to detect given the variability in stormwater runoff from streets and roads (as well as the variability in street conditions and types across a community).

The variability in sediment and nutrient concentrations measured on both swept and un-swept streets is enormous (Figure 11).

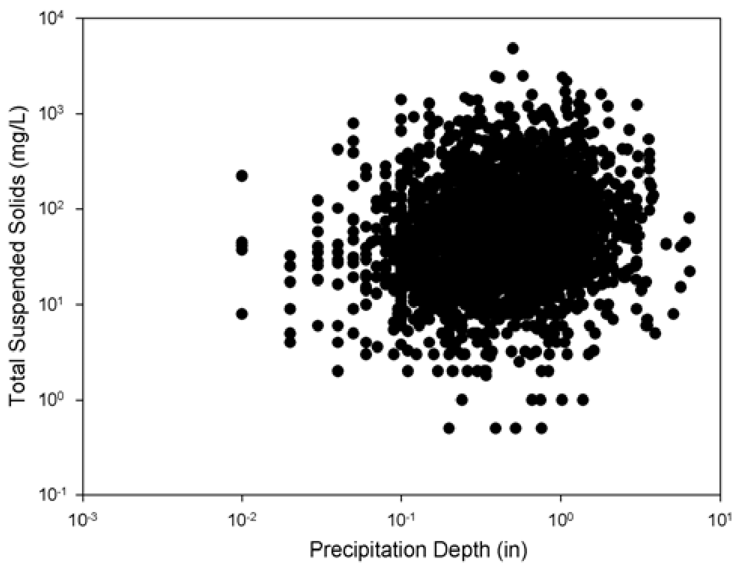

Figure 11 Example of the Variability of TSS Event Mean Concentration in Urban Stormwater Runoff (Source: Pitt et al, 2004)

Figure 11 illustrates the variability in sediment concentrations as a function of rainfall depth (on a logarithmic scale) during more than 3,500 runoff events included in the National Stormwater Quality Database (Pitt et al, 2004). The coefficient of variation (COV) associated with the pollutant concentrations in stormwater runoff samples range from 1.0 to 1.8 (Table 14). A higher COV indicates higher variability, which means a greater number of samples are needed to detect a significant difference for street cleaning treatments.

Table 14. Samples Required to Detect Change Given EMC Variability

Pollutant	Coefficient of Variation [1]	Approx. No. of Samples Required [2]
TSS	1.8	250
TN	1.0	75
TP	1.3	150

[1] Per most recent edition of National Stormwater Quality Database (Pitt, 2014)
[2] 95% confidence interval and assuming a sampling error rate of 25%, as shown in Figure 2 of Sample et al (2012).

The practical implication is that a very large sample size is required to overcome this variability and establish whether a significant difference between treatments exists. Hundreds of paired samples may need to be collected to detect a significant difference within an individual catchment (if it exists), which is beyond the scope of most research budgets (Table 14).

The difficulty in getting enough stormwater samples has been cited as a major problem by many sweeping researchers in the past (Selbig and Bannerman, 2007, Law et al, 2008 and SPU, 2009), and most researchers have now shifted to hydrologic simulation models to evaluate the water quality impacts of street cleaning.

The panel agreed that modeling was the best means to derive reliable sediment and nutrient reduction rates associated with street cleaning at this time. The advantage of a modeling is that it allows managers to assess removal rates for hundreds of different street cleaning scenarios that could never be definitively established by a monitoring program (e.g., parking conditions, street types, sweeping frequencies, etc.).

While a modeling approach helps managers make more informed decisions, the panel cautions that users should also be aware of the inherent limitations and uncertainty involved in any model predictions.

Section 5: WinSLAMM Modeling Analysis

The Panel selected the Source Loading And Management Model for Windows (WinSLAMM) as the best tool to estimate sediment removal rates associated with different street cleaning scenarios in the Chesapeake Bay watershed (Version 10.1.0, P&V Associates 2014; Pitt and Voorhees 2000). WinSLAMM is a widely accepted and documented model that simulates urban hydrology, pollutants and the effect of stormwater practices.

WinSLAMM is an event-based model that calculates mass balances for both particulate and dissolved pollutants and runoff flow volumes from different urban source areas (e.g., roofs, streets, parking areas, landscaped areas and undeveloped areas). The basic street cleaning module in WinSLAMM conservatively simulates sediment reductions associated with different street cleaning scenarios, and relies on sediment production and wash-off functions derived from empirical monitoring data. At this point in time, the model does not have the capability to explicitly simulate the effect of leaf drop on street solid dynamics.

The expert panel concurred that the existing street cleaning control module in WinSLAMM was a robust tool to evaluate a wide range of street cleaning scenarios. The model has been used to evaluate the water quality impact of street cleaning in earlier studies (Pitt et al, 2004, Sorenson, 2013), and has been accepted by regulators in at least two regions as a tool to determine TP reduction credits for lake TMDLs (Upper Midwest and New England). Figure 12 shows a screen shot of the user interface for the street cleaning module.

5.1 Customizing WinSLAMM for Chesapeake Bay Street Sweeping

Under the technical direction of the expert panel, Tetra Tech developed a Chesapeake Bay application of the WinSLAMM model to estimate the effect of street cleaning under a wide range of scenarios. The panel and Tetra Tech worked together over nine months in 2014 to conduct the modeling analysis, and document the assumptions used and scenarios evaluated. The two products of this effort were a technical memo summarizing the street cleaning scenarios that were evaluated (Tetra Tech, 2015), and a spreadsheet developed to allow users to calculate their own sediment reductions. Copies of both products are available on the Chesapeake Stormwater Network website (www.chesapeakestormwater.net).

The street cleaning module was calibrated and verified to real street solids datasets. The Bay application was customized to incorporate east coast sediment buildup and wash-off functions, Chesapeake Bay rainfall data, and a representative range of street types, sweeper technologies and parking conditions (Table 15). Once the panel approved the model, it was then used to assess different scenarios involving different combinations of sweeping technology, frequency, parking density and controls at four different street types that were used as a baseline.

The Panel elected to not to use WinSLAMM to explicitly simulate nutrients, and instead estimated them based on empirical nutrient enrichment ratios for street solids (see Section 4.4).

<table>
<tr><td colspan="2">Table 15. Adapting the WINSLAMM Model for the Chesapeake Bay Watershed</td></tr>
<tr><td colspan="2">Bay rainfall data. The model used the calibration period from 1995 through 2005 using Washington National Airport Station event-based rainfall data. The rainfall data was processed assuming the minimum number of hours between events is 6 hours and the minimum rainfall event depth is 0.01 inch.</td></tr>
<tr><td colspan="2">East Coast input data files were prepared to represent street conditions across the Chesapeake Bay watershed. The particle size distribution and peak-to-average flow ratio files were set to the program default average pavement and flow ratio files</td></tr>
<tr><td colspan="2">Four different street types were simulated to represent in different land uses that had curb and gutter drainage systems:

Single-family residential: Approximately 0.25-acre lots, with cul-de-sacs connecting to two-lane residential feeder roads with parallel parking on one side; light traffic; and 25 mile-per-hour (mph) speed limit. Approximately 33 houses in a 10-acre area. The driveways are simulated as draining onto the roads.

Commercial (80 percent impervious): Big box stores and parking lots. Feeder roads (two travel lanes and center turn lane) with no on-street parking, 35 mph speed limit, and heavy traffic.

Ultra-urban downtown (95 percent impervious): Multistory buildings. Two-lane urban roads with parallel parking on both sides of the street, sidewalks, and 25 mph speed limit.

Arterial highway: A four-lane divided road with median with barrier; high-speed traffic with turn lanes; and no on-street parking. Assumed to be commercial land use</td></tr>
<tr><td colspan="2">Three different sweeping start/stop dates to reflect regional differences in climate across the watershed:
Sweeping occurs over the entire year
Sweeping suspended December 1, restarts March 15
Sweeping suspended December 15, restarts February 15</td></tr>
<tr><td colspan="2">Six different fixed sweeping schedules</td></tr>
<tr><td>2PW = 2 passes per week
1PW = 1 pass every week
1P2W = 1 pass every 2 weeks</td><td>1P4W = 1 pass every 4 weeks
1P8W = 1 pass every 8 weeks
1P12W = 1 pass every 12 weeks</td></tr>
<tr><td colspan="2">Four seasonal sweeping schedules (more intensive in Spring or Fall)</td></tr>
<tr><td colspan="2">S1: Spring – One pass every week from March to April. Monthly otherwise
S2: Spring – One pass every other week from March to April. Monthly otherwise
S3: Spring and fall – One pass every week (March to April, October to November). Monthly otherwise
S4: Spring and fall – One pass every other week during the season. Monthly otherwise</td></tr>
<tr><td colspan="2">Two Levels of Sweeper Technology</td></tr>
<tr><td>MBC = Mechanical broom cleaning</td><td>VAC = Vacuum assisted cleaning</td></tr>
<tr><td colspan="2">Four Options for Street Parking Density and No Parking Enforcement</td></tr>
<tr><td colspan="2">For more details, consult the technical memo (Tetra Tech, Inc., 2015)</td></tr>
</table>

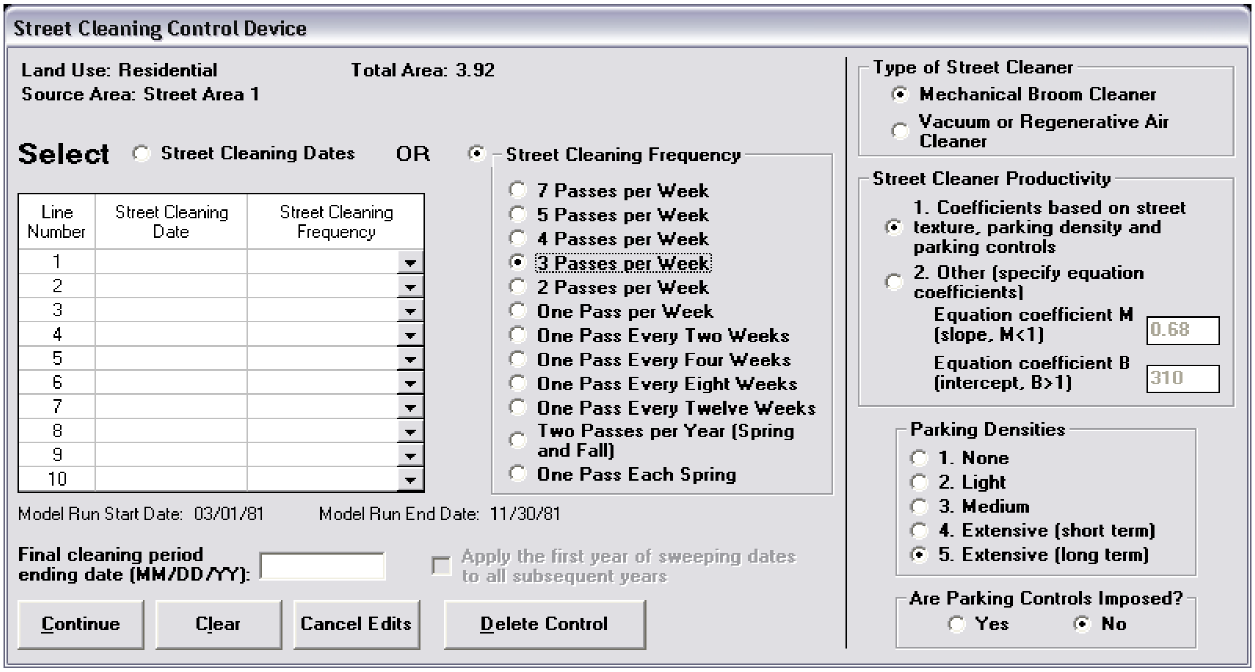

Figure 12. Screen Shot of WinSLAMM User Interface (P&V Associates, 2014)

Section 5.2 Key Findings from the WinSLAMM Modeling.

The detailed findings on sediment reductions for different street cleaning scenarios can be found in Tetra Tech (2015) and they generally mirror the basic findings that emerged from prior monitoring studies. Some of the general findings are described below.

- While nearly a thousand street cleaning scenarios were evaluated, only half of them produced significant sediment reductions (i.e., > 5% of annual sediment load reduced).

- The model predicted very low sediment reductions for nearly every mechanical broom cleaning scenario analyzed (see panels B and D in Table 16). Mechanical broom sweepers still comprise much of the local sweeper fleet in the Bay watershed.

- By contrast, vacuum assisted and regenerative air sweepers were estimated to reduce sediment by 5 to 45%, with higher reductions associated with more intensive sweeping regimes. The relationship between sweeping frequency and sediment reduction for advanced sweeper technologies is illustrated in Figure 13. The estimated sediment reduction is very modest for weekly and quarterly sweeping, but begins to climb sharply when bi-weekly or even more frequent sweeping is conducted.

- Figure 13 also indicates that sediment reduction is influenced by the type of road that is swept. Arterial, ultra-urban and residential streets had higher sediment reduction rates than commercial streets. The effect of street type on sediment reduction, however, was masked by the effect of on-street parking (Panel C in Table 16). As can be seen, high levels of on-street parking sharply decrease street-cleaning efficiency.

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- S3 was found to be the most effective seasonal cleaning scenario (one pass every week from March to April and October to November, and monthly sweeping the rest of the year).

- Another seasonal impact involves the length of the winter shut down period, which varies between the top and the bottom of the Bay watershed. Sweeping is not feasible during snowy or extremely cold weather, since sweeper water lines freeze, street surfaces are covered by ice and snow and operators are re-assigned to drive snow plows. The effect of the winter sweeping shutdown was very modest, compared to areas here sweeping can be done year round (Panel A in Table 16).

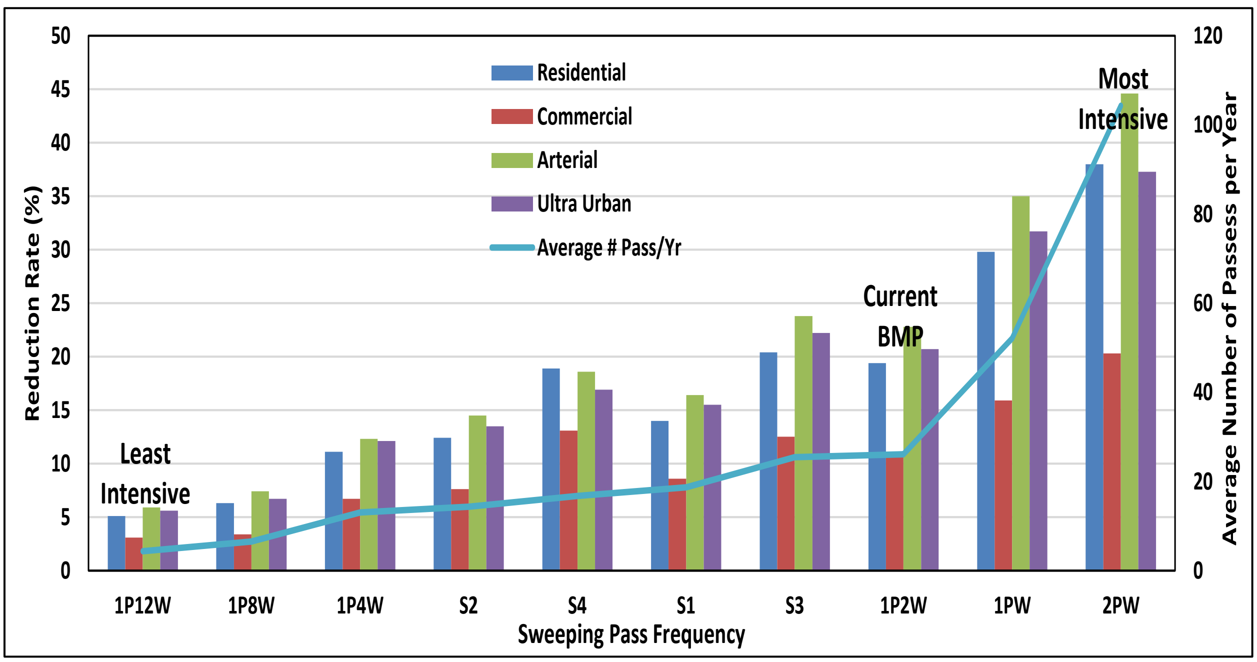
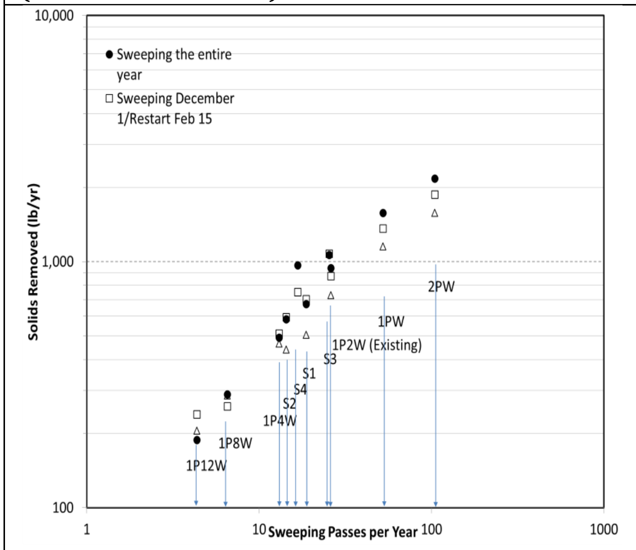


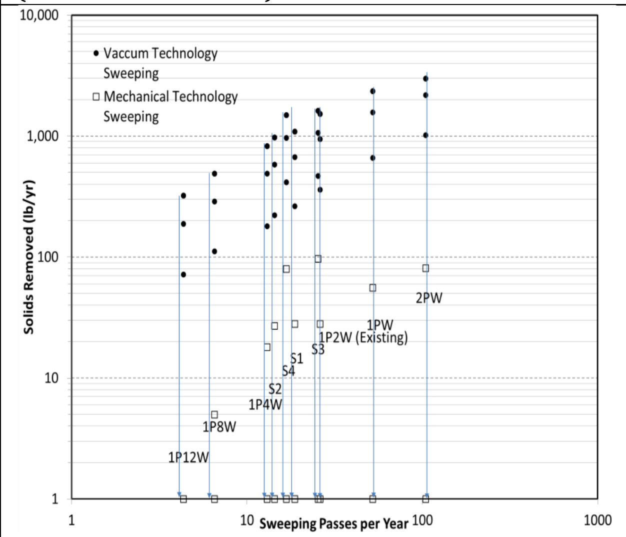
Figure 13. Effect of Sweeping Frequency and Street Type on Sediment Removal, Achieved by a Vacuum Assisted Sweeper (Tetra Tech, Inc, 2015).

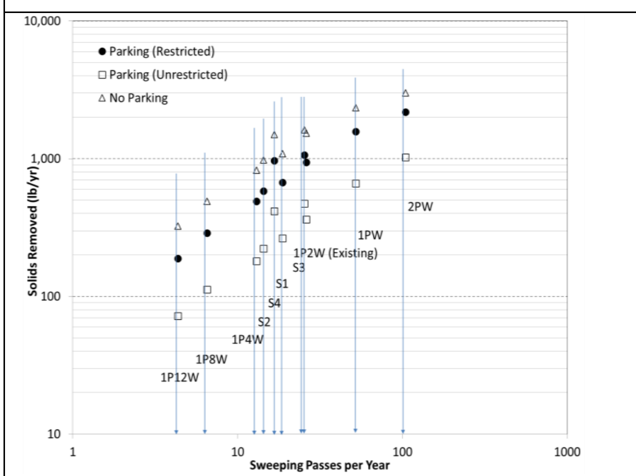
Table 16.
WINSLAMM Sediment Output for Different Street Cleaning Scenarios
(Tetra Tech, 2015)

Panel A: Effect of Winter Shut Down (residential street)

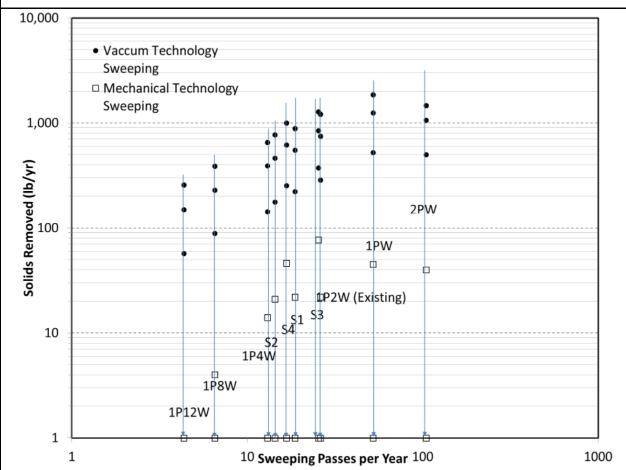


Panel B: Effect of Sweeper Technology (residential street)





Panel C
Effect of Parking Controls (Residential Street)



Panel D
Effect of Sweeper Technology (Ultra-urban)

Section 6:Recommended Credits for Street and Storm Drain Cleaning

Section 6.1 Derivation of the Street Cleaning Credit

The panel used the model output from the Chesapeake Bay version of WinSLAMM to develop its protocol for calculating sediment and nutrient reductions associated with different street cleaning scenarios. The model simulated the expected annual sediment reduction for 960 different street cleaning scenarios, which included 3 different lengths for winter shutdown, 4 types of streets, 2 sweeper technologies, 10 different cleaning frequencies, and 4 combinations of street parking conditions and controls. A spreadsheet was created to store the estimated percent sediment removal for each street cleaning scenario using a standard sweeping unit of curb-miles swept.

The spreadsheet tool was then used to define percent nutrient removal rates by applying a nutrient enrichment ratio (Table 18) to the mass of sediments removed per acre in each street cleaning scenario, and subtracting the resulting nutrient load from the unit area nutrient load for impervious cover calculated by the watershed model.

The standard street cleaning unit are curb miles swept. In general, one impervious acre is equivalent to one curb-lane mile swept, assuming they are swept on one-side only. Credit is also provided for cleaning municipal and commercial parking lots (in this case, the acres of parking lot swept are reported, and converted to lane miles using the one acre = one curb lane mile rule of thumb.

The panel elected to consolidate the model results to show specific removal rates for eleven different street cleaning practices, primarily involving the use of advanced street cleaning technology at different frequencies (Table 17).

Table 17. Pollutant Reductions Associated with Different Street Cleaning Practices

Practice #	Description [1]	Approx Passes/Yr [2]	TSS Removal (%)	TN Removal (%)	TP Removal (%)
SCP-1	AST- 2 PW	~100	21	4	10
SCP-2	AST- 1 PW	~50	16	3	8
SCP-3	AST- 1 P2W	~25	11	2	5
SCP-4	AST- 1 P4W	~10	6	1	3
SCP-5	AST- 1 P8W	~6	4	0.7	2
SCP-6	AST- 1 P12W	~4	2	0	1
SCP-7	AST- S1 or S2	~15	7	1	4
SCP-8	AST- S3 or S4	~20	10	2	5
SCP-9	MBT- 2PW	~100	1.0	0	0
SCP-10	MBT- 1 PW	~50	0.5	0	0
SCP-11	MBT- 1 P4W	~10	0.1	0	0

AST: Advanced Sweeping Technology MBT: Mechanical Broom Technology
[1] See Table 15 for the codes used to define street cleaning frequency
[2] Depending on the length of the winter shutdown, the number of passes/yr may be lower than shown

The rationale for consolidating the 960 street cleaning scenarios into 11 generic street cleaning practices was as follows. First, 65% of the street cleaning scenarios that were simulated showed no pollutant reduction benefit, and therefore could be ignored. Second, fewer BMP options helps reduce the reporting burden for local and state agencies, and makes it easier to incorporate them within Scenario Builder (i.e., the tool used to enter BMPs into the CBWM).

Third, the main determinant of sediment removal rate was advanced sweeping technology and cleaning frequency. While the WinSLAMM model was sensitive to other factors (e.g., street type, parking density, parking restrictions, and length of the winter shutdown period), it would be hard to map or verify them over the entire Chesapeake Bay watershed. In addition, while the model is a useful optimization tool, the panel did not want to oversell the accuracy, precision or reliability of its predicted sediment reduction rates.

The street cleaning credit is an annual practice, so communities must report the number of curb miles swept for each of their qualifying street cleaning practices every year.

Communities that want to compute the pollutant reduction associated with their local street cleaning program can estimate the credit, based on lane miles that are swept by each SCP.

Table 18 Example of Estimating Pollutant Reduction by a Local Street Cleaning Program

Lane Miles/ Acres	SCP	Removal Rate (%) [1]			Mass Removed (lbs) [2]		
		TSS	TN	TP	TSS	TN	TP
150	SCP-2	16	3	8	31,200	69.8	14.5
50	SCP-7	7	1	4	4,550	7.8	3.8
25	SCP-4	6	1	4	1,950	3.8	1.9
75	SCP-9	1	0	0	9.75	0	0
Total for Community					37,710	81.4	20.2

[1] From Table 17, and assume one curb mile equals an acre
[2] Assume annual load from impervious cover of 1,300 lbs/ac/year (sediment), 15.5 lbs/ac/yr (nitrogen) and 1.93 lbs/ac/yr (phosphorus) --Table 4

Table 18 shows the estimated reductions in a community that relies mostly on advanced street cleaning technology at different frequencies across its 300 mile road network each year. By contrast, if same road network was swept by a fleet of older mechanical broom sweepers, the sediment and nutrient reduction credits would be trivial. For this reason, communities are encouraged to use the spreadsheet for planning purposes in order to optimize which combination of street cleaning scenarios can maximize pollutant reduction within their jurisdiction at the least cost.

6.2 Note on Interaction of Street Cleaning and Other BMPs

A key modeling issue involves how street cleaning interacts with other BMPs located within the same catchment. Roads inevitably intersect drainage areas that may (or may not) be served by upstream and/or downstream BMPs. A potential double counting situation is created when street cleaning interacts with other BMPs in the same catchment. The panel could not find a practical method to isolate the BMP interaction effect over the entire road network of a MS4, and certainly not at the scale of the Chesapeake Bay watershed. The panel concluded that there was a small possibility for double counting, but the effect was too small to quantify.

6.3 Phase out of the Existing Methods to Calculate Street Cleaning Credit

The panel agreed that the two existing methods for calculating pollutant reduction for street cleaning by the 2011 panel should be phased out in the following manner:

- The existing "qualifying lane miles method" should be replaced by the more versatile credit proposed by this expert panel as soon as possible. The WinSLAMM modeling used to define the new credit is more technically defensible and provides municipalities with a greater range of street cleaning scenarios in which they can earn credit, assuming they use advanced sweeper technology.

- The existing "mass loading method" may continue to be used until 2017, but should be completely phased out when the Phase 6 CBWM model becomes operational (2018).

- Until the new street cleaning credit is fully adopted, the panel encourages states to require that locals use only <u>one</u> of the existing methods to report the credit. The panel felt that it was not wise to provide two methods that may give different answers to the same question.

6.4 Storm Drain Cleaning Credit

The panel recommended a sediment and nutrient reduction credit for solids that are directly removed from storm sewer systems (i.e., catch basins, within storm drain pipes or captured at the storm drain outfall). The storm drain cleaning credit does not apply to sediment removal operations that occur during ditch maintenance along open section roads. It does apply to sediment removal operations that occur in open, concrete-lined conveyance channels.

The credit promotes innovative practices such as outfall net filters, gross solids controls, and end of pipe treatment (Figure 14), as well as traditional catch basin cleanouts.

The credit is computed in three steps:

Step 1: Measure the mass of solids/organic matter that are effectively captured and properly disposed by the storm drain cleaning practice on an annual basis.

Step 2: Convert the initial wet mass captured into dry weight. The following default factors can be used to convert wet mass to dry weight in the absence of local data. The conversion factors are 0.7 for wet sediments (CSN, 2011) and 0.2 for wet organic matter (Stack et al, 2013).

Step 3: Multiply the dry weight mass by the default nutrient enrichment factor depending on whether the material captured is sediment or organic in nature (see Table 19). Note: locals may substitute their own enrichment factor if they sample the nutrient and carbon content of the materials they physically remove from the storm drain.

The aggregate load captured over the course of a year is reported for credit and is expressed in terms of pounds of sediment and nutrients.

The panel also established three qualifying conditions to ensure that storm drain cleaning efforts have a strong water quality focus:

(1) To maximize reduction, efforts should target catch basins that trap the greatest organic matter loads, streets with the greatest overhead tree canopy and/or outfalls with high sediment or debris loads.

(2) The loads must be tracked and verified using a field protocol to measure the mass or volume of solids collected within the storm drain system. The locality must demonstrate that they have instituted a standard operating procedure (SOP) to keep track the mass of the sediments and/or organic matter that are removed. Appendix F provides an example of an SOP developed by Baltimore County, MD that may serve as a useful template for tracking storm drain inlet cleaning.

(3) Material must be properly disposed so that it cannot migrate back into the watershed.

Table 19. Mean Nutrient Enrichment Factor to Apply to Dry Weight Mass of Solids Physically Removed From Storm Drains

Nutrient Enrichment Factor *	% P	% N	Notes
BMP and Catch Basin Sediments	**0.06**	**0.27**	See Table B-4
Organic Matter/Leaf Litter	**0.12**	**1.11**	See Table 11

* Multiply the mass (dry weight) of sediment removed from the storm drain (in pounds) by a factor of 0.0006 and 0.0027, for TP and TN, respectively. The result is the lbs/year of TP and TN credited.

Figure 14: Capture of Organic Matter at the End of Storm Drain System

Photo Credits: Stack et al 2013

Photo Credits: MWCOG 2009

Section 7: Accountability for Street Cleaning Practices

7.1 General Issues on Practice Reporting and Verification

One of the deficiencies of the previous expert panel report was that it lacked detail on how the street cleaning practice would be reported, tracked and verified, so the current panel paid close attention to this issue. The panel relied on the general principles for verification of urban practices established by the Urban Stormwater Workgroup (USWG, 2014) and approved by the CBP partnership as a whole.

The Panel noted that there were some unique verification issues associated with street cleaning practices. Operational practices such as street cleaning can be variable, given that the level of sweeping effort may change from year to year due to budget resources, the size, age and technology of the local sweeper fleet, weather conditions and other factors. For this reason, street cleaning should always be reported as an annual practice, as the actual curb lane miles swept may be different every year.

7.2 Reporting, Tracking and Verifying the Street Cleaning Credit

Reporting - The panel recommended that governments only submit the total qualifying lane miles swept in the community each year that correspond to the appropriate SCP category shown in Table 17. In most cases, governments will provide additional documentation about their street cleaning effort in the annual MS4 report they submit to their state stormwater agency.

Unlike other structural BMPs that require a specific geographic address (e.g., latitude and longitude), it is not really practical or useful to report a NEIEN address for the entire network of routes subject to local street cleaning. The BMP verification guidance approved by the USWG (2014) specifically allows states and localities to simplify reporting in these situations. For example, communities can simply provide the coordinates for either the centroid of (a) the jurisdiction or (b) the route in which the street cleaning occurs so that it can be assigned to the right jurisdiction within the appropriate river-basin segment. Alternatively, localities may also report the 12 digit HUC code for the watershed in which the street cleaning occurred.

Tracking and Record-Keeping - Under this approach, governments may need to keep accurate records to substantiate their actual street cleaning operations (including routes and mileage) so that their cleaning effort can be tracked and verified by the state MS4 regulatory agency, where necessary.

Record-keeping requirements, however, should not be so onerous that localities spend more time on paperwork than cleaning their streets. The recommended documentation may include:

1. Actual sweeper routes (and type of road)
2. Total curb miles swept on each route
3. Average parking conditions and controls along the route (optional)

4. Sweeper technology used (AST or MBT)
5. Number of sweeping passes per year on each qualifying route

In addition, the locality should maintain records of the actual miles swept, by date, for entire the MS4 sweeper fleet, over the reporting year.

Verification- All panel recommendations on tracking and verification are advisory in nature, and are not binding on any state. Individual Bay states can provide alternate verification methods for street cleaning, as long as they satisfy the general verification principles agreed to by the Chesapeake Bay Program Partnership (CBP, 2014).

The panel recommended an annual verification protocol to document local street cleaning efforts over time and provide quantitative data on sweeper waste characteristics. The proposed verification protocol entails collecting one high quality street sweeper waste sample on one route for each unique SCP they report for credit every year. The single sample is used to characterize the mass and quality of sweeper waste picked up along a single route by a single sweeper that is disposed at a landfill or a solid waste transfer station (and is not mixed with any other waste source).

For the annual sample, the MS4 should measure or estimate the following parameters:

- Volume of sweeper waste collected in the hopper, truck or dumpster (in cubic feet)
- Total wet mass of the sweeper waste (measured)
- Number of curb-miles swept over the entire route
- Sweeper conditions (i.e., date swept, weather, days since antecedent rainfall, street type, parking conditions and any other operational notes)

A sub-sample of the overall sweeper waste sample should be collected and sent to a laboratory to measure the:

- Actual dry weight of the wet sweeper waste
- Particle size distribution of the sweeper waste
- Average carbon, nitrogen and phosphorus content of the sweeper waste

These measurements can be used to better estimates of the:

- Acreage dry weight solids load collected over the route (lbs/curb mile)
- Wet mass to dry weight conversion factor
- Sweeper waste nutrient enrichment ratios

This data can be shared with other communities to provide better data to support the street cleaning practice across the Chesapeake Bay watershed.

7.3 Reporting, Tracking and Verifying the Storm Drain Cleaning Credit

Reporting - Reporting the annual storm drain credit is very straight forward. The local government simply submits the annual TSS, TP and TN load removed by the practice(s) each year (in pounds), and the coordinates of the centroid of either (a) the jurisdiction or (b) the 12 digit HUC watershed in which the cleaning occurs. This is necessary to assign the pollutant reduction credit to the proper river basin segment.

Tracking- Local governments will need to institute a tracking system and maintain records to substantiate how they calculate their annual sediment and nutrient reductions. It is strongly recommended that they develop a standard operating procedure that clearly defines:

- How the mass or volume of sediments and/or organic matter are measured in the field or at the final point of disposal
- Independent supporting documentation for storm drain cleaning effort (e.g., dumpster loads, disposal tickets, tipping fees, or vactor truck loads)
- The equation(s) used to convert wet sediment volumes to dry sediment mass, including any default values
- The nutrient enrichment ratios that are applied to the sediment mass
- The spreadsheets used to make the final computations of storm drain cleaning activity, as outlined in section 6.4 of this report.

The SOP should also contain quality assurance/quality control (QA/QC) procedures (i.e., who enters the data, who checks it and who signs off on its accuracy). The locality will need to maintain these records over time to ensure they are properly calculating the pollutant reductions. An excellent example of a SOP used to track storm drain cleaning activity has been developed by Baltimore County, MD, and is provided in Appendix F of this report.

Verification-- All panel recommendations on tracking and verification are advisory in nature, and are not binding on any state. Individual Bay states can provide alternate verification methods for storm drain cleaning, as long as they satisfy the general verification principles agreed to by the Chesapeake Bay Program Partnership (CBP, 2014).

The panel recommended a process to verify the storm drain cleaning practice that is similar to the approach used for street cleaning. Once a year, a composite sample is collected from the storm drains that are cleaned during the day. After being initially weighed, the sample is then mixed and allowed to dry over several days. After a week, the sample is measured to determine the:

- Dry weight of the sample (to compute wet to dry mass conversion)
- Fraction of the sample that is sediment, organic matter or trash.

A subsample of the dominant fraction of the sample (e.g., sediment, organic matter) is then sent to a laboratory to measure its average carbon, nitrogen and phosphorus content. Some useful guidance on sampling methods can be found in Stack et al (2013) and Kalinosky et al (2014). The resulting data can be submitted in annual MS4 reports, and may be used to adjust default values in the local storm drain cleaning SOP.

Section 8. Future Research and Management Needs

8.1 Panel's Confidence in its Recommendations

One of the key elements of the BMP Review Protocol is that each expert panel should express its confidence in the BMP removal rates that they ultimately recommend (WQGIT, 2014). The panel concluded that its recommendations are based on a much stronger scientific foundation than the previous panel estimate in 2011. It does acknowledge that gaps still exist about the fate and transport of nutrients and sediment from streets, and that the panel had to rely heavily on stormwater models to define the probable impact of different street cleaning scenarios.

The panel agreed that its recommended credit should be reevaluated by a new panel when better research data on seasonal sweeping performance or other practices, such as leaf collection, become available in the next few years.

8.2 High Priority Research Recommendations

The panel identified the following high priority research recommendations to close the remaining gaps in our understanding of street and storm cleaning practices.

1. The panel noted that only one street cleaning research study was conducted in the Bay watershed over the last decade. Consequently, more local data are needed on the particle size distribution and nutrient content of street solids and sweeper wastes across the watershed. Given that the verification protocol calls for periodic local sub-sampling of these parameters, it is recommended that a data-sharing mechanism be established across the watershed. In addition, municipalities and other governmental entities will require better guidance on the best methods to collect and analyze samples, and provide adequate quality assurance and quality control.

2. More research is needed on the fate, transport and processing of leaf litter and other organic detritus in urban streets to determine its significance as a nutrient source. If they are found to be significant, more research could determine whether intensive sweeping or catch basin cleanouts during the fall leaf drop might have a real water quality impact.

3. Tracer studies are needed to assess the mobility of the different particle sizes found in street solids and how this influences their delivery from the street to the gutter and from the storm drain to the urban stream corridor. The tracers should

look at both the mineral and organic fractions of street solids, as well as seasonal factors.

4. Field testing would help define the sediment and nutrient pick-up efficiency of the next generation of street sweeping technology, under real world conditions. One clear need is more research on the sediment pickup efficiency on streets and highway shoulders that lack curb and gutters.

5. Further testing to determine whether street or storm drain cleaning could be an effective strategy for keeping toxics, chloride, trash or gross solids out of local waterways, and meeting local TMDLs for trash and toxics.

6. More research should be focused on the sediment and trash reduction capabilities of catch basins under various cleaning scenarios, as well as basic investigations of whether the traditional catch basin design could be improved or optimized for greater retention.

8.3 Future Implementation Considerations

The panel identified several priorities to improve local capability to modify their existing street and storm drain cleaning programs to maximize the amount of pollutants that they remove from local waters and the Chesapeake Bay.

- Develop more detailed sampling guidance and standard operating procedures to support the proposed verification protocols for street and storm drain cleaning.

- Establish a support website for MS4s across the Chesapeake Bay watershed on street cleaning, which provides updated guidance, standard reporting forms, a downloadable version of the spreadsheet, and list of sweeper models that are eligible for higher credit. The website might also include an interface for users and practitioners to share their verification samples.

- Offer training and technical assistance to local governments to upgrade their sweeping programs to provide more water quality benefits (e.g., workshops and/or webcasts that describe the new credits, show how to use the spreadsheet, techniques to report and verify the practice).

- Provide an annual forum for MS4 fleet managers to exchange tips on how to streamline their sweeper programs. The forum might also focus on route optimization software, WinSLAMM model training, and enhanced operator skills training. The forum could showcase how GIS can be utilized to optimize removal by street cleaning, by screening for street types, curb and gutter drainage, ADT, adjacent land use and other mapping layers.

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Appendix A
Summary of 5.3.2 STREET SWEEPING Practice

Status: This credit was approved by a CBP BMP Expert Panel in March of 2011

Definition: Frequent street sweeping of the dirtiest roads and parking lots within a community can be an effective strategy to pick up nutrients and sediments from street surfaces before they can be washed off in stormwater runoff.

Technical Issues: The basic data for defining the credit were initially developed by Law et al (2008) based on a Baltimore monitoring study and a nationwide literature review of prior street sweeping studies.

Recommended Process: The first and most preferred option is the **mass loading approach**, whereby the mass of street dirt collected during street sweeping operations is measured (in tons) at the landfill or ultimate point of disposal.

Step 1: Determine the hopper capacity of your current sweeper technology

Step 2: Weigh the street solids collected to develop a simple relationship between street solid mass (in tons) to hopper capacity

Step 3: Keep records on the annual mass of street solids collected from qualifying streets

Step 4: Convert tons into pounds of street solids (multiply by 2000), and converted to dry weight using a factor of 0.7

Step 5: Derive your nutrient reduction credit by multiplying the dry weight of the solids by the following factors:

- Lbs of TN = 0.0025 pounds of dry weight sweeping solids
- Lbs of TP = 0.001 pounds of dry weight sweeping solids

These factors are based on sediment enrichment data reported by Law et al (2008), adjusted from original mg/kg values of 1200 (TP) and 2500 (TN)

Step 6: Compute the TSS reduction credit by multiplying the annual mass of dry weight sweeping solids by a factor of 0.3. This correction eliminates street solids that are greater than 250 microns in size, and therefore cannot be classified as total suspended solids. This factor was developed by the BMP panel and reflects particle size data from two recent street sweeping studies. SPU (2009) estimated TSS removal from street sweeping that was approximately 20% of the total dry sweeping solids load recovered. The particle size distribution for recovered street sweeping solids by Law et al. (2008) showed approximately 30% of the recovered solids in this TSS size range (i.e. ≤ 250 μm) by mass.

The second accepted method is **the qualifying street lanes method**.

Step 1: Each locality reports the number of qualifying lane miles they have swept during the course of the year.

Step 2: Qualifying lane miles are then converted into total impervious acres swept by multiplying the miles (5280 feet) by the lane width (10 feet) and dividing by 43,560. If both sides of the street are swept, use a lane width of 20.

Step 3: Multiply the impervious acres swept by the pre-sweeping annual nutrient load using the Simple Method unit loads (Schueler, 1987).

TP = 2.0 lbs/impervious acre/year
TN = 15.4 lbs/impervious acre/year

Step 4: Multiply the total pre-sweep baseline load by the pickup factors shown in Table A-1 to determine the nutrient and sediment load credit for street sweeping.

Table A-1 Multipliers to Reflect Effect of Street Sweeping on the Baseline Load [1]

Technology	TSS	TP	TN
Mechanical	.10	.04	.04
Regenerative/Vacuum	.25	.06	.05

[1] interpolated values from weekly and monthly street sweeping efficiencies as reported by Law et al (2008)

Qualifying Conditions for Street Sweeping Nutrient Reductions: The nutrient reductions only apply to an enhanced street sweeping program conducted by a community that has the following characteristics:

- An urban street with an high average daily traffic volume located in commercial, industrial, central business district, or high intensity residential setting.
- Streets are swept at a minimum frequency of 26 times per year (bi-weekly), although a municipality may want to bunch sweepings in the spring and fall to increase water quality impact.
- The reduction is based on the sweeping technology in use, with lower reductions for mechanical sweeping and higher reductions for vacuum assisted or regenerative air sweeping technologies.

Local Tracking, Reporting and Verification: Localities will need to maintain records on their street sweeping efforts using either method, and provide a certification each year as to either the annual dry solids mass collected or the number of qualifying street miles that were swept.

Appendix B.
Supplementary Data Tables

Table B-1: Comparison of General Particle Size Distribution of Street Solids				
Study	**Coarse**	**Medium**	**Fine**	Cutoffs
Sorenson 2013	30	61	9	2/.125
Sorenson 2013	15	71	14	2/.125
CSD, 2010	14	79	7	2/.075
CSD, 2010	17	79	4	2/.075
CSD,2010	16	78	7	2/.075
SPU, 2009	19	73	8	2/.075
SPU, 2009	24	68	8	2/.075
SPU, 2009	11	78	11	2/.075
Selbig et al 2007	15	77	8	2/.125
Selbig et al 2007	12	77	11	2/.125
Law et al 2008	16	65	19	Approximate
Pitt and Bissonette, 1984	24	66	10	1/.063
Pitt and Bissonette, 1984	24	64	12	1/.063
Wasbusch, 2003	27	67	9	1/.063
Terstriep et 1982	43	52	5	1/.063
Sartor and Boyd,72	31	55	14	1/.063
GRAND MEAN *	**19.9**	**65.3**	**9.2**	
* numbers do not add up to 100% due to rounding				

Table B-2 Nutrient Content of Street Dirt Measured Around the Country (mg/kg)			
Location	Citation	TN	TP
Seattle, WA (S)	SPU et al 2010	3297	690
Seattle, WA (U.S)	SPU et al 2010	3313	439
San Diego, CA	CSD, 2011	518	239
San Diego CA	CSD, 2011	495	199
Baltimore	Law et al 2008	2163	1034
Boston, MA	Sorenson, 2012	ND	500
Boston MA	Sorenson, 2012	ND	700
Grand Mean: TN: 1957 TP: 543			

Table B-3 Nutrient Content of Sweeper Waste Measured Around the Country (mg/kg)			
Location	Citation	TN	TP
Seattle WA	SPU et al 2009	3090	648
Seattle WA	SPU et al 2009	3170	633
Seattle, WA	SPU et al 2009	3540	516
San Diego, CA	CSD, 2011	1136	260
Delaware	Walch, 2006	900	150
Delaware	Walch, 2006	657	290
Delaware	Walch, 2006	799	395
Florida	Sansalone et al, 2011	430	381
Florida	Sansalone et al, 2011	832	374
Florida	Sansalone et al, 2011	546	350
Grand Means TN: 1510 TP: 400			

Table B-4 Nutrient Content of Catch Basin Solids Measured Around the Country (mg/kg-dw)			
Location	Citation	TN	TP
Seattle WA	SPU et al 2009	3380	708
Seattle WA	SPU et al 2009	4300	817
Seattle, WA	SPU et al 2009	6745	817
Baltimore, MD	Law et al 2008	781	585
Baltimore,MD	Law et al 2008	3480	980
Maryland	MWCOG, 1993	1760	267
Maryland	MWCOG, 1993	1719	365
Florida	Sansalone et al, 2011	467	301
Florida	Sansalone et al, 2011	773	423
Florida	Sansalone et al, 2011	785	537
Nationwide	Schueler, 1994	2931	583
Bellevue WA	Pitt and Bissonette, 1984	2100	769
Grand Means TN: 2435 TP: 596			

Appendix C. Conformity with BMP Review Protocol

The BMP review protocol established by the Water Quality Goal Implementation Team (WQGIT, 2014) outlines the expectations for the content of expert panel reports. This appendix references the specific sections within the report where the panel addressed the requested protocol criteria.

1. **Identity and expertise of panel members:** See Table in Section 1, page 8

2. **Practice name or title:** The street cleaning practice (SCP) refers to 11 different street cleaning scenarios that vary based on sweeper technology and the number of sweeping passes per year. The pollutant reductions associated with the 11 SCPs are provided in Table 17 (p. 41) and the specific definitions for each street cleaning scenario are provided in Table 15 (p. 36). The storm drain cleaning practice is defined in Section 6.4.

3. **Detailed definition of the practice:** See Section 2 in the report for a comprehensive list of the definitions used in the report (pages 11-13).

4. **Recommended N, P and TSS loading or effectiveness estimates:** The percent removal rates for sediment and nutrients for *each street cleaning practice* (SCP) are provided in Table 17. One curb-mile swept is assumed to be equivalent to one acre of impervious cover. The *storm drain cleaning credit* is expressed as the actual pounds of sediment and nutrients that are captured and properly disposed, as calculated by the equations provided in Section 6.4 (page 44).

5. **Justification of selected effectiveness estimates:** The panel conducted an extensive review of the available science to justify its street cleaning removal rates (see Section 4), as well as supervising the development of WinSLAMM model adapted for the Chesapeake Bay watershed to determine removal rates over a wide range of street cleaning scenarios (see Section 5). The storm drain cleaning credit is empirically derived based on a national review of the nutrient enrichment of solids removed from BMP and catch basin sediments.

6. **List of references used:** The panel reviewed more than 100 papers and reports, which are provided in the *References Cited* section, beginning on page 51.

7. **Detailed discussion on how each reference was considered:** See Sections 3 to 5 of the report for the panel's assessment of the existing literature.

8. **Land uses to which BMP is applied:** In the Phase 5.3.2 model, the practices apply to the impervious cover land use. In Phase 6, the practice will be restricted to the new transport impervious cover land use.

9. **Load sources that the BMP will address and potential interactions with other practices**: Both practices reduce loads from urban impervious cover, although the reduction is calculated in two different ways (see sections 6.1 and 6.4, respectively). The issue of how street and storm drain cleaning interact with other structural BMPs in the same watershed is discussed at length in Section 6.2

10. Description of pre-BMP and post-BMP circumstances and individual practice baseline: Since it is an annual practice, there is no need for a baseline. Street and storm drain cleaning BMPs were not considered in the original calibration of the Phase 5.3.2 CBWM.

11. Conditions under which the BMP works/not works: The WinSLAMM model showed a wide range of scenarios in which the street cleaning practice does not work. These options were excluded from the panel's final recommendations.

12. **Temporal performance of BMP including lag times between establishment and full functioning:** The pollutant reductions occur in the same year as the street or storm drain cleaning efforts occur.

13. Unit of measure: For street cleaning: curb-lanes mile swept for each SCP.
For storm drain cleaning: pounds removed.

14. Locations in CB watershed where the practice applies:
Anywhere in the Bay watershed where the qualifying conditions are met.

15. Useful life of the BMP: One year

16. Cumulative or annual practice: Annual practice. The street or storm drain cleaning credit needs to be reported every year.

17. Description of how BMP will be tracked and reported: See Section 7 for a discussion on how jurisdictions track, report and verify the street and storm drain cleaning practice to the Bay Program (page 41- 45). Additional details can also be found in Appendix E "Technical Requirements for Scenario Builder"

18. Ancillary benefits, unintended consequences, double counting: The panel noted that an advanced sweeping technology program could have the potential ancillary benefit of reducing loads of gross solids, trash and toxic contaminants to local waterways, as well as improving the safety and appearance of both green and conventional streets. The panel could not identify any other unintended consequences associated with effective local street and/or storm drain cleaning programs. The Panel evaluated the potential double counting issue involving the interaction of street cleaning and structural BMPs within the same catchment (Section 6.2), and concluded it was not a significant issue.

19. Timeline for a re-evaluation of the panel recommendations. The panel did not set a timeline to reconvene, but did note that it may be advisable to do so when more research on the seasonal influence of leaf drop, cleaning and removal is completed in the Bay watershed.

20. Outstanding issues: The panel outlined its confidence in its recommendations in Section 8.1, its priority research recommendations in Section 8.2 and recommendations to improve local implementation in Section 8.3.

APPENDIX D:

Consolidated Meeting Minutes for the Panel

Street Sweeping, Catch Basin and Storm Drain Cleaning Expert Panel
Teleconference Call
Meeting Minutes
Tuesday, September 3, 2013

EXPERT BMP REVIEW PANEL		
Panelist	***Affiliation***	**Present?**
Dr. Stu Schwartz	UMBC	Yes
Norm Goulet	NVRC	No
Jenny Tribo	HRPDC	Yes
Tim Karikari	DDOE	No
Sebastian Donner	WVDEP	Yes
Bill Frost	KCI	Yes
Justin Shafer	City of Norfolk	Yes
Steve Stewart	Baltimore County	Yes
William R. Selbig	USGS	Yes
Tom MaGuire	MassDEP	Yes
Dr. Neely Law	CWP	Yes
Tom Schueler Jeremy Hanson	CSN CRC (Panel co-facilitators)	Yes Yes
Non-panelists: Cecilia Lane – CSN		

1. **Call to Order and Panelist Introductions Tom Schueler, CSN**, called the meeting to order, thanked the panelists for their participation in the Expert Panel and gave a brief overview of the Chesapeake Bay Program's BMP Panel Review Process (Attachment B). **Tom** asked the panelists to introduce themselves.

2. **Review of the Charge for the Panel, the BMP Panel Review Process and Panelist Responsibilities** Tom reviewed the charge for the Street Sweeping, Catch Basin and Storm Drain Cleaning practices (Attachment A) and asked the panelists if they had any questions. **Sebastian Donner** asked if ditch cleaning was covered in this panel and Tom clarified that it is not but may be covered in a future panel. **Schueler** then went over the general CBP protocol for developing pollutant removal rates for urban BMPs and the expectations for the panelists (Attachment B). **Tom McGuire** asked about how cold climate will impact pollutant removal rates for these practices. **Schueler** commented that this is something the panel will need to cover and should be added to the charge: "To look at road salt application issues".

Bill Selbig asked about incorporating the recommendations into the CBWM and **Schueler** clarified that yes, part of the charge of the panel is to evaluate and recommend changes to simulating the practice in the CBWM.

3. **Background on Last Expert Panel: Schueler** gave a brief overview of the recommendations of the original street sweeping panel (Attachment C). He explained that the current credit had two methods: a "mass loading approach" and a "percent removal" for acreage of qualifying street lanes swept. Both methods required biweekly (26 times a year) sweeping. The original Panel was conservative in its provisions b/c didn't feel there were good RTV procedures to ensure street sweeping is occurring (to receive pollutant reductions) but now there are Bay-wide Verification procedures…Because of the high frequency required, local govts are not using this method to achieve reductions, also asked about removal of solids from catch basins, mass loading approach needs to be revisited.

   Neely Law and **Steve Stewart** discussed the science behind the original recommendations. Neely went over the 2008 CWP literature review and how it informed the current street sweeping credit. More information can be found in the presentation (overview of research…, Dropbox folder for meeting #1) but the following is a highlight of the discussion:

   - Existing recommendations heavily rely on literature (versus existing study in Balto). 3 general observations/findings:
   - "Pick-up efficiency" (pick up by individual street sweeping technology at street level) vs. "pollutant removal efficiency" used in stormwater world (end of pipe) – first one doesn't necessarily translate to second
   - Particle size distribution: different pollutant contribution dependent on size of particles which varies by study
   - sampling results can vary depending on the sampling methods. Automated samplers (e.g. ISCO) may not pick up the full range of sediment sizes that are contributing pollutant loads
   - Access to curb – what are some of the limitations to accessing that area (12" from curb)
   - "Treatable load"

   Tom Schueler noted that there are discrepancies between the tables in the 2008 report and the table in the original panel recommendations (Attachment C) which reflects an interpolation to get a biweekly number (from weekly and monthly frequencies) also data is not from typical suburban streets (high EMC). **Tom Maguire** noted that studies occurring in Massachusettes happened in Cambridge and interstate highway.

Steve Stewart (Baltimore County) discussed the catch basin cleanout study that was conducted: street sediment and inlets were sampled for pollutant concentrations (weight and percent volume).

- **Tom Maguire** asked to explain the design of the catch basin inlets.
- **Steve** clarified that they are designed to be "self-flushing" inlets, with the outlets located at the bottom of the inlet.
- **Tom Maguire** noted that "deep sump catch basins" in NH study found no removal in 2 years (measured at end of outlet pipe)
    - **Tom Maguire said would forward the link to the UNH study – to be added to the literature list**
- **Post-meeting note from Bill Frost**: Regarding catch basin cleaning: my understanding is that "deep sump" catch basins which collect sediment and standing water date back to CSOs. Almost all storm drain inlets currently designed are the self-flushing type. We might consider changing our terminology, to avoid confusion among Expert Panel members, and call all the shallow self-flushing features "inlets" instead of "catch basins".
- **Tom Schueler** noted that definitions are very important and the panel will need to be conscious about defining things such as: standard catch basins vs. deep sump catch basins
- **Tom Schueler**, original panel did not assign a removal for catch basin cleanouts b/c of CWP survey – found nobody cleaned out the catch basins greater than once every two years (and usually only in response to citizen complaints).
    - **Tom Maguire** said the same was true in NE
- **Steve Stewart** – 70-80% inlets had no material at all. Only maintain inlets on a regular basis that are "known offenders" – known to have material
- Stratification of solids in pipes
- **Bill Selbig** noted that catch basins are designed to capture a certain size particle and the panel will want to look at how N and P concentrations vary with particle size

Tom Schueler then briefly went over some of the concerns regarding the existing credit and identified technical issues that need to be resolved.

4. **Background: How Street Sweeping is currently estimated/simulated in the Watershed Model: Matt Johnston, CBPO**, gave a brief overview on how the street sweeping is currently simulated in the Chesapeake Bay Watershed Model. What follows is a brief overview of the discussion and more information can be found in the presentation (simulating street sweeping BMPS, in Dropbox folder for meeting #1).
- How nutrient and sediment is modeled – HSPF modeled that simulates 1 acre of impervious land and unit acre of pervious land – doesn't explicitly model street surfaces (one part of impervious land).
- Every county has a specific load that comes off of an impervious acre. Street sweeping provides an efficiency per load.

- Alternatively, if submit loads collected, can reduce overall impervious load by number of pounds collected.
- If don't sweep the minimum – only receive a sediment credit (not N and P).
- **Tom Maguire** asked that the N and P reductions (3 and 9%) are based on the literature survey.
- **Neely** clarified that none of the street sweeping studies reviewed looked at the pollutant content of the *water* in the pipe (looked at pick-up efficiencies). Reduced by performance factors to get an expected amount at outfall.
- **Tom Maguire** commented that is the case with most of the studies being conducted
- **Tom Schueler** agreed that will need to look at more recent literature for this reason.

5. **Review Process of Recent Literature on Street Sweeping, Catch Basin and Storm Drain Cleaning Practices: Jeremy Hanson, CRC**, explained the literature review process. Asked panelists to identify and submit important existing black and grey literature on studies that are not yet included in our reference list (Attachment D). Jeremy noted that all of the literature is going to be housed on a Dropbox website to which he will be sending around a link. **Jeremy will be sending an invite to the dropbox folder which houses all of the literature for the panel.** He will be assigning the literature to the panelists for presentation at the next meeting. **Neely** noted that the literature should be identified by practice category to which it applies. **Tom Schueler** agreed that this is something that CSN/CRC will be sure to do in advance of the literature assignments.

6. **Tom Schueler** went over the draft agenda for the upcoming research workshop and asked the panelists to comment on how the workshop should be structured (Attachment E).
   - **Bill Frost**: lit review for DelDOT and the findings for modeling
   - **Neely Law**: Gross solids and leaf litter research
   - **Stu Schwartz**: to present on build-up and wash-off of sediments from impervious cover
   - **Steve Stewart**: catch basin research
   - **Jenny Tribo**: to present on local govt collection programs, changes in technology, the reporting for the past 10 years on annual pounds collected through street sweeping and catch basin cleanout efforts and some monitoring (please include frequency of sweeping programs)
   - **Cecilia to contact Paula Kalinosky about presenting on her research at the next panel meeting**

7. **Scoping of Technical Issues to Address Tom Schueler, CSN**, explained how other panels have been approaching the pollutant removal rates. Identified that panel has been charged with nutrient concentration in sediment loads in the urban landscape. **Schueler** asked the panel to review the sediment summary table that had been sent to them over the summer. He explained that CSN put this table

together two years ago (sediment summary table, in Dropbox folder for meeting #1) to compare the nutrient concentrations of sediments found in different areas of the urban landscape. **CSN will add the studies used to create this table to the literature database**. **Tom Schueler** then asked the panel to consider is it possible to go beyond a simple removal rate and apply a protocol of some kind? Stream restoration panel took this approach for one of its protocols - the 'prevented sediment' protocol gives credit for sediment prevented from eroding…

8. **Set Next Meeting Date and Adjourn. Tom Schueler** discussed next steps for the panel amd indicated the next meeting will take place in the middle-end of October. **Cecilia Lane to send out doodle poll link by end of the day** for scheduling and **Panelists are asked to complete the poll by Monday, September 9. CSN** will revise the draft agenda for the meeting, coordinate with presenters and assign and distribute papers. Panelists are requested to send actual (papers not just citations) for additions to the literature database.

Tom Schueler then asked the panelists to reflect on the charge of the panel and comment on what they think the main issues will be going forward:

- **Neely**, particle size + follow the fate of the particle and what potential losses and gains along the way
- **Stu**, has two ideas: fine particulates, coarse, organic and gross trash; try to reconcile numbers (table) with urban nutrient budgets
- **Bill Frost**, identify the loads from the streets vs. those at the outfall (where the load is coming from), particle size governs where nutrients are and where coming from – protocol for determining particle size at the local govt level (Neely's 'discount factor' approach from 2008 was good)
- **Tom MaGuire** – how street sweeping actually improves water quality/c very few studies have been conducted;
- **Bill Selbig**, something about particle size; would like to be able to inform the model
    - **Tom** commented that model separates pervious/impervious areas but there is a lot of overlap in real life
- **Steve**, beware of double counting b/c street runoff can go to other BMPs
- **Sebastian**, looking forward to the panel
- **Justin**, remain flexible for local governments, City of Norfolk has been collecting nutrient data since 2010 from street sweeping on a monthly basis – **Justin to forward this data to CSN**
- **Jenny**, two main things:
    - science will be helpful to understand relationship between street sweeping and water quality;
    - be cognizant of how loads are generated (assumptions of the model) so not provide more complexity then is - would like to hear more from the modelers on how urban loads generated and the variability that exists within them
    - **CSN will ask the modelers to provide ppt at next workshop**

Tom Schueler thanked the panelists for their service. Typically get minutes out within the next week. Please respond to doodle poll promptly. Would like to finish up by next March. Monthly meetings. Etc. Recommends looking at the approved reports at the cbp.org. Agenda.

List of Attachments

- Attachment A – The Proposed Charge for the Panel
- Attachment B – The CBP Protocol
- Attachment C – 2011 Street Sweeping Expert Panel Findings
- Attachment D – Literature List
- Attachment E – Draft Agenda for Second Meeting

Street Sweeping, Catch Basin and Storm Drain Cleaning Expert Panel
Research Workshop
Meeting Minutes
Tuesday, October 29, 2013

EXPERT BMP REVIEW PANEL		
Panelist	***Affiliation***	**Present?**
Dr. Stu Schwartz	UMBC	Yes
Norm Goulet	NVRC	Yes
Jenny Tribo	HRPDC	Yes
Tim Karikari	DDOE	No
Sebastian Donner	WVDEP	Yes
Bill Frost	KCI	Yes
Justin Shafer	City of Norfolk	Yes
Steve Stewart	Baltimore County	Yes
William R. Selbig	USGS	Yes
Tom MaGuire	MassDEP	Yes
Dr. Neely Law	CWP	Yes
Tom Schueler Jeremy Hanson	CSN CRC (Panel co-facilitators)	Yes Yes
Non-panelists: Cecilia Lane – CSN; Paula Kalinosky – U. of Minnesota; Matt Johnston – UMD, CBPO; Jeff Sweeney – EPA, CBPO		

9. **Call to Order and Introduction Tom Schueler, CSN**, called the meeting to order, thanked the panelists for their participation in the Expert Panel and gave a brief overview of the agenda. Tom asked the panel to focus on: (1) any efficiency data to improve the panel's estimates, and (2) nutrient content and issue of street sediment and urban vegetation detritus in urban landscape.

Meeting minutes

Norm Goulet conveyed that just because there are existing recommendations (from preexisting panel) doesn't mean that can't change/adapt. The panel should not feel boxed in by previous recommendations.

DECISION: The panel approved the minutes from the 9/3/13 meeting.

10. **Literature Update**

ACTION: Panelists should send any final studies to Jeremy Hanson (jhanson@chesapeakebay.net) by November 12th, or upload them directly to the Dropbox literature folder (and let Jeremy know that they have been added). ***The call for literature will end on November 13th.***

ACTION: Panelists should indicate if they cited any literature or research in their presentation that is not currently listed on the panel's list of literature.

Presentations are all posted to the Panel's Dropbox. Major highlights are captured below, along with key discussion, questions, and answers. Please consult the presentations for more details.

Schueler notified the group that we are looking for the panel to find areas of concurrence, common threads and also identify areas of missing information.

Tom Maguire, **Paula Kalinosky**, **Bill Selbig**, **Matt Johnston**, **Stu Schwartz**, **Bill Frost** and **Neely Law** all gave research presentations on various research projects associated with street sweeping/catch basin cleanout/street sediment, etc.

11. **Quantifying Nutrient Removal through Targeted, Intensive Street Sweeping – Paula Kalinosky**
    - Study done in Prior Lake area of MN. Looked at relationship between overhead tree canopy and recovered solids, nutrients. Used regen-air system for whole study, which found nutrient loading follows vegetation cycle; recovered loads per curb mile were significantly higher for high canopy cover routes. Coarse organics accounted for majority of nitrogen loads. Found that EMC based studies don't have statistical strength to model/predict effect of street sweeping as a BMP. Was able to create a spreadsheet based model that correlates well with collected data that localities can use to estimate the pollutant removal benefits and to prioritize the street sweeping activities
    - **Goulet**: if had to redo the study, would there be any changes to the methods?
        - **Kalinosky**: Can always have better data, but ours is pretty good (392 samples). Would be nice if there were 3 routes with the same canopy cover that could be swept at different frequencies. In the lab we did not do TSS in the water samples, so some solids were unaccounted for.
        - **Tom**: on the routes, were there any active leaf waste collection programs?
            - **Kalinosky**: Unsure if they have leaf collection. Residents were not supposed to put leaves in the street, though sometimes that happens when residents know the sweepers are scheduled to come through.

- **Stu** asked about the forms of organic carbon in the collected litter. Not just concerned with mass, but availability.
  - **Kalinosky**: Study looked at TN and TP. Could look at decomposition study published by Sarah Hobbie for information about carbon.
- **Schueler**: Was lot size pretty much the same?
  - **Kalinosky**: Prior Lake was pretty typical suburban for the area. Could reasonably translate these results to the region, but perhaps not to other areas.
- **Kalinosky**: There is a report that will be posted online. Some academic papers are in the works. **ACTION**: **Paula to share report when available for citation by Panel.**

12. USGS Studies Conducted in Massachusetts – Tom MaGuire

- Four studies in MA in conjunction with USGS: Smith (2002) found no differences observed between pre and post sweeping loads in the inlets. Zarriello et al (2002) was a modeling study. Breault et al (2005) had limited funding and looked at two multifamily residential areas; found high per-sweep efficiency. Lower efficiency when looking at smaller particles. Sorenson (2013) found 521 lbs/curb mile (on the street) in commercial and 740 lbs for multi-family (Cambridge, MA). Per sweep efficiency was high, similar to previous study. Regenerative air was most efficient, averaging 8-9% on annual basis. Mechanical brush, 1-2% for phosphorous. The frequency did not appear to impact the phosphorous removal for Regen.
- **Selbig** noted there's a point of diminishing returns for sweepers. That could have something to do with the phosphorous removal.
- **MaGuire**: Massachusetts is a cold climate area, and the sand added to the streets in winter can be a phosphorous source.
- **Schueler** noted the 3 early studies had relatively limited sample sizes and asked if there were seasonal effects. **MaGuire** indicated the 3 earlier studies were limited in sample size. He explained that in the New Bedford study street sweeping was conducted in the summer months, in the southeast expressway study sweeping was conducted for a 2-year period, including the winter months.
- **Schueler** pointed out that the removal rates in these studies were consistent with the original panel findings/recommendations.

13. Street Sweeping as a Water Quality Management Tool and New Research on the Role of Particle Size Distribution in the Urban Environment – Bill Selbig

- Used vacuum cleaners to measure street load. Wisconsin has large sand applications in winter. Were missing a large part of load by only sweeping the area nearest the curb. There are many reasons why it is hard to detect changes in water quality from sweeping, including solids stratification bias in storm sewer. Developed a depth integrated sample arm (DISA) to overcome issues with the old fixed point sampler. DISA had much less bias than fixed sampler. Able to model and predict with much more significance thanks to DISA data.

- **Schueler** asked about the mobility issue with extreme storms.
    - **Selbig**: Relationship exists, but can only speak qualitatively. It depends on the source material.

Tom asked for thoughts on themes heard by the panelists during the morning session.

- **Frost**: loads for different types of streets. Categorizing by tree canopy is an interesting way to go, and could perhaps tie into the Watershed Model. Information for pickup per curb mile could also be an interesting way to go. Reporting weight collected may not be way to go since not everyone weighs the trucks every time they sweep.
- **Schwartz**: Keep hearing about the importance of particle size distribution and what reaches the stream or not. Should give credit for picking up nutrients/sediments that would reach the stream, not just the larger particles that will not reach it except in larger events. We really need to approach this in a mass balance sense. It has to all add up.
- **Goulet**: Echo Stu's point about particle size. Glad to hear about DISA sampling methodology. Interested to hear what Matt Johston has to say about how load exists in the Model now.
- **Sebastian Donner**: If we reduce load before it gets to the street (e.g. leaf collection), we need to think about how to avoid double counting.
- **Jenny Tribo**: Important to consider the total effect of the trees. May decrease the runoff, though they increase the biomass that ends up on the streets.
    - **Schueler**: Norm and I will touch base with Forestry Workgroup's panel on Urban Tree Canopy BMP.
- **Schueler**: in our final report we can make recommendations regarding maintenance activities.

Schueler began the afternoon session by explaining it is important for panel to not only depict how BMP functions in the real world, but recommend how it should fit into the Bay Watershed Model and the Bay Program Partnership modeling tools.

14. Watershed Model (WSM) and Scenario Builder – Matt Johnston

Johnston described how the Watershed Model and Scenario Builder simulate nutrient and sediment loads.

- **Goulet**: what do we know about vegetative loads in the urban sector in the model? Are there loads from lawn clippings, leaf litter, etc?
    - Johnston: We have target rates from the literature that are intended to include all those mentioned factors, but perhaps better data is available. He noted the nitrogen submodel will be simplified for the Phase 6 WSM and will more closely resemble the phosphorous submodel.

- **Schueler**: for the Phase 5 model, the target loads were primarily derived from national stormwater database with some modifications for the Phase 5.3.2 WSM. most stormwater scientists measure end of pipe but HSPF is a groundwater model so N and P assigned to pervious land. 'Extra' values 'dumped' into this area but can come from all sources and N dynamics not fully understood.
- **Johnston**: Good points. It is true that these factors are implicitly included in the model simulation, but cannot currently break out the explicit sources from the target loads.
- **Law**: the documentation states a concentration of 2mg/L N for urban impervious areas?
    - **Jeff Sweeney**: you take the EMC and multiply it by the runoff from the land calculated by the model.
    - **Schueler** noted that a BMP's efficiency can be reduced when a large storm event is simulated, e.g. 1" per hour or 2.5" per day.
        - **Sweeney**: cannot switch 'off' completely, but can go low, e.g. to 10% of original efficiency.
    - **Selbig**: Is the buildup/washoff in HSPF similar to SWIMM?
        - Sweeney was not familiar with that model and could not be sure.
    - **Schueler** summarized that the accumulation/washoff is kept within a specified range of values to match the target loads. The WSM is more concerned with the accuracy of the annual loads.
    - **Johnston**: we could have the HSPF experts come back to the panel about some of these points.
    - **Schwartz**: would like more information about the role of leaves/trees in the nitrogen submodel.
        - **Johnston**: For pervious urban, there won't be trees/leaves in the simulation. Areas with enough trees are modeled as forest…
        - **Schueler**: important to note that pervious and impervious urban simulations are very simplified.
            - **Johnston** noted the partnership continues to push for further simplification in the Model.
            - **Selbig**: the WinSLAMM model already includes a lot of this information.
    - **ACTION: Jeremy to obtain Source Loading and Management Model for Windows (WinSLAMM) documentation for the Panel's reference.**
    - **Frost**: from my perspective, would care more about breakdown of sources, not land uses.

15. Street Sweeping and Water Quality: What are we Sweeping? – Stu Schwartz

- Sansalone studies complement Selbig's ealier discussion of bias. Ying and Sansalone (2010) found decreasing median particle size downstream (finer material closer to the inlet). Larger material is what accumulates and does not drain. Sweeping typically picks up the larger material. Research suggests that we need to go beyond mass collected.

- **Schwartz**: Important to think about the 4 fractions of the 'street debris':
  - Extreme events – yes will eventually move the coarse material
  - Fine particulates (settleable)
    - Fine particulates represents a mix of finer particles (with fuzzy particle size boundaries) but something like a combination of what Sansalone called suspended (less than 25 micron) plus the settleable (25-75) micron material that has much higher surface area and contaminant adsorption capacity. In a fuzzy boundary it may even extend up to about 100-150 microns or so. Will most readily mobilize - and therefore least likely to be left on the street- during runoff. It captures a mix of sizes that drop out in the inlet structure, basin, or quiescent water, as well as the suspended material that overwhelmingly accounts of instream TSS.
  - Coarse particulates
    - Sand to gravel sized particles that are rapidly winnowed in flow across pavement and "typically" compose most of the road grit in the curb and around the inlet, that is effectively picked up by streetsweepers. Typically accounts for most of the metal load, but much less of the nutrient load. This is what Sansalone calls the "sediment" fraction.
  - Organic debris (leaf litter) – how much of it is 'readily leachable'?
  - Gross Trash
- **Schueler**: We will need to focus on definitions as a next step with the panel process – might be worth using these categories as a starting point
- **Schueler**: storm drain network is designed to transport and self clean, which has unfortunate result of grinding and causing decay of coarse organic.
- **Selbig**: we may need to develop some delivery coefficient or something similar.
- **Cecilia Lane** reminded panelists to provide the citations to any studies referenced in their presentations.

16. DelDOT Street Sweeping Plan for New Castle County – Bill Frost

- Bill discussed the study that was done in association with DelDOT. Conducted a national literature review and considered a number of scenarios.
- **Schueler**: the type of analysis that was done as part of this study is ultimate 'tool' that local governments would need to use.
- **Law**: numbers are good for sediment but nutrients are variable which is most likely a function of what is being measured; not sure that data gap has been filled since the original panel met
- **Frost** noted that multiple variables need to be considered: size of particles, type of nutrients, efficacy of the sweeper
- **Bill Frost to share the referenced studies.**

17. Gross Solids – Neely Law

- Neely presented on research she's been involved with that have dealt with nutrient characterization of 'street dirt' and gross solids, including: Baltimore City, the Baltimore County Catch Basin project, and gross solids research that conducted in Talbot County, MD.
- Catch basin study
    - **Stewart** did not do nutrient analysis by particle size on the catch basin study
    - **Schueler** noted that catch basins provide a good opportunity for denitrification
- 30 percent of TP attributed to leaves and other vegetative material.
- Law: For gross solids characterization study in Talbot County, MD, wanted to know if the dry weight could be estimated from the wet weight. The sample with the highest TN concentration was a result of lawn clippings that had been dumped down the storm drain.
- Tom explained the revised "Table 5 – TN and TP Concentrations in Sediments in Different Parts of the Urban Landscape."
- **ACTION: Jeremy to update sediment summary table with median nutrient concentrations from literature/presentations.**

18. Lit review – Jenny Tribo

- The draft permit has equations for practices such as street sweeping and leaf litter collection. However, there are no sources for the data listed in the document.
- **Maguire** noted it is not an MS4 permit, but a draft residual designation permit for three towns in the Charles River watershed. He offered to check into the source for the draft permit. It has been held up in the review process. Mass is not a delegated state, so the permit is from EPA Region 1.
- **Goulet** noted that he probably provided the original document, so he'll check his records for more data or documents.
- **ACTIONS:**
    - **Cecilia and Jeremy to follow up with Tom MaGuire and Norm to track down the source/citations.**
    - **Jeremy to follow-up with Neely for the Charles River Association rep re: permit**

19. Lit review – Sebastian Donner

- **Schueler** asked about the definition for winter road treatments in Shaheen 1975.
    - **Donner to double check.**
- **Schueler** noted that every panel report has to include a background section about the practice in the CB region. Has anything dramatically changed in the last 6 years that would modify results from the survey?
    - **ACTION: Panelists to read through CWP's 2007 survey, and ask selves "has anything changed?"**
    - **ACTION: CSN and Jeremy to summarize the survey in 1-2 pages and circulate to the panel for next meeting. Will be used for**

"Background on Street Sweeping in the Chesapeake Bay" section of report.
  - **Goulet**: not much change, but perhaps less frequency due to economic downturn.
  - **Tribo**: Norfolk has increased its street sweeping, but think everyone else is the same.
  - **Shafer**: we are trying some different things. Once a month, with some areas more frequently.
- **Summarize results from the survey to share with Panel.**
- Justin: for past two years we have been sampling our sweeping monthly. Just started testing our new sweepers. Schueler asked him to provide median values.
  - **ACTION: Justin to analyze data on spreadsheets he sent – use median and share with panel; CSN to add to table.**

20. Lit review – Justin Shafer
- Kalinosky covered first study.
- Other study was a masters thesis with Bob Pitt as an advisor. There was some data included in the appendices that could be useful.

21. Lit review – Steve Stewart
- Sorenson study was discussed this morning. There was an end of winter cleanup that demonstrated extremely high yields, presumably from the winter materials.
- Berretta et al 2011, conducted in 14 MS4 areas in Florida. Will have to double check if the weights are wet or dry. Not clear if the catch basins were associated with the street sweeping routes. Was unclear how they derived their cost-per-pound.

22. Lit review – Norm Goulet
- Norm will present his lit review at the next meeting.

23. **Discussion of main technical issues and next steps**
- Tom thanked the panelists. He asked the panelists to describe (1) what surprised them and (2) what was reinforced to them.
  - **Schueler**: Particle size matters and will need to be considered. Might be able to reach a definition. Reminded him of urban nutrient management panel – can't always equate application and delivery
  - **Selbig**: we can characterize what's on the street all we want, but what matters is the transport to the streams.
  - **Tribo**: Echo Bill's point. Neely's study demonstrated that some of this material was reaching the stream. Need to consider under what conditions material reaches the stream.
  - **Shafer**: Should consider bi-directional flows in tidewater area that can re-suspend material in storm drains.

- **Frost**: There are factors to consider for prioritizing street sweeping, not just traffic volume, but also tree canopy. Some factors like canopy can be addressed with GIS. We may be sweeping a lot of material, but it may only be a small part. In the end, need determine if sweeping is doing anything for water quality.
- **Schwartz**: surprised by the significance of the organic load. It reinforced the importance of thinking about delivery ratio. Need a mass balance.
- **Donner**: Surprised that so little nutrients attached to sediments overall. Reinforced the concern about biomass produced by some BMPs and ignore what happens later on.
- **Goulet**: The community still doesn't have a good handle on this, even after several years. Will have to nail down (1) transport mechanisms, and (2) put this in format/method that the locals can utilize.
- **Stewart**: agree with Selbig. Perhaps discount based on delivery ratio. Some of the delivered material will transform when it reaches the stream. One reason we need the bulk removal option is that most localities will still not be able to meet frequency requirements. Also, the nets/inlet cleaning will be bulk measurements.
  - **Goulet** agreed. We will need the bulk option, but there should be a carrot/stick approach. Perhaps require analysis of the material to get credit for bulk removal.
- **Law**: NCSU is undertaking a gross solids study that perhaps we can use. We need to think about what we are measuring and what we will give credit for.
- **Schueler** asked what other science is needed in order to answer some of these questions. (1) Ratio of TOC in outfalls vs streams, and (2) what is the velocity in gutters are and movement of particles by size. Perhaps there is some data that could help on this.
- **Schueler**: we can start discussing reporting, tracking and verification issues at the next meeting.
- **Donner** commented about a stacked/treatment train BMP approach.
  - **Schueler**: It is in purview of this panel to determine if it should be treated as a stackable BMP or not.
- **Schwartz**: it would be interesting to see a list of all the potential urban BMPs in comparison to a typical urban segment.
  - We could ask CBPO staff to provide this kind of data.
  - **ACTION: Jeremy to get progress report data on street sweeping from CBPO staff.**

- Schueler thanked all the participants for their time and insights.

Next panel meeting in December to come up with a conceptual approach to handle issues identified today, part of that will be the definitions of the components, particle sizes, locations in storm drain system, discounts for delivery issues, tracking/reporting/verification.

Street Sweeping, Catch Basin and Storm Drain Cleaning Expert Panel
Research Workshop
Meeting Minutes
Tuesday, December 3rd, 2013

EXPERT BMP REVIEW PANEL		
Panelist	***Affiliation***	**Present?**
Dr. Stu Schwartz	UMBC	Yes
Norm Goulet	NVRC	No
Jenny Tribo	HRPDC	No
Tim Karikari Matt Robinson	DDOE DDOE	No Yes
Sebastian Donner	WVDEP	Yes
Bill Frost	KCI	Yes
Justin Shafer	City of Norfolk	Yes
Steve Stewart	Baltimore County	Yes
William R. Selbig	USGS	Yes
Tom MaGuire	MassDEP	Yes
Dr. Neely Law	CWP	Yes
Tom Schueler Jeremy Hanson	CSN CRC (Panel co-facilitators)	Yes Yes
Non-panelists: Cecilia Lane – CSN;		

24. **Call to Order and Introduction Tom Schueler, CSN**, called the meeting to order, thanked the panelists for their participation in the Expert Panel and gave a brief overview of the agenda.

Meeting minutes

DECISION: The panel approved the minutes from the 10/29/13 meeting.

25. **Review of West Coast street sweeping studies and other panel research review report outs**
- Tom noted that none of the studies had pre- and post- water quality monitoring. Some of the studies had a wealth of street dirt sample data; he summarized the relevant data in some tables for the panel. The San Diego studies had more data on particle size distribution or both street dirt and sweeper waste. They do not get to central question regarding whether the swept/collected material would reach the stream or not. Bill S. noted the Oakland study is ongoing and they'll be working with USGS over coming months as they continue to collect samples.

26. Literature update and remaining search topics

- Jeremy noted that Tom and Stu had provided a couple dozen more studies for the literature list. He explained the new studies are listed in a word document and will be added to the literature spreadsheet.
- Stu explained that three groups of papers stood out in the additional literature. One group on first flush, which helps understand the marginal impact of street sweeping. Another set discussed the transport and load and size distribution of the sediment and particles. Some of the fine particles are quite mobile, and there are questions about how well the sweepers are able to pick up. A couple papers (Miguntanna and Liu) show that land use is a poor predictor of pollutant buildup. Shaw (2011) found that the time between storm events was not a significant predictor of buildup and accumulation of material available for pickup, which raises questions about sweeper frequency needed to see a water quality benefit.
- Matt Robinson: DC did a study (by EA) that was printed back in 2007. It was a particle removal study comparing vacuum and other sweepers.
    - **Matt to send EA report to Tom**
- Neely asked Stu about the Shaw study.
    - Stu: In a regression analysis, the time between storm events was not a significant factor of buildup.
    - Bill S: I have also looked at several of Stu's cited papers for other projects for background purposes.
    - Tom: will categorize the list into groups and assign 1-2 articles to the panelists
    - **Stu and Tom to provide the studies to Jeremy for uploading to Dropbox.**

27. Some proposed definitions and particle size classifications

- Tom reviewed some proposed definitions with the Panel. He noted they are just a first cut, so the panel can definitely tweak the definitions moving forward.
- Street dirt + street detritus = street solids.
    - Steve: may be missing the trash component, which can comprise about 10% of the weight.
        - Bill: should break that out as its own category. Leaving detritus its own makes sense.
        - Neely: we have used particulate matter, because there is broken up pavement material included.
        - Bill S suggested categories of street solids, gross solids, and total solids. Gross solids are combination of gross sands, gravel, and trash.
        - Steve: feel it's important to break out the trash component since some locals have to track it for purposes of a trash TMDL.
        - Tom cautioned the panel about having a category that may be difficult to quantify numerically. With that said, we can adjust the definitions as needed moving forward.

- Tom: was surprised by consistency or lack thereof in the particle size classifications.
  - Tom M: would advocate for 62-62.5 microns for the fine sand and silt split. That is what we use in Massachusetts.
  - Bill: It depends what protocol you use, ASCE or USGS.
  - Stu: we may not want to lump very small particles (<25 microns) that won't settle out with particles that will (e.g., 75 microns).
    - Tom: No decisions today, just want to have a simple three-part breakout.
- Matt: would it be prudent for panel to create a list of the various proprietary sweeper technologies used in the watershed?
  - Tom: we can try to build that, but it's not in the scope of the panel to build a comprehensive list of sweeper technologies.
- Neely: does the Model have any particle size assumptions that we need to be aware of?
  - Tom: in terms of loading, the edge of field loads in the model are completely agnostic to size distribution.
- Tom reviewed the draft outline for the research review section of the report along with some preliminary tables that compare data from the literature.
  - **Tom asked panelists to review the tables and provide comments, additions, or revisions by Dec 31st.**
  - Bill: the devil is in the details. The categories are pretty broad. In our studies, about 30% to a third of the mass was between 250-500 micron range, over the four study basins. The distribution by percentage was very similar in the street compared to what is in the water.
- Tom reviewed some initial thoughts on street detritus.
  - Matt R: we may have some data on how much water it takes to move these leaves through the storm drains.
  - Stu: a couple of key points here. Caution looking at direction of these trends without context of the mass balance. Suggest we'll have to ground ourselves by looking at a mass balance.
  - Neely: can follow up on a study about the fate/transport of urban tree canopy that I've seen.
  - Bill S: We are currently working on a leaf pickup study. Not sure how we could possibly do a comprehensive mass balance. It takes a significant storm event to move the leaves.

28. State of current street cleaning practices in the Chesapeake Bay

- Jeremy briefly reviewed Attachment E with the panelists.
  - **Panelists to provide any comments or edits to Jeremy on Attachment E.**
  - **Tom asked Neely to review Attachment E and provide any edits/revisions to Jeremy.**

29. Proposed outline for research review section and some initial research comparisons

- Combined in above agenda items.

30. Panel brainstorm session: options for modifying the two removal rate protocols

- Tom reviewed a few slides with the panel for Attachment G. He reminded panelists that a main purpose of the panel is to generate protocols that localities are able to follow and report. He outlined several possible modifications for each existing protocol. He offered a pair of rough conceptual new protocols for the panel to consider. Any other potential options?
    - Bill: Credits for pounds per miles swept. Agencies generally know how many miles they sweep. Could potentially be a new protocol.
    - **Tom will work up some options for reporting, tracking and verification of street cleaning activities for January.**

31. **Set next meeting date/agenda and adjourn**

- Jeremy will contact the panel with options for a few weeks in January. There will be some homework and action items to complete in the mean time.
- **Tom to invite Ken Belt to speak at our next call.**
- **Bill S. to invite Roger Bannerman to talk about WINSLAMM- derived sweeping credits at our next call**
- **ALL**: BEFORE NEXT MEETING
    - **Go through the data tables in the Initial Data Comparisons, and add in any additional studies, and provide quality control on existing data entries in the table**
    - **Go thru Attach G and prepare 3 or 4 slides on your *initial thoughts* on how to modify/create protocols for the effect of different forms of street sweeping**
    - **Go thru Attach D and suggest any additional definitions, revised definitions and your preferences on the particle size classification.**
- **Jeremy and Tom to begin writing of the Research Review Section, and put together outline for final report**
- Tom thanked the panelists for their time and participation.

Street Sweeping, Catch Basin and Storm Drain Cleaning Expert Panel Teleconference
Meeting Minutes
Friday, January 10th, 2014

EXPERT BMP REVIEW PANEL		
Panelist	***Affiliation***	**Present?**
Dr. Stu Schwartz	UMBC	Yes
Norm Goulet	NVRC	Yes
Jenny Tribo	HRPDC	Yes
Marty Hurd	DDOE	Yes
Sebastian Donner	WVDEP	Yes
Bill Frost	KCI	Yes
Justin Shafer	City of Norfolk	Yes
Steve Stewart	Baltimore County	No
William R. Selbig	USGS	Yes
Tom MaGuire	MassDEP	Yes
Dr. Neely Law	CWP	Yes
Tom Schueler Jeremy Hanson	CSN CRC (Panel co-facilitators)	Yes Yes
Non-panelists: Cecilia Lane – CSN; Ken Belt – US Forest Service; Roger Bannerman – Wisconsin DNR;		

Call to Order and Introduction Tom Schueler, CSN, called the meeting to order and gave a brief overview of the agenda. He noted the addition of Roger Bannerman (Wisconsin DNR) and that the call would run an extra half hour for discussion. Schueler welcomed Marty Hurd (DDOE) as the new panel rep from DC.

DECISION: The panel approved the minutes from the 12/3/13 call.

The gutter subsidy and organic carbon dynamics in urban watersheds

- Ken Belt (US Forest Service) described his research and results of nutrient and carbon loads from leaf litter in urban areas. His presentation is available to the Panel for more details on the Dropbox. He noted that there is a load of leaves during the summer, not just in autumn. Pound for pound, this "greenfall" contains more nutrients. Schueler opened the floor for questions from the panel.
    - Hurd asked for clarification on the concept of "flux."

    - Belt: Flux is the concentration multiplied by flow rate. This is an important concept for managers to understand what the load is per unit time.
  - Stu Schwartz asked Ken for a copy of his calculations.
    - Ken agreed to provide this and also plans to provide additional information to the panel.
  - Belt mentioned he intends to develop an aquatic ecological component for iTree. He encouraged any panelists to contact him if they are interested in helping to identify parameters for that project.
  - Selbig: most of Ken's work is focused on urban streams. Roger and I are interested in what would happen if we removed the DOC from the pathways. Is there plenty food for bugs or do they rely on that flux?
    - Belt: Personally think there is plenty for the bugs. The loads are so high there is plenty leftover. There are some papers that indicate there is a lot of impact from DOC from geochemical processes in streams themselves. As managers, there are probably some things we can do to harness it. Frequent, small storms can compose a lot of the runoff
  - Roger mentioned a study that demonstrated rapid decline of macroinvertebrate community along with urbanization. There is an interesting dynamic. There is a flux and input of organic matter, but it does not always support the macroinvertebrate community in urbanized areas.
    - Belt: Have a lot of bug data as well. If we were able to inexpensively extend the residence time for large particulate matter like leaves, would be curious about effects.
  - Tom: Was surprised to find that decomposition rates in urban streams are still so high in absence of shredders and macroinvertebrates. There is an increased microbial presence in urban streams that apparently makes up the difference.
  - Selbig asked Belt if he has any data on nutrient concentrations by season.
    - Belt: Not from my unfunded research, but that was something I would have really liked to include.
    - Tom: he did provide some literature on greenfall rates. Risley and Crossley (1988). It supports the notion that the leaf litter is more nutrient rich in the summer than in the fall.
  - Law: requested some info from Dave Nowak on leaf litter in Baltimore. Will follow up with him on how the data was generated by species and land use.

Additional literature to consider

- Schueler explained that he and Stu had a lot of discussion about street detritus since the last call.
- Schwartz presented a lot of information on street detritus and leaf litter from additional studies that he located. His presentation is available to the panelists on

the Dropbox for more detail, but he offered a few main points based on his review:

1. There is no evidence of a significant detectable direct nutrient "gutter subsidy" that would be affected by street sweeping.
2. Neither DOM nor FPOM in urban streams suggests a significant detectable carbon "gutter subsidy" that might suggest a surrogate signal affected by street sweeping; and
3. The fraction of urban leaf fall that could reach and remain in the curb is not known but there are many alternate retention pathways and storage sites in urban/suburban landscapes that will substantially reduce the delivery ratio of the canopy leaf fall.

- Tom noted the time and introduced Roger Bannerman (Wisconsin DNR).

Use of the SLAMM model for estimating water quality benefits of street cleaning

- Bannerman described his studies and results from Wisconsin, which included modeling using the WinSLAMM model.
- Tom: when you have continuous parking, there needs to be parking enforcement
  - Bannerman: Cambridge has designated days or half days when parking is off limits for certain streets. It takes money for signage, etc., but initial results suggest it is worth the expense.
- Schwartz asked for Bannerman's thoughts about implications on street sweeping effectiveness for reducing nutrient loads.
  - Bannerman: We did phosphorous analysis on street dirt samples, but had limited resources to do much work on nutrients. We can bring nutrients and heavy metals into understanding of benefits from street sweeping. The model will keep getting better.
- Schwartz: aware of any studies that measure benefits from sweeping based on monitored discharge from a pipe?
  - Bannerman: We have not seen a change at end of pipe. If you reduce the washoff of sediment, should also reduce phosphorous. Willing to work with panel if there are other ideas or questions. Maybe with a new sampling method can see smaller changes at end of pipe. Took the modeling approach in the studies because end of pipe is more complex.
- Hurd: what are the key variables to get accuracy of this? Sweeper type, time between sweeping, frequency, etc.
  - Named most of them. Trying to duplicate the sawtooth pattern from the presentation. There is a criticism that most machines do not go the same speed as the test sites; they sometimes go faster. There is not much that can be done about things like that.
    - Frost: DelDOT is equipping sweepers with GPS and equipment to show when the sweeper is down, where they are, and what speed they are going. Not common, but feasible.
- Bannerman noted some papers coming out on perennial pavement and phosphorous, among others.

Panel feedback

- Schueler noted the time and asked to break from the agenda and seek the panel's input and thoughts during the final half hour.
  - Goulet: The more we dive into this, it becomes increasingly clear that it is more complicated than we ever previously thought. There are so many different sources and variables. Do not know if we will be able to put this together in a fashion that is acceptable across the whole watershed where the conditions are widely different. Will have to keep it simple, which will add to the variability.
  - Belt: Should think about going beyond trucks and sweeping, perhaps considering the role of homeowners and leaf collection or management.
  - Tribo (had to leave early, provided input via email):
    - I really like the latest thoughts on street detritus (1/6/14). I think it is a great summary of much of the literature and makes some great points about how the larger particulate matter becomes the smaller matter over time. I think this is an important point that often seems to get glossed over when talking about what particle sizes the sweeper is collecting. Even if the sweeper cannot get the fine particles present, it is preventing fine particles from forming by removing the coarse particles before they further decompose. I also agree with the initial conclusion that a timely and targeted leaf program can reduce TN and TP. I think the panel needs to focus on defining these parameters. I think today's presentations were very helpful in moving us closer to this goal.
      - As far as my thoughts on modifying the current protocol, I do not have any firm recommendations yet. My thoughts at this time are as follows:
        - Consider sweeper type – higher efficiencies for vacuum sweepers.
        - Credit lower frequencies of sweeping and targeting seasonal sweeping
        - Consider differential rates for street types – today's last presentation seems to support this idea.
        - Add credit for catch basin cleanouts
        - Add credits for yard waste management programs and leaf collection programs
        - I would like to see us keep the mass pickup credit, but given today's presentations I'm not sure how much this is really supported by the science.
        - I would like to see the protocol define and describe a model program and the efficiency for this program, but then define decreasing credits for programs that don't quite meet the model. This allows localities to get some credit for what they are doing, but have something to move towards.

        - I would also like to see the protocol identify the information that is missing in order to have higher confidence in the efficiencies of sweepers and include a section on research priorities.
    - There are still a lot of details to work out, but I think these meetings and especially today's presentations have been very informative and helpful for moving forwards.
- MaGuire: still concerned about the part of the load that gets into the water. There are so many sources for what gets to the road, but what gets to the water.
- Frost: We might think about adding a credit for leaf collection. Most places I know of end up composting the leaves and selling it as mulch. Thought the recommendation of pounds per curb mile was pretty good. We might be able to offer a boosted credit if they are able to document how the sweeping is done. Removal per mile may vary by frequency. Will get less per mile if sweeping is done more frequently.
- Hurd: Think we should be recommending that the jurisdictions should move towards tracking more than just the distance or amount swept. The dates, weights, and distance for particular trips. Do not expect they could start reporting such info overnight, but perhaps the jurisdictions should be expected to provide metadata at some point.
- Law: street sweeping may not be the right BMP to consider the nutrient contributions from leaf litter. Maybe we should push that aside and focus on the mineral particulate matter and the nutrients in that component. We could view leaf litter separately.
- Donner: Also agree with the curb mile approach. We could ask for additional factors or information for reporting, but they would only be required to gather and submit that data if they want the boosted credit. If they only report the curb miles and frequency, they would get some basic credit. Give opportunity for more advanced jurisdictions to receive more credit.
- Selbig: Do not think that simply measuring the mass in a hopper or the distance/area swept is enough. It might tell us what is picked up, but it does not tell us anything about what was there to begin with, or what was transported to the water. Perhaps there would be a way to put information into SLAMM or some other model.
    - Schueler was supportive of that concept, but need to consider verification as well.
    - Hurd: we can only make a very coarse estimate, but if there is more intense data available, there should be an incentive to submit that better data.
- Shafer: Agree with idea for keeping it simple and providing opportunity for increased credit. There is so much variability for lane miles swept. Would like to see some volume based approach.
- Schwartz reiterated Goulet's comment. There is still little to no evidence of a water quality benefit from street sweeping. Perhaps the panel could take an approach such as the Urban Nutrient Management Panel, which

recommended a temporary credit for a couple years, by which point there will hopefully be more information available. Open to using some form of SLAMM, but would have concerns about variability. May have additional thoughts to share in writing after the meeting.

- Schueler**:** We can now say the research phase is over. Jeremy will schedule a call for February.
- Schueler asked panelists provide a one page set of bullets of where they feel the panel should go for the reporting protocols. Would help meld everything together and gauge what directions the panel wants to go. Probably the first two weeks of February.
    - **ACTION**: By next conference call (TBD), panelists to provide one page or less of bullets of their thoughts on reporting protocols for street sweeping.

Adjourned

Street Sweeping, Catch Basin and Storm Drain Cleaning Expert Panel Teleconference
Meeting Minutes
Thursday, February 20th, 2014

EXPERT BMP REVIEW PANEL		
Panelist	***Affiliation***	**Present?**
Dr. Stu Schwartz	UMBC	No
Norm Goulet	NVRC	Yes
Jenny Tribo	HRPDC	Yes
Marty Hurd	DDOE	No
Sebastian Donner	WVDEP	Yes
Bill Frost	KCI	No
Justin Shafer	City of Norfolk	Yes
Steve Stewart	Baltimore County	Yes
William R. Selbig	USGS	Yes
Tom MaGuire	MassDEP	No
Dr. Neely Law	CWP	Yes
Tom Schueler Jeremy Hanson	CSN CRC (Panel co-facilitators)	Yes Yes
Non-panelists: Cecilia Lane – CSN; Matt Johnston – UMD, CBPO		

Call to Order and Introduction Tom Schueler, CSN, called the meeting to order and gave a brief overview of the agenda.

Review of meeting minutes and action items from January meeting

- Hanson directed the panelists' attention to the January minutes. He noted some corrections from Stu Schwartz. Schueler asked for any additional comments or edits; none were raised, the minutes were approved.

DECISION: The panel approved the minutes from the 1/10/14 call.

- Schueler noted that Law had received a spreadsheet from Nowak with data for Baltimore.

Panel perspectives on street sweeping

- Schueler noted the street detritus issue will be split up into two parts and addressed in part during the next panel call. Schueler directed the panelists' attention to Attachments B and C. He noted the options outlined in the attachment were for the panel's consideration and discussion only and should not constrain the panel.

- He conveyed some thoughts from Stu Schwartz who was unable to join the call:
    - First, Stu is very skeptical due to the lack of monitoring data that shows end of pipe benefits from street sweeping. He suggests the panel should try to set upper and lower bounds for the BMP removal rates based on the issue of detectability.
    - Second, given the lack of "smoking gun" evidence from monitoring data, the panel ought to consider which studies or methods are most persuasive from the studies that the panel has reviewed.
  - He noted that Bill Selbig and Bannerman had exchanged several emails with him. Following their presentation on the WinSLAMM model we discussed if it could potentially be used as a tool to estimate reductions from street sweeping. Schueler talked with them about the potential level of effort for using the Model.
- Schueler reviewed the options described in Attachment B. He asked for questions and noted the panelists could choose more than one preferred option if they wished.
  - Selbig preferred options one or two. Feel the other options may over simplify a complex issue. Simply measuring what's in the hopper tells us nothing about what was on the street or what was prevented from washing off. Options 1 and 2 take advantage of a model that has built on decades of data.
    - Schueler: in some of the phosphorus TMDLs in Wisconsin they use the WinSLAMM model.
    - Selbig: they don't require the use of the model, but they recommend a few models, including WinSLAMM.
    - Law: what other parameters does WinSLAMM simulate?
      - It's fairly diverse. Roger Bannerman is the authority on the Model, Selbig focuses more on gathering data for the model. But there are many variables that can be included when resources are available to gather data. Not able to say with significance that there is a difference at the end of the pipe, but if you can get the accumulation and wash-off function correct, then you should be able to trust what the WinSLAMM model predicts.
      - Schueler noted that based on discussion with Roger and Selbig, the nitrogen is not as nailed down as the phosphorus or sediments in the WinSLAMM model.
      - Selbig noted he is in the middle of a leaf collection management study. As we started collecting data we realized that the phosphorous loads could be much higher than SLAMM initially predicted.
  - Schueler pointed to written comments from Bill Frost who was unable to join the call. Frost is not inclined toward option one, but feels option 2 is more workable. Frost suggests it might be possible to use CAST to estimate the credits. His comments are available to the panel on the Dropbox.

- Tribo: Different localities run different types of programs, so suggest keeping the reporting options available at least in the short term. Think there would be pushback asking locals to run the WinSLAMM model. Resources and training would need to be available for that approach. Think it's important to have credit for different frequencies of sweeping. In terms of practicality, measuring the reduction in pounds per mile makes more sense than a percent effectiveness. We should consider what the Watershed Model assumes is delivered before we make assumptions for load reductions. If it assumes everything is delivered then we can credit based on what is removed.
- Law: went back and looked at some of the studies. Looking at the SLAMM model in some of the studies, it appeared the SLAMM model is limited in its ability to calculate reductions from leaf litter. Encouraging to hear from Selbig that the SLAMM model is continually being improved. The nutrient loading from organic sources on streets is usually less than 10% of the total annual load based on our CWP studies, but perhaps the load is more significant on a seasonal basis. For options 3-9, need to take a closer look at the nutrient concentrations or enrichment factors based on the research. Overall, would recommend two things. First, would like to see a comparison, perhaps using a case study, between options 1-2 and the empirical options of 3 or 4. Based on the data needs to run the SLAMM model, think it would be difficult for jurisdictions to use it in the shorter term. Suggest this panel makes a recommendation based on the other options and perhaps reconvene a panel after there has been time to use the SLAMM model in some study areas in the Bay watershed.
    - Goulet: It would be interesting to see some of those comparisons and analysis. Not sure we have an accurate sense of how much road is out there, and have to make lots of generalizations about widths, etc.
- Shafer: agree with Tribo about working with the Watershed Model. Prefer the waste yield options, but in terms of the curb mile options, like the idea of Option 2, where we work with a model based on some constraints. Like option 7 because we sweep different streets at various frequencies. With catch-basin cleaning and storm drain cleaning, may likely need to take the waste yield approach.
- Stewart: Question the usefulness of options 1 and 2 because we would need to have some verification of the locals' use of the model, which would be problematic for option 1. Option 2 is better, but some metrics would still be problematic. Looked at our data from 1991-2012, which ranged from about .3 tons/curb mile to .88 tons/curb mile. No problems with option 6, but the issue is the required frequency of 26 times per year. Think option 7 is the best option. Would also support option 8. If locals will be required to sweep under their MS4 permits, then we should offer some kind of credit.
- Goulet: At this point leaning more towards the waste yield methods, with a carrot/stick approach to encourage hopper analysis. This could potentially help to develop more accurate estimates and science in the future. If we

have to take a curb mile approach, would suggest making it as simple as possible.
    - Donner: different here in WV. Not as built out, and the sweeping programs are not as complex. Would like to have a simple method. Okay with option 4 if we can relax the minimum frequency requirement.
- Schueler summarized support for option 2, perhaps down the road. Some argument for a combination of options 3 or 4 with details for technology or types of roads. Some disagreement over the hopper method, but we can develop some options for our next discussion. Ignoring the detritus issue, what might be an upper bound for the load of street dirt that will otherwise be delivered to the water? What might we be able to attribute to the effect of street sweeping, as an upper bound?
    - Selbig: We do know that sweepers are more effective when there is more on the street. The dirtier the street, the more is removed, but there is a point of diminishing returns. Sweepers in Wisconsin are most effective in the spring when the curb loads are highest. We can say that sweeping reduces street dirt, but how that translates to runoff is the confounding factor. You can assume some minimal detectable change. Pitt has done some work to demonstrate how to calculate the number of samples needed to reduce variability in the data. It is usually cost-prohibitive to take enough samples in the case of street sweeping.
    - Law noted she could pull a summary description of Pitt's work from a previous study. Agree with Selbig. To respond to Goulet's and Stewart's concerns, it might be valuable to compare empirical methods with SLAMM in an area where they have sufficient data.
    - **ACTION**: Law to provide the summary description of Pitt's work referenced in the discussion.
    - Goulet: We may have to treat this BMP differently. We will not be able to measure end of pipe benefits or monitoring results. The most complex we can probably get is measuring what is removed.
    - Stewart noted the average load in the watershed model for Baltimore county is about 1269 lbs/acre of impervious cover. We will need to make sure our numbers match up with the Watershed Model.
    - Schueler: we can work with the modelers regarding the loading numbers in the model. He asked Stewart to provide some of the Baltimore County data to Jeremy.
    - **ACTION**: Stewart to provide Jeremy with his street sweeping data for Baltimore County.
    - Goulet: We will need to check how common street sweeping is in the calibration.
    - **ACTION**: CBPO staff to check the street sweeping data in the calibration.
    - Law: it will eventually be dependent on the method used to derive the credit. Street sweeping studies show a diminishing return from sweeping too much, though it should be done monthly or more frequent. Do not think there would be a benefit if less frequent than monthly.

- Schueler: should we make technology based distinctions in our recommendations? Recent studies have shown that vacuum assisted regenerative air is the most effective.
  - Jenny: there are different costs associated with those technologies, and would be great to have incentive for adopting those technologies.
  - Donner: there were some studies that showed regenerative air is better at picking up the larger particles, but without the vacuum assist it can actually increase the load of smaller particles.
  - Selbig: both worked really well. One reason we had an increase in smaller particle size, the curb is concrete and the street is asphalt, so the crack in the interface of the two surfaces can trap dirt over time which the sweepers can expose. Ultimately the regenerative air and vacuum assist do perform much better than mechanical broom. Should keep in mind that precipitation is a great street cleaner. Ideally you would sweep before the precipitation washes away the dirt. In terms of frequency, would have to sweep at least once a month.
- Schueler asked for thoughts on next steps from the panel. The discussions of frequency and technologies have been helpful. We need some kind of mass balance to make sure any sweeper waste yield approach makes sense in relation to the Watershed Model. Law will pass on info about the Bob Pitt sampling frequency and Stewart will provide public works sweeping data to Jeremy. We will talk more about street detritus at our next meeting.
  - Schueler: Going forward, option 1 is probably off our list. Option 2 might still be on the list, at least in the longer term. Not sure we have the budget to run the numbers, but will try to get some numbers from Wisconsin DNR to see how the WinSLAMM numbers compare. No support for option 10. We can come up with more details for options 3, 4, 7 and 8.
- Selbig offered to give a year 1 summary of results from our ongoing leaf collection study.
- Schueler thanked the panelists for their time and discussion.

Adjourned

Street Sweeping, Catch Basin and Storm Drain Cleaning Expert Panel
Teleconference
Meeting Minutes
Monday, March 24th, 2014

EXPERT BMP REVIEW PANEL		
Panelist	***Affiliation***	**Present?**
Dr. Stu Schwartz	UMBC	Yes
Norm Goulet	NVRC	No
Jenny Tribo	HRPDC	Yes
Marty Hurd	DDOE	Yes
Sebastian Donner	WVDEP	Yes
Bill Frost	KCI	Yes
Justin Shafer	City of Norfolk	Yes
Steve Stewart	Baltimore County	Yes
William R. Selbig	USGS	Yes
Tom MaGuire	MassDEP	Yes
Dr. Neely Law	CWP	Yes
Tom Schueler Jeremy Hanson	CSN CRC (Panel co-facilitators)	Yes Yes
Non-panelists: None.		

Call to Order and Introduction Tom Schueler, CSN, called the meeting to order and gave a brief overview of the agenda.

Review of meeting minutes and action items from February meeting

- Schueler directed the panelists' attention to the February minutes.

DECISION: The panel approved the minutes from the 2/20/14 call.

- Hanson noted that Law had received a spreadsheet from Nowak with data for Baltimore; the spreadsheet is on the panel's Dropbox along with other files received as follow-up actions.

Discussion of Bounding estimates: minimum detectable change and street solids mass balance relative to CBWM

- Schueler reviewed current assumptions in the Chesapeake Bay Watershed Model (CBWM). He pointed out that sweepers pick up more total sediment than is delivered from an urban impervious acre in the Model, so the panel should keep this in mind while developing its recommendations.

- He asked for volunteers to run the calculations for a minimum detectable change analysis. **Law and Schwartz to help with this task.**
- Schwartz: Is this part of the power test discussion?
  - Law noted Selbig sent out an update to that approach. Need to compare with the CWP study design. Can speak with Schwartz offline about this.
- Schueler noted the panel will continue to look through these numbers during its next meeting.
- Schwartz: been looking into power analysis. Very robust literature on this in other fields especially the medical field. Retrospective power analysis is valid, but post-hoc power analysis is not. There are some significant differences that can be drawn. A study from UCLA (Stenstrom) looked at 15 street sweeping studies and found that each of those studies did not achieve the 80% power analysis. **ACTION: Schwartz will write up some thoughts to share with the panel along with the Stenstrom paper.**
- Selbig: are we saying that the CBWM is overestimating urban nutrients based on sweeping data?
  - Schueler: No. There are other sources of nutrients to account for in the urban sector. Perhaps the detritus issue will be part of the explanation.

Panel perspectives on street sweeping (continued)

- Schueler asked panelists that were not present in February to share their thoughts on the options described in Attachment C.
- Frost mentioned MAST/VAST/CAST do not seem to follow the protocols the previous panel developed. He noted his comments were captured pretty well in the February minutes since he submitted his written comments.
- Tom MaGuire: Been thinking about the seasonality of sweeping. We have a higher load in winter because of winter applications. The seasonality of when they sweep is really important for load reductions.
- Hurd: Agree that options 2 or 3 are better than option 1. Ideally we can move in a direction where we collect more data so we can maybe improve our estimates and methods in a few years.
- Schwartz: Think we need a separate discussion of what the best evidence is in terms of water quality benefits for street sweeping. Suggest we separate discussion from what is easy to implement/track and what is best way to evaluate the evidence. We'll get into that with the minimum detectable effect discussion. Think it would have some value to use WINSLAMM in a targeted way to represent some of the mechanics to help build estimates. Agree with Hurd we should try to get additional data to revisit this again in a few years or so.
- MaGuire: USGS did WINSLAMM modeling in Massachusetts. Part of the question is whether we see an improvement in the receiving water body. We definitely pick up and get phosphorus credit for picking it up in the street, but do not necessarily see the benefit in the water.
- Schueler noted there may be a possibility for Tetra Tech to do some WINSLAMM analysis and modeling for the panel. It would be limited, but could help give some answers. First, would like the panelists' thoughts on whether this would be

worthwhile. If panel wants to pursue this, will want volunteers to help define the scope of work. Would be using some of the parameters that Selbig and Bannerman have put together as a starting point.

- MaGuire: would be helpful to run different scenarios in Chesapeake Bay area.
- Selbig: could be difficult to obtain the data that needs to go into the model, but running the model itself is not difficult once you have that data. Would be willing to help given experience.
- Law: when we are running WINSLAMM want to make sure we are setting it up so it is comparable to the CBWM.
- Selbig: we were able to measure the loads on the street…are able to use the model as a best guess estimate to evaluate the street loads. Different than what goes on in the pipes in terms of water quality.
- MaGuire: Visually, do not see a difference on the street when a regen air sweeper goes slightly faster than recommended speed. You can see more fine residue when a rotary brush sweeper goes faster than recommended.
- Schueler: Hearing no objections, so we will proceed. **ACTION: Tom and Jeremy will work with Tom M. and Bill to develop scope of work for contractor**. He noted the caveat that WINSLAMM cannot account for parking, sweeping speed, etc.

The Great Detritus Debate

- Schueler noted the debate was scheduled to occur at a February STAC workshop, which was rescheduled to late April due to snow.
- View the presentation for more details about on Law's and Schueler's points. Highlights from the discussion following the debate are capture below.
- MaGuire: crunched some of the numbers from our MA studies. For us, winter was highest loading period, followed by summer, then spring, then fall. Fall and spring were very similar in phosphorus loads, at least for the highways in our studies.
- Selbig: Great points and counterpoints. Want to point out that a lot of the studies, particularly monitoring studies do not show phosphorus reductions, but we usually end our studies before fall and the leaves drop.
- Selbig: Law had a great photo, but noticed the filter bags were in the steam. How long were bags sitting there before measuring the concentrations?
    - Law: We were sampling the recalcitrant material left in the leaves. Sampled every 2 weeks, when a third to a half full. Some of the material came from storm drains, so we could not be sure of the lag times and state of all the matter.
- Schueler: for catch basins, monitored 4-6 months after leaf fall.
- **Schueler proposed the panel has a more expanded discussion on this during its next meeting.**

Results of First Year Wisconsin Leaf Study

- Bill Selbig reviewed some preliminary results from an ongoing paired-basin pilot study on leaf collection in Madison, WI. His presentation (Attachment E) is available on the panel's dropbox. Early results indicate very high P concentrations and yields in fall when leaves are not collected. Timing is critical. The larger the load of leaves on the street, the greater the risk of high-P washoff into the storm drains.
- MaGuire: Any sand applications?
  - Selbig: Yes, all sanded. Salt applied in intersections.
- MaGuire: In MA we see high winter loads because of sand.
  - Selbig: As a result of our studies they sweep as early as possible in the spring to collect the sand before the first spring rains.
- Tom and Jeremy will get in touch with panel on scheduling next call. Will proceed with Tetra Tech as discussed earlier.
- Tom thanked the panelists for their time, presentations, and discussion.

Adjourned

Street Sweeping, Catch Basin and Storm Drain Cleaning Expert Panel Teleconference
Meeting Minutes
Friday, May 30th, 2014

EXPERT BMP REVIEW PANEL		
Panelist	***Affiliation***	**Present?**
Dr. Stu Schwartz	UMBC	Yes
Norm Goulet	NVRC	Yes
Jenny Tribo	HRPDC	Yes
Marty Hurd	DDOE	Yes
Sebastian Donner	WVDEP	No
Bill Frost	KCI	Yes
Justin Shafer	City of Norfolk	Yes
Steve Stewart	Baltimore County	Yes
William R. Selbig	USGS	No
Tom MaGuire	MassDEP	Yes
Dr. Neely Law	CWP	Yes
Tom Schueler Jeremy Hanson	CSN CRC (Panel co-facilitators)	Yes Yes
Non-panelists: Mark Sievers and Jon Butcher, Tetra Tech; Cecilia Lane, CSN		

Call to Order and Introduction Tom Schueler, CSN, called the meeting to order and gave a brief overview of the agenda.

Review of meeting minutes and action items from March meeting

- Schueler directed the panelists' attention to the March minutes; no comments or corrections were raised.

DECISION: The panel approved the minutes from the 3/24/14 call.

Finalize Scope of Work for Tetra Tech

- Tom recapped that the panel felt WinSLAMM would be a good approach for estimating loads from streets based on various factors. The CBP was able to provide some funds for Tetra Tech's work. He reviewed the scope of work that was shared with the panel. Roger Bannerman provided some comments on the document. The first task will estimate baseline conditions. The second task will use various sweeper technology and frequency options. WinSLAMM can also consider parking density and parking controls. Altogether there will be 1,944 results to define sediment mass removed and removal rates.

- Frost: for seasonal sweeping there are times when there is just a single pass in the year, e.g. in the spring to collect sand or winter applications.
    - Schueler: Only one pass would be a trivial reduction
    - MaGuire: not worth it for just one pass in a year. Don't think that should qualify for credit. It would be so little removal for that one day compared to the whole load. Would be worth evaluating different sweepers and frequencies, but not for once a year.
    - Law: we could include some other minimum frequency, like 3 times a year.
        - Schueler: we can add 4 times a year (~every 12 weeks) to the analysis
    - Law: could there be different particle size files for Piedmont and Coastal Plain? Don't want to double the runs, but might be useful. Think that question might come up, should at least have a reason for not considering it in the model runs. Defer to Tribo or Stewart since they have coastal areas.
        - MaGuire: what would be the difference? There may be difference in precipitation from coast to Piedmont.
        - Schueler: About 5" difference from coast to the mountains.
        - Stewart: we did not see much difference in storm drain accumulation.
        - Schwartz: might be useful to clarify if the particle size files are simulating the winter applications.
        - Schueler noted that Roger Bannerman and Bill Selbig agreed to help out as the WinSLAMM tasks progress. Will share their contact info with Sievers and Butcher.
        - Schueler: We've already looked at the national distribution of particle size, and Bill Selbig had some additional data. Have to respect the limited budget. So it is best for us to provide them with the data, not ask them to compile the data themselves.
        - **ACTION**: Will reduce to only 2 sweeper technologies, and include frequency option for every 12 weeks (4 times/year). Schueler will help to solicit input files from Bob Pitt, Bill Selbig, and Roger Bannerman. MaGuire can provide any relevant input files from Massachusetts.
    - Schueler: Panel will probably want to see Task 1 results, around the end of June.
    - Schwartz: would like to see how particle size fraction/distribution affects the loading estimates, or perhaps we could disaggregate load by particle size.
        - MaGuire was not sure if the disaggregation would be is possible.
        - Bill, Roger Bannerman, and Tom offered to provide quality control and assistance for Tetra Tech.
    - Butcher: Need to include some specificity on urban catchment designs and examples.
- No street sweeping for highways

- MaGuire: the Mass DOT provided funding for our expressway study. After the study they did not bother seeking credit for sweeping on highways.
- Hurd: our DPW does have a night time highway operation, a lot of major arterials are considered highways in the DPW program, e.g. Wisconsin Ave.
- MaGuire: in our expressway study, we were finding a lot of material in both the hoppers and the catch basins.
- Schueler: So the panel is leaning towards credit for any arterials like Wisconsin Ave, but freeways without curb or gutter drainage would be excluded.
- **ACTION**: If panelists have any comments or questions on the WinSLAMM project, contact Sievers and Butcher at TetraTech.

Sediment nutrient enrichment

- There does not seem to be too much variation, but …
  - **ACTION**: Hanson to share info on District's leaf litter collection program with the panel.
  - Schwartz felt sensitive to particle size issue. Sweepers are better at picking up larger materials like gravel, so the nutrient content will vary by particle size distribution.
  - Schueler summarized that based on conversation, seems it will help to compile some numbers for the panel's reactions.
  - Butcher: the most relevant data would be the particle size distribution of what is in the hopper, if that data is available.
  - **ACTION**: Tom to compile comparison table for panel's consideration.
  - Tribo: might also be good to offer option for sampling their hopper waste.
  - MaGuire: but there is also the consideration of what gets mobilized. The sweepers were very efficient, but there were still huge loads running off that we collected in the catch basins.

Should we do minimum detectable change analysis

- Schueler recalled the action item for a small group to consider minimum detectable change analysis.
- Law described the context. Existing studies do not specifically link the sweeping to water quality benefits at the outfall. Issue is how loads picked up by sweepers translates to water quality benefit.
- Schwartz mentioned Jean Spooner (NCSU) and her work on minimum detectable change. Schwartz looked at issue of stream power and consequence of studies that collect too few samples. There may be older studies that could be useful.
- Law: how to best use retrospective analysis to help qualify or interpret results.
- Schueler: other broad aspect may be an adaptive management approach, and revisit recommendations in a few years. Could recommend study design that would benefit and test this panel's results or recommendations.

- Spooner suggested that the hopper material could be analyzed in water, to see what is extractable or mobilizes. That could be an interesting analysis.

Options for reporting, tracking, and verification

- Schueler asked for thoughts on the reporting, tracking, and verification approach he outlined.
  - Goulet: discussion reinforces that we need to collect information or encourage analysis for additional credit.
  - Frost: seemed like a reasonable compromise and keeping it manageable.
  - Shafer: we thought it was manageable.
    - Tribo and Stewart agreed.
  - Hurd: will review and get back to Tom on this.
- Law raised issue for non-MS4.
  - Schueler: in general, non-MS4s will probably not have sweeping programs or seek sweeping credit.
  - MaGuire: most of our non-MS4 communities sweep once a year.
  - Schueler: the smaller communities sweep very infrequently, but might be able to seek credit for certain areas they sweep more often. Non-MS4 areas are more of an acute issue for PA and parts of VA.
- Hurd: At least in DC, we do track where practices are done, because it is important for the TMDLs we have for different water bodies.
- Schwartz: if we consider curb mile reporting criteria, maybe useful to incorporate hopper weight into that. If we have curb mile option, might do some kind of upper bound or limit analysis.
- Tom: Lane miles approach based on WinSLAMM. If we go through WinSLAMM and nutrient enrichment analysis, then we may not need to take a hopper method. There are issues that we have discussed with the hopper approach.
- Tribo: not opposed to the lane miles approach, but will need to clearly explain the reasons for that approach in the report. Some localities may only weigh hopper loads, and will want an explanation if there is no credit for it.
  - We may need to have credit for both approaches, but might restrict when hopper method could be applied.

Next steps

- Schueler explained the Tetra Tech report is due in August under the technical directive. He suggested the panel reconvenes later in August. In mean time, Tom and Hanson will start drafting text for the report. Any interim WinSLAMM results will be shared with panel for their immediate input.
- Shafer: asked about lit review or research on clean outs, outfall nets, etc.
  - Schueler: we already have some research and studies and can start compiling tables on those as well. Can hopefully have a rough draft to discuss in August. Would be pleased if we can aim to seek consensus on the draft in October.

- Frost: make parking density binary, either allow parking or not. Controls or not. Saves model runs that way.
    - **ACTION**: Parking density and parking controls will be binary for model runs.

Adjourned

Street Sweeping, Catch Basin and Storm Drain Cleaning Expert Panel Teleconference
Meeting Minutes
Thursday, November 13th, 2014

EXPERT BMP REVIEW PANEL		
Panelist	***Affiliation***	**Present?**
Dr. Stu Schwartz	UMBC	Y
Norm Goulet	NVRC	Y
Jenny Tribo	HRPDC	Y
Marty Hurd	DDOE	Y
Sebastian Donner	WVDEP	Y
Bill Frost	KCI	N
Justin Shafer	City of Norfolk	Y
Steve Stewart	Baltimore County	N
William R. Selbig	USGS	Y
Tom MaGuire	MassDEP	Y
Dr. Neely Law	CWP	Y
David Wood	CRC	Y
Tom Schueler Jeremy Hanson	CSN VT (Panel co-facilitators)	Y Y
Non-panelists: Mark Sievers, Navid Nekouee, and Jon Butcher, Tetra Tech		

Call to Order and Introduction Tom Schueler, CSN, called the meeting to order and gave a brief overview of the agenda. He noted the panel had not met in a while, and he summarized the panel's status and previous work.

Review of meeting minutes and action items from May meeting

- Schueler directed the panelists' attention to the May minutes; no comments or corrections were raised.

DECISION: The panel approved the minutes from the 5/30/14 call.

Presentation: Results of the Summer WinSLAMM Modeling

- Tom recapped that the panel felt WinSLAMM would be a good approach for estimating loads from streets based on various factors. The CBP allocated some funds for Tetra Tech's work.
- Mark Sievers noted they are in the process of finalizing the report. Jon and Navid discussed the WinSLAMM model setup, land use normalization, and results.

- Bill S: in reality, the winter months are off-limits while snow is on the ground, so need to be careful when using annual numbers. Other studies typically use a 6-month period.
- Navid noted that mechanical/broom results were almost all zero or close to zero.
- Bill S: The math for the normalization, but not sure normalizing is necessary in this case. Do not want to over inflate the efficiency of the sweepers by focusing on the street level. Could just do a comparison for one scenario to see what the effect of the normalization is.
    - Tom: will discuss that with Mark offline to see if they can do that check.
    - Tetra Tech expects to have revised report available for the panel early next week.

Roads as a Land Use in Phase 6 Model

- Tom reviewed his slides with the panel, reviewing findings from Tetra Tech's analysis of urban land use loading rates.
- Tom M: Mass DOT is asking DEP and EPA to break out roads from the models used for TMDLs in Massachusetts.
- Neely: What's the process for moving forward regarding recommendations for roads as a Phase 6 land use?
    - Tom: the Land use workgroup recommended to the Modeling Workgroup and WQGIT that a transportation land use should be added to the Phase 6 Model. If the Panel has strong recommendations to support or not support such a land use, those groups would take the panel's recommendations into consideration.

Panel discussion: Sediment nutrient enrichment

- Tom noted that the CBP study by Neely et al was at the high end. He also included values for BMP sediment. The means from various studies all fall within a fairly tight range. Street solids are what was collected in the vacuum studies, whereas the sweeper waste was what was picked up by the sweeper.
- Tom reviewed some options for incorporating the nutrient enrichment data with the estimated sediment reductions associated with sweeping. He asked the panel members for their thoughts.
- Sebastian: Like the first two options, in terms of practicality.
- Neely: In our study we removed the leaf material, but sweepers do likely pick up some of that leaf or organic material. For option 3, there is a lot of degradation or breakdown of the material, so would need to have a certain frequency of the cleanout, e.g. once or twice a year. Option 4 does provide the most flexibility for localities, but not sure we want to go that route as it would be difficult to refine that option.
- Stu: Particularly interested in the particle size. Question the assumption that mass removed from the street translates to mass not transported to the stream. If we're thinking about generic urban impervious areas, it would be helpful to sketch out a conceptual mass balance and how much of that 15.5 lbs N/ac is

coming from dirt, organic matter, etc. Would help us define what part of the load street sweeping really is addressing. Concerned there are no available studies that link water quality improvements with street sweeping.

- Bill S: Appreciate Stu's concern about end-of-pipe studies. There's still a lot to be done, but that is why we turn to the use of models like WinSLAMM. As more research is conduced, WinSLAMM and similar tools can be updated. Just quickly checked some data from ongoing leaf collection studies, and the enrichment factors appear to match up with what Tom compiled. Like Option 2 and the ability to apply different efficiencies for different sweepers or enrichment factors.
- Tom M: In Massachusetts we do offer a credit for catch-basin cleaning credit when they clean the catch-basin 4 times per year.
- Jenny: A little confused about which options are mutually exclusive. Think Option 3 needs more work in terms of safeguards or delivery factors, but it does fill void about offering credit for catch-basin cleanout. Would like to spend more time refining Option 4. There is a need to encourage localities to innovate and reward them for doing so. Not sure how we could get there, but could spend more time on that discussion. A locality might want to do catch-basin cleanout in the same are they do street sweeping. There are some double-counting or verification issues to work out, but think localities
- Bill S: Do not think Option 3 is viable. In the fall a lot of the nutrients are in dissolved form and are not captured.
- Justin: there is still phosphorus in the catch-basins, based on our 21 months of analysis. Would really want to see the panel include these options.
- Norm: A lot of the data shows that a lot of the nutrients are lost early on. Do agree with Option 4 and being able to account for innovative practices.
- Tom: Option 3 needs more work, given some issues noted by panelists. Option 4 is a placeholder at the moment and really needs more fleshing out.

Panel discussion: next steps in finalizing report

- Tom will begin drafting the science section of the report. Would like the panel to meet again in mid-December, with the goal of reaching consensus in the January timeframe. Will distribute the revised WinSLAMM report from Tetra Tech, and will reserve some time for discussion during the December call.

Adjourned

Street Sweeping, Catch Basin and Storm Drain Cleaning Expert Panel Teleconference
Meeting Minutes
Friday, January 23rd, 2015

EXPERT BMP REVIEW PANEL		
Panelist	***Affiliation***	**Present?**
Dr. Stu Schwartz	UMBC	Y
Norm Goulet	NVRC	Y
Jenny Tribo	HRPDC	Y
Marty Hurd	DDOE	N
Sebastian Donner	WVDEP	Y
Bill Frost	KCI	Y
Justin Shafer	City of Norfolk	Y
Steve Stewart	Baltimore County	Y
William R. Selbig	USGS	Y
Tom MaGuire	MassDEP	Y
Dr. Neely Law	CWP	Y
David Wood	CRC	Y
Tom Schueler Jeremy Hanson	CSN VT (Panel co-facilitators)	Y Y
Non-panelists: Mark Sievers, Navid Nekouee, and Jon Butcher, Tetra Tech		

Call to Order and Introduction Tom Schueler, CSN, called the meeting to order and gave a brief overview of the agenda.

Review of meeting minutes and action items from November meeting

- Schueler directed the panelists' attention to the November minutes; no comments or corrections were raised.

DECISION: The panel approved the minutes from the 11/13/14 call.

Presentation: Results of WinSLAMM Modeling

- Bill Selbig: Are the results solids removed just from the streets or at the outfall?
    - Navid Nekouee: It is at the outfall. So it incorporates all the other sources. It only incorporates solids removed.
- Schueler pointed out that we are not making judgment on the Tetra Tech model. We don't have to accept the memo as-is, but we should appreciate the work Jon, Mark, and Navid put forward.
- Selbig: Did we consider seasonal sweeping without the monthly otherwise?
    - Navid: Monthly allows pick-up of middle sized particles
- Neely Law: Is the model set up so the two technique (vacuum and mechanical) are picking up different size particles?
    - Navid: Yes, that is correct. I can send the details of the assumptions.

- Stu Schwartz pointed out that it is important to understand the source of the seasonality. He will follow-up with the Tetra Tech team offline.

Document E: Necessary Panel Decisions and Holdover Issues

Decision 1. *The WinSLAMM Model is an acceptable tool to estimate sediment removal rates*. The basic street cleaning module that it is utilized in the WINSLAMM model is a reasonably conservative simulation of the potential sediment reductions associated with different street cleaning scenarios, as it is reflects East coast sediment buildup and washoff processes, Chesapeake Bay rainfall patterns, and expected variations in street types, technologies and urban land uses.

Option 1: Concur

- Neely

Option 2: Concur, but add cautionary language about uncertainty, model limitations, "false precision" and other modeling issues, etc.

- Bill F., Sebastian, Norm, Jenny, Justin, Bill S., Tom M., Stu, Jeremy, Steve

Option 3: Disagree, the modeling tool is not acceptable

- No support.

Additional Comments:

- Neely: It was very rigorous analysis, there are no red flags in terms of outlandishly high reductions, and they concur with other research findings.
- Sebastian: My main concern is having regenerative sweepers
- Stu: It is reasonable to estimate sediment that is picked up, not as sediment delivered to the end of the pipe and delivered downstream.
- Jeremy: I don't want us to go into too much detail of uncertainty or limitations.

Decision 2. *Which of the different street cleaning scenarios in the Tetratech analysis should be included in our final recommendations? (*e.g., climatic zone, street type, sweeping frequency, sweeper technology, parking density and controls).

Option 1: Use all of them, but provide cautionary language that a few them need more research corroboration (e..g, parking controls).

- Justin, Steve

Option 2: Pick a smaller subset of scenarios based on either (a) real differences in sediment pickup or (b) stronger research validation for the sweeping effect being modeled

- Neely, Bill F., Sebastian, Norm, Bill S., Tom M., Jeremy

Option 3: Dump all of them, the modeling tool is not acceptable

- No support.

Additional Comments:

- Neely: I am interested in finding out which sweeping scenarios were not effective at all. I don't know if we want to use the maximum reductions. N and P reduction threshold of minimum 10 or 20% solids reduction efficiency. I will defer to practitioners and whether they think some scenarios are feasible.
  - Bill F.: There are sufficient scenarios with same results, we can simplify those. Twenty five or 26 sweeps a year is unfeasible. Threshold is 4% N and 9% solids.
  - Jenny: We need more time to think about this. Maybe display it all like your spreadsheet. It should be available so it doesn't seem like we're hiding anything.
- Justin: We should leave as many options as we can, but I would be ok with option 2 as long as we don't eliminate anything municipalities may be using.
  - Stu: I will defer. It is implementation question, and I appreciate hearing that local jurisdictions like more choices. I think we can cluster the choices, but explain to jurisdictions what diverse options might fall into those clusters.
  - Steve: Local jurisdictions street sweeping programs are likely to cover the entire range of scenarios. By using the all of the scenarios, local jurisdictions can make better informed decisions on any changes that they may want to make in their street sweeping programs.

Decision 3. *For the non-seasonal street sweeping scenarios, what nutrient enrichment factor is most plausible to apply to the sediment mass picked up ?*

Option 1: Go with the factor used by the last expert panel (see Table 1)

- No support.

Option 2: Go with the mid-point of data factor (Table 1) as being more representative of the empirical data

- Consensus (Stu Schwartz deferred until he had more information)

Option 3: Go with some other factor (please supply your rationale)

- No support.

Additional Comments:

- Neely: My gut feeling is to look at street solids numbers because a lot of factors effect N and P transfer. I would say midpoint, taking out other types of studies.
  - Jenny: Use the midpoint, remove catch basin sediment and recalculating midpoint.
- Justin: Use the midpoint, but modify it to get rid of irrelevant information.

Table 1: Nutrient Enrichment of Street Sediment				
Solid Type	Value	% P	% N	Reference/Notes
Street Solids	**Mean**	**0.10**	**0.25**	**CBP EP Report (2011)**
Street Solids	Mean	0.05	0.20	Mean 5 Studies
Street Solids	Mean	0.07	0.14	Baker et al (2014)
Street Solids, Fine	Mean	0.08	---	Sorenson (2012)
Sweeper Waste	Mean	0.04	0.15	Mean of 5 Studies
Catch Basin Sediment	Mean	0.06	0.24	Mean 6 Studies
BMP Sediment	Mean	0.06	0.29	Mean of 20 Studies
Mid-Point of Data	**--**	**0.07**	**0.20**	**Estimated**

Decision 4. *For the* ***seasonal*** *street sweeping scenarios, what nutrient enrichment factor is most plausible to apply to the sediment mass picked up?*

Option 1: Go with the "mid-point of data" factor shown in Table 2

- Consensus (Stu Schwartz and Neely Law deferred)

Option 2: Go with another factor that is more representative of the data

- No support.

Option 3: Use the non-seasonal factor selected in the preceding decision # 3

- No support.

Option 4: Allow an MS4 to use their own factor based on local hopper monitoring

- No support.

Additional Comments:

- Bill F. and Norm: Locally derived data would be best.
  - Justin: I don't know why we ran spring-only seasonal, but not fall-only seasonal.
  - Jenny: Localities submit their own data if we give them methodology.
- Bill S.: I don't know where enrichment factors came from or whether they apply. Option 1, 2 and 4 are legitimate. I calculated my own enrichment factors and there is a seasonal difference.

Table 2: Nutrient Enrichment of Coarse Organic Matter *				
Type	Value	% P	% N	Reference/Notes
Coarse Organic Matter	Mean	0.17	1.6	Baker et al 2014
Municipal Leaf Litter	Mean	0.10	0.94	Heckman and Kluchunski, 1996
Leaves	Mean	0.06	0.80	Rushton, 2006
Leaves	Mean	0.08	0.96	Stack et al 2013
Mid-Point of Data	**--**	**0.10**	**1.0**	**Estimated**
* excludes any initial nutrient leaching, especially TP, which cannot be effectively be picked up by sweepers				

Decision 5: *Need to come up with a standard definition of the unit "curb miles swept" that EVERYONE uses*

Option 1: One impervious acre is equal to one curb-lane mile swept, for streets/roads with curb and gutters, assuming they are swept on one-side only -- (**Note**: is this consistent with the street assumptions used in the Tetratech analysis?)

- Sebastian, Norm, Justin, Bill S., Tom M., Stu, Steve

Option 2: A better definition, please provide.

- Bill F.: I'm not sure if equating impervious acreage to the length of the lane that is swept is accurate.

Additional Comments:

- Neely, Jenny, and Jeremy deferred.

Decision 6. *Need to develop a verifiable method to document the actual sweeping effort, based on annual lane miles for each unique local street cleaning scenario submitted.*

Option 1: Let locals use the new spreadsheet to estimate annual individual and aggregate reductions achieved by their sweeping program, and keep local records to substantiate their assumptions on length of sweeping route, frequency, sweeper technology and parking conditions, as part of MS4 permit.

- Consensus (Neely Law deferred)

Option 2: Have the locals submit their sweeping program data to state MS4 reporting agency which will use the spreadsheet to calculate their sediment and nutrient reduction credits.

- No support.

Option 3: Other method for reporting and verification?

- No support.

Additional Comments:

- Jeremy: The Watershed Technical Workgroup will be able to weigh in on this.
- Stu: Convenient to let locals use the spreadsheet, but how will we verify? I would like to see them report the tons picked up. They can report their effort, but also require subsampling of tons collected.
- Steve: Not sure on this one, needs more discussion. I would say a combination of Option 1 and Option 2. The locals use the spreadsheet to estimate the aggregate reductions, keep local records (reports of dates or route sweeping, a GIS layer of routes that includes type (residential, commercial, arterial), and hopper weights for verification of calculated weights, and periodic sample results for verification of Nitrogen and

Phosphorus concentrations. The locals submit this to the state, which in turn evaluates quality of data. State should conduct periodic verification of local program.

Decision 7. *Allow an additional nutrient credit for organic matter that is directly removed from catch basins, storm drain pipes or collected at the outfall, based on the dry weight of the hopper mass collected, and using a locally measured nutrient factor or an acceptable default value (cf Decision # 4).*

Option 1: Yes

- Sebastian, Jeremy (with caveat below)

Option 2: Yes, but must qualify as targeted program with additional verification measures.

- Bob F., Jenny, Justin

Option 3: No

- Stu, Tom M.

Option 4: Not Sure, let's talk more about it

- Bill S., Tom M., Norm, Jenny, Steve

Additional Comments:

- Consensus that this issue needed to be discussed further.
  - Bill F.: Expanded from organic matter to any street solid. Should explain why you are doing what you're doing.
- Norm and Jenny: Need to still include catch basins to some degree.
  - Justin: We should be able to count sediment beyond just organic matter.
- Tom M.: A lot of catch basins sit for long periods of time and I think there is too much movement of material between cleanings.
- Stu: I'm hesitant to have catch basin cleanout credit. There is not enough data to support that idea.
- Steve: Baltimore County uses a calculation of the weight based on the study conducted with CWP where the volume of material in the inlet is calculated based on before and after measurements. Using the study data to determine mean bulk density the weight is then calculated. I recommend using the method detailed in the MDE Guidance document.

Decision 8. *The existing sediment delivery ratio used by the Chesapeake Bay Watershed Model reasonably accounts for the fact that not all of street solids picked up by sweepers will ultimately reach the Chesapeake Bay.*

Option 1: Yes

- Bill F., Sebastian, Jenny, Justin, Tom M., Jeremy, Steve

Option 2: No

- Stu

Option 3: No strong feelings, let's give the modelers this job going forward.

- Norm, Justin, Jeremy

Additional Comments:

- Bill S., and Neely deferred.
- Steve: Should be evaluated going forward as should all expert panel recommendations.

Report Draft Write-up:

- Tom Schueler: In next two or three weeks, I will have a draft write-up that reviews the science on the topic. I will leave some areas open for you to discuss, or I will ask you to look over your own research. We have most of a core of recommendations to make or tweak. After everyone has had time to review the draft, we will have another panel meeting to discuss review/revisions.

Review of Remaining Issues:

- Tom Schueler: Decision 7 is still up in the air, I will work on that for next meeting. There are issues on uncertainty, leaf detritus, and double-counting.
- Bill Frost: With regards to getting credit for sweeping, I like mass-loading approach, but not having it tied to a particular frequency.
- Norm Goulet: I agree with Bill’s comment on frequency. With verification, I lean towards reporting tons along with swept miles. Agree with organics issue as well.
- Justin Shafer: Catch basin organics, and double counting. On the modeling side, I’m concerned with a frequency of every four weeks as opposed to monthly cleaning. I don’t know what flexibility we have with land use categories. I have a

concern about fall-only cleaning versus spring-only cleaning. I think we should add in temporary credits for research and data gathering.

- Bill Selbig: I'm concerned that if we use what SLAMM has produced, we are rendering mechanical sweepers useless. There is still a disconnect between delivery to streets and the outfall.
- Stu Schwartz: On the uncertainty issue, we should introduce "potential pollutants" language. Another issue is addressing what fraction of sediment mass in the street or catch basin is influenced by street sweeping, and I'm leaning towards less than 100%.
- Jenny Tribo: I suggest we spend more time on Decision 5. I also do not think we will ever reach complete agreement with regards to the catch-basin issue, so I think we should have one more big discussion and then leave it to Tom. I think there are ways around double counting issues. We need more time on verification issues in terms of the reporting and record-keeping needed for verification. We also need to decide whether or not we are going to comment on leak collection.
- Steve Stewart: I believe all recommendations from all expert panels should be reviewed on a 5 year cycle.
- Tom Schuler thanked the entire panel for an extremely productive meeting.

Adjourned

Enhanced Street and Storm Drain Cleaning Expert Panel
Teleconference Minutes
February 20, 2015
***** 2:00 to 4:00 PM *****

EXPERT BMP REVIEW PANEL		
Panelist	***Affiliation***	**Present?**
Dr. Stu Schwartz	UMBC	Y

Norm Goulet	NVRC	Y
Jenny Tribo	HRPDC	Y
Marty Hurd	DDOE	Y
Sebastian Donner	WVDEP	Y
Bill Frost	KCI	Y
Justin Shafer	City of Norfolk	Y
Steve Stewart	Baltimore County	Y
William R. Selbig	USGS	Y
Tom MaGuire	MassDEP	N
Dr. Neely Law	CWP	N
David Wood	CRC	Y
Tom Schueler Jeremy Hanson	CSN VT (Panel co-facilitators)	Y Y
Non-panelists: Emma Giese, CRC		

1. **Call to order, review of meeting minutes & action items from January 23 Meeting** (Attach A-1 and A-2)
   - Tom reviewed the decisions from the last call, and the holdover issues.
   - There were no objections to the minutes from Jan 23 as written.
   - Tom will write the next draft of the report based on the decisions agreed to on the last conference call.

2. **Panel Decision. Dealing with the Catch Basin Cleanout Framework and Final Discussion on Feasibility of Hopper Credit** (Attach B)
   - Tom asked for panel feedback on the holdover issues outlined in the short memo provided in Attach B.

Decision 1. *Allow an additional nutrient credit for solids that are directly removed from catch basins, storm drain pipes or collected at the outfall, based on the dry weight of the mass of solids collected, using the default value shown in Table 1.*

Table 1: Nutrient Enrichment of Catch Basin and BMP Sediment				
Solid Type	Value	% P	% N	Reference/Notes
Catch Basin Sediment	Mean	0.06	0.24	Mean 6 Studies
BMP Sediment	Mean	0.06	0.29	Mean of 20 Studies
Mid-Point of Data	**--**	**0.06**	**0.27**	

Option 1: Yes

- Sebastian

Option 2: Yes, but must qualify as a targeted program AND have additional verification measures. Examples might include:

- Jeremy

(a) field assessments targeting catch basins trapping the greatest organic matter loads, streets with the greatest adjacent tree canopy, outfalls with highest debris loads or other factor.

- Bill Frost, Bill Selbig

(b) field protocol to measure the mass or volume of solids collected and periodic sub-sampling of the carbon/nutrient content of the solids.

- Jenny, Justin Schafer, Marty

Option 3: Yes, but the solid mass reduction must be adjusted by the CBWM sediment delivery ratio of 0.13 to estimate the sediments that actually reach the Bay (e.g., 87% reduction in the solids mass that is credited).

Option 4: No, because (a) method cannot be technically supported at this time and/or (b) it is doubtful whether any community would utilize this kind of credit and/or (c) too hard to verify it or prevent cheating.

- Stu Schwartz

Option 5: Not sure, let's talk more about it.

- Bill Selbig

<u>Additional comments</u>

- Sebastian: Jurisdictions should get more reductions if they can verify them with more data and sampling.
- Bill Frost: 2a is something the jurisdictions would want to do anyway.
- Bill Selbig: There should still be some benefit for catch basins.
- Marty: Recommend 2b with strong verification measures in place.
- Jeremy: Both 2a and 2b would be useful to make sure cleanouts are achieving the water quality benefits.
- Norm: Suggest combining Options 2 and 3
- Jenny will go with the group on the delivery ratio if 3 is preferred.
- Bill Frost disagrees with option 3

- Stu Schwartz: The panel needs to address how to deal with closing the mass balance. If we take the WinSLAMM model output as delivered load rather than sediment pick up than the effect of catch basins are already included, therefore wouldn't want to give credit for catch basin cleanout on top of this. Would like to understand how the credit will interact with existing street cleaning credit.
- Tom: The panel seems to be leaning toward 2a/2b, however we won't dissuade the option 4 and option 5 people. Tom will move forward with write-up, but the panel can return to this catch basin issue if panelists have second thoughts.

Decision 2: Feasibility For Any Hopper Credit

Option 1: No, it is never a good idea to provide two methods that may give different answers to the same question. We invested a lot of time and resource in our WINSLAMM approach, so let's go with a single option, and reduce the possibility that users will "shop" for the method that gives them the most credit.

- Bill Selbig, Stu, Norm, Jeremy (or Option 2)

Option 2: No, although I support use of hopper data to verify the aggregate mass of solids that are actually picked up by the local sweeper fleet.

Option 3(a): Yes, but only to support the storm drain credit (#1, i.e., no hopper credit is provided for street solids pick up).

Option 3(b): Yes, but only in very rare instances. For example, credit is offered to MS4s that design, implement and measure a unique program to keep fine solids and organic matter out of the storm drain system, through a scenario that cannot be matched to the street types, sweeper types, sweeping frequencies, and parking scenarios that are already are addressed in our WINSLAMM modeling work.

The credit would be similar to the existing mass loading credit developed by the last expert panel, except that the MS4 would be required to sample the dry solids mass, nutrient content and particle size of the material removed by their unique program.

- Jenny, Marty, Sebastian, Justin

Option 4: Yes, allow it for all instances where sweepers pick up solids, using the same basic calculation for the hopper credit approved by the last expert panel.

- Steve Stewart

Additional comments

- Jenny: Option 3b would be valuable as a verification measure.
- Marty: Option 3b is data that we can collect and report
- Sebastian: WV's non-MS4s with voluntary implementation tend to report by weight with less detail in the reporting. Was leaning toward option 4, but 3b is workable.
- Bill Frost: Recommend option 1 or Option 3b to keep it simple. Suggest that jurisdictions be able to pick their percent removal from a menu of options.
- Justin: With 3b, if we reopen this panel, we will have more data in the future.
- Bill Selbig: Recommend Option 1 because there is no connection between what's in the hopper and what gets delivered to the pipe.
- Stu: Majority of street mass being picked up is never washed in to the stream. End up getting the coarse heavy particles in the hopper that wouldn't be washed in to the stream anyway. If the panel chooses 3b, we need further explanation. Suggest that we fill in what we believe the mass balance numbers are.
- Jeremy is in favor of option 1 or 2, however we might want or need 3b available.
- Stewart: Suggest that we provide Option 4 for a set period of time to allow local jurisdictions to switch over to a new methodology. They will have to set up new tracking and reporting processes.
    - Tom will work with CBPO on an option to sunset the hopper credit.

Decision 3: Seasonal Sweeping Enrichment Factor

Option 1: Use a split enrichment factor to apply to solids reduction during high organic matter seasons and the rest of the year (50:50 blend of the street solids and organic matter enrichment factors we discussed last time, or possibly 75:25 split

Option 2: just used the enrichment factor we agreed for street solids, and drop the high organic matter ratio until we have collected for filed data to characterize a better seasonal factor.

Additional comments

- Norm was in favor of Option 2
- Panel will return to Decision 3 in more detail at a future discussion

4. **Panel Discussion on Other Remaining Issues**

- Frost presented several practical issues related to verifying the practice. Recommend flexibility so that jurisdictions don't have to conduct street cleaning in the winter in order to get credit.
- Selbig: Concerned with zero credit for mechanical sweeping technology. However, data shows that mechanical sweeper fails to perform, even when operated at a high frequency. Recommend against water quality credits for mechanical sweeping.
  - Schueler: There will be some pushback on this recommendation. The panel will have to document this thoroughly when presenting the report for approval.
- Shafer: Currently using a simple equation based on sweeper width to measure curb miles swept. Found a range of 0.9 – 1.2 acres after looking at a number of models. Consider establishing ranges for different sweeper broom widths.
  - Marty: Recommend making the reporting link up as closely as possible with that the jurisdictions are tracking and setting milestones on.
- Schwartz: Overall Concerns on WINSLAMM modeling were how much of the street grit load is mobilizable, and what fraction is potentially removed by street sweeping. Only a small proportion of street grit is susceptible to being swept off. Only a small amount of the mass picked up is influencing removal to the stream. Hopper load is not a good predictor of water quality benefit. Comfortable with the pickup rates. Recommend using the term potential pollutants. Concern about double counting the catch basin pieces.
- Schueler: Particle size and delivery of nutrient fractions in organic matter and sediment. Found a bimodal distribution, with disproportionately higher amounts in the coarse grain and fine grain material. Medium grain was intermediate value. Tom will present the tables of results in the report.
- Tribo: Propose that the hopper credit be only available in areas where no street sweeping credit is available. This could provide jurisdictions an alternative credit where they have only mechanical sweeping. Leaf collection programs were in the panel charge, recommend the panel to circle back to leaf collection and outfall collection, and consider crediting these where there is not street sweeping credit.
  - Schueler: Have so far not given leaf collection credit. Other communities in Massachusetts have offered one for P. Unable to find research to establish a basis for the credit.
  - Selbig: So far have not found noticeable reductions from street cleaning in spring.
  - Marty: There have been studies showing nutrient leaching rates for leaves. Can amounts of leaves removed help quantify the nutrient removal?
  - Schueler: The panel was split on this issue previously. Options include: adding a research recommendation or recommendation for a future panel in the report.

- Frost reviewed how sweeping removal credit could tie in with impervious cover treatment requirements for MDE NPDES permits.
  - Schueler: State specific issue, but it will be helpful to MDE.

5. Other Holdover Issues Identified by the Panel

- The panel will return to decision #3

6. The next conference call will be held in mid-march

Adjourned

Appendix E.
Technical Requirements to Entering Street and Storm Drain Practices in Scenario Builder and the Chesapeake Bay Watershed Model

Presented to the WTWG March 3, 2016

Background: In accordance with the *Protocol for the Development, Review, and Approval of Loading and Effectiveness Estimates for Nutrient and Sediment Controls in the Chesapeake Bay Watershed Model* (WQGIT, 2015) each BMP expert panel must work with CBPO staff and the Watershed Technical Workgroup (WTWG) to develop a technical appendix for each expert panel report.

The purpose of this technical appendix is to describe how the Street and Storm Drain Cleaning Expert Panel's recommendations will be integrated into the Chesapeake Bay Program's modeling tools including NEIEN, Scenario Builder and the Watershed Model.

Part 1: Technical Requirements for Reporting and Crediting Street Cleaning BMPs

Q1. How are street cleaning BMPs defined in the Chesapeake Bay Watershed Model?

A1. Street cleaning is defined by the expert panel as a program that uses either mechanical broom sweepers, regenerative-air sweepers or vacuum assisted sweepers to pick up solids off the street surface in an effort to improve water quality. Street cleaning is broken into 11 distinct BMPs based upon the type of sweeping technology and how frequently it is used.

Q2. What types of street cleaning programs can be reported for credit in the Phase 6.0 Watershed Model?

A2. The Panel used the WinSLAMM model to assess over 960 different street cleaning scenarios and elected to consolidate the model results into eleven different street cleaning practices that may be reported for credit in the Chesapeake Bay Program's modeling tools.

The street cleaning practices are defined primarily by whether or not the program uses advanced street cleaning technology and by the cleaning frequencies. The following 11 street cleaning practices may be reported to NEIEN for credit in a progress scenario or reported to the CBPO for credit in a planning scenario:

Practice Number	Technology Type*	Sweeping Frequency
SCP1	Advanced	2 per week
SCP2	Advanced	1 per week
SCP3	Advanced	1 per 2 weeks
SCP4	Advanced	1 per 4 weeks
SCP5	Advanced	1 per 8 weeks
SCP6	Advanced	1 per 12 weeks
SCP7	Advanced	Seasonal 1 or 2**
SCP8	Advanced	Seasonal 3 or 4**
SCP9	Mechanical Broom	2 per week
SCP10	Mechanical Broom	1 per week
SCP11	Mechanical Broom	1 per 4 weeks

* Advanced technologies include Regenerative-Air Sweepers and Vacuum Assisted Sweepers. Definitions for each technology can be found in Section 2 of the report.
**Seasonal sweeping definitions can be found in Table 15

Q3. Which land use categories are eligible to receive nutrient and sediment reduction credit from street cleaning BMPs in the Phase 5.3.2 Watershed Model, and the Phase 6.0 Watershed Model?

A3. In the Phase 5.3.2 Watershed Model, nutrient and sediment reduction credit from street cleaning BMPs would be applied to the "impervious cover" land use. In the Phase 6.0 Watershed Model, nutrient and sediment reduction credits from street cleaning BMPs are applied to the "roads" land use and the "tree canopy over roads" land use.

Q4. How much nitrogen, phosphorus and sediment reduction credit are associated with each of the street cleaning practices?

A4. The nutrient and sediment reduction efficiencies are outlined in Table 1:

Table 1. Pollutant Reductions Associated with Different Street Cleaning Practices

Practice #	TSS Removal (%)	TN Removal (%)	TP Removal (%)
SCP1	21	4	10
SCP2	16	3	8
SCP3	11	2	5
SCP4	6	1	3
SCP5	4	0.7	2
SCP6	2	0	1
SCP7	7	1	4
SCP8	10	2	5
SCP9	1.0	0	0
SCP10	0.5	0	0
SCP11	0.1	0	0

Q5. What do jurisdictions need to report to NEIEN in order to receive street cleaning credit?

A5. For street cleaning credit, jurisdictions will need to report the following to NEIEN:
- *BMP Name*: Practice name (e.g. SCP3) that best defines the jurisdiction's street cleaning program.
- *Measurement Name*: Total number of (feet) or (acres) cleaned under the specified street cleaning practice, with no duplication or overlapping
- *Geographic Location:* Qualifying NEIEN geographies including: Latitude/Longitude (preferred as the coordinates of the centroid of the street cleaning route); *or* County; *or* County (CBWS Only); *or* Hydrologic Unit Code (HUC12, HUC10, HUC8, HUC6, HUC4, State (CBWS Only)
- *Date of Implementation:* Year the sweeping was done
- *Land Uses:* Impervious Cover (for Phase 5.3.2); Roads or Tree Canopy Over Roads (for Phase 6.0)

Q6. Will jurisdictions have the option to report street cleaning practices using the existing street sweeping practice reporting methods established by the 2011 panel, for the 2015, 2016 and 2017 Progress in the Phase 5.3.2 Watershed Model?

A6. Yes. While it is strongly preferred that jurisdictions report street cleaning practices using the new "qualifying lane miles method" outlined in this report, jurisdictions will retain the options to report using the existing "qualifying land miles method" and the existing "mass loading method", for all remaining Progress years in the Phase 5.3.2 Watershed Model.

Q7. Will jurisdictions have the option to report street cleaning practices using the existing street sweeping practice reporting methods established by the 2011 panel, in the Phase 6.0 Watershed Model and Phase 6.0 Historic Data Cleanup?

A7. No. Beginning with 2018 Progress, jurisdictions will only be able to report street sweeping practices using the new "qualifying lane miles method" outlined in this Panel's report.

Q8. If a jurisdiction does not know which of the defined street cleaning practices they qualify for, which practice should they submit as a default?

A8. Jurisdictions should report SCP11 as the default street sweeping practice. Reporting the lowest available efficiency as the default if no other information is available is consistent with requirements for other previously approved BMPs.

Q9. Are street cleaning practices cumulative or annual BMPs?

A9. All street cleaning BMPs are annual practices and must be reported each year in order to receive nutrient and sediment reduction credit in the CBP modeling tools.

Q10. How do street cleaning BMPs interact with other BMPs located within the same catchment in the CBP modeling tools?

A10. Roads treated by street cleaning programs inevitably intersect drainage areas that may (or may not) be served by upstream and/or downstream BMPs. A potential double counting situation is created when street cleaning interacts with other BMPs in the same catchment. The panel could not find a practical method to isolate the BMP interaction effect over the entire road network of a MS4, and certainly not at the scale of the Chesapeake Bay watershed. The panel concluded that there was a small possibility for double counting, but given its conservative protocol, made it too small to quantify.

Part 2: Technical Requirements for Reporting and Crediting Storm Drain Cleaning BMPs

Q11. How are Storm Drain Cleaning BMPs defined in the Chesapeake Bay Watershed Model?

A11. Storm drain cleaning is defined by the expert panel as the removal of sediment and organic matter from catch basins in a targeted manner that focuses on water quality improvements. The storm drain cleaning program should 1) focus on catch basins trapping the greatest organic matter loads, streets with the greatest adjacent tree canopy and/or outfalls with highest sediment or debris loads; 2) be verified using a field protocol to measure the mass or volume of solids collected within the storm drain pipe system; and 3) properly dispose of removed material so that it cannot migrate back through the watershed.

Q12. How will states and localities calculate nutrient and sediment reductions for storm drain cleaning practices?

A12. The credit is computed in three steps:

- **Step 1:** Measure the mass of solids/organic matter that is effectively captured and properly disposed by the storm drain cleaning practice on an annual basis.
- **Step 2:** Convert the initial wet mass captured into dry weight. The following default factors can be used to convert wet mass to dry weight in the absence of local data. The conversion factors are 0.7 for wet sediments (CSN, 2011) and 0.2 for wet organic matter (Stack et al, 2013).
- **Step 3:** Multiply the dry weight mass by a default nutrient enrichment factor depending on whether the material captured is sediment or organic in nature (see Table 20). Note: locals may substitute their own enrichment factor if they

sample the nutrient and carbon content of the materials they physically remove from the storm drain.

Table 20. Mean Nutrient Enrichment Factor to Apply to Dry Weight Mass of Solids Physically Removed From Storm Drains

Nutrient Enrichment Factor	% P	% N	Notes
BMP and Catch Basin Sediments*	**0.06**	**0.27**	See Table B-4
Organic Matter/Leaf Litter	**0.12**	**1.11**	See Table 11

* Multiply the mass of sediment removed from the storm drain (in pounds by a factor of 0.0006 and 0.0027, for TP and TN, respectively.

Q13. How will the modeling tools estimate the actual load reductions from each storm drain cleaning practice?

A13. Storm drain cleaning practices will be treated in the same way as stream restoration practices in the model. This means that storm drain cleaning reductions will apply to loads exiting upslope acres after they have filtered through upslope BMPs. The pounds reduced for each project within a land-river segment will be added together and applied as a reduction at the watershed outlet for each segment. The model simulates further reductions to nutrients between the watershed outlet and the Chesapeake Bay.

Q14. What do jurisdictions need to report to NEIEN to receive storm drain cleaning credit?

A14. To receive storm drain cleaning credit, jurisdictions must report the following to NEIEN:

- *BMP Name*: Storm Drain Cleaning
- *Measurement Name*: Lbs TSS; Lbs TN; Lbs TP
- *Geographic Location:* Qualifying NEIEN geographies including: Latitude/Longitude (preferred as the coordinates of the centroid of the street cleaning rout); *or* County; *or* County (CBWSOnly); *or* Hydrologic Unit Code (HUC12, HUC10, HUC8, HUC6, HUC4, State (CBWSOnly)
- *Date of Implementation:* Year the storm drain cleaning was done
- *Land Uses:* Approved NEIEN land uses – The default land use group for Storm Drain cleaning BMPs will be UrbanWithCss

Q15. Is storm drain cleaning a cumulative or annual BMP?

A15. Storm drain cleaning is an annual practice and must be reported each year in order to receive nutrient and sediment reduction credit in the CBP modeling tools.

Q16. How do storm drain cleaning BMPs interact with other BMPs located within the same catchment in the CBP modeling tools?

A16. Roads treated by storm drain cleaning programs inevitably intersect drainage areas that may (or may not) be served by upstream and/or downstream BMPs. A potential double counting situation is created when storm drain cleaning interacts with other BMPs in the same catchment. The panel could not find a practical method to isolate the BMP interaction effect over the entire road network of a MS4, and certainly not at the scale of the Chesapeake Bay watershed. The panel concluded that there was a small possibility for double counting, but given its conservative protocol, made it too small to quantify.

Q17. Given that a large portion of sediment loads in urban areas are related to channel erosion, will the street sweeping and storm drain cleanout reductions only apply to upstream sources?

A17. A: Yes. Reductions from both practices will only apply to loads generated from upstream impervious and pervious lands. This will be particularly important if the Phase 6 Model is able to separate the contribution of loads due to streambank erosion from upstream sources.

Additionally, the WTWG recommends that loads in each land-river segment may not dip below zero due to any combination of BMPs in the Phase 6 Model. If streambank erosion loads are separated out in the Phase 6 Model, then this recommendation would apply to upland loads and associated BMPs, as well as to streambank erosion loads and associated BMPs.

Q18. Will the Phase 6 Model treat fine sediments differently than course sediments removed by street sweeping or storm drain cleanout practices?

A18. Not at this time. Beyond the considerations already built into the recommended reductions, there will is currently no distinction made between the treatment of fines and course sediments in the Phase 6 Model. With that said, the WTWG recommends that the Modeling Workgroup consider separating fines and sands in the Phase 6 Model. This separation could include 1) separating total sediment runoff from each land use into these two categories, and 2) developing separate sediment delivery ratios for the two categories.

Appendix F
Storm Drain Cleaning Program

Baltimore County Department of
Environmental Protection and Sustainability
Watershed Management and Monitoring Section

Excerpts from Baltimore County MS4 Permit Annual Report (2014) and Draft SOP(2015) .

The Baltimore County DPW stormdrain geodatabase is still being compiled, and will be updated via field investigations, quality control, and compilation from recent storm drain drawings. A copy of this geodatabases accompanies this report. Below are totals from DPW's stormdrain geodatabases as of 12/17/2014.

The Baltimore County storm drain system consists of approximately 1,591 miles of storm drainpipes, channels, and swales, 53,107 inlets, 29,091 manholes, 20,061 in-network structures, and 8,364 outfalls. This is a conservative estimate from DPW's stormdrain geodatabasewhich continues to grow as field investigations, quality control, and compilation of recent storm drain drawings continue.

In order to keep the entire storm drain system clean of trash, debris, and sediment, the Department of Public Works maintains three storm drain cleaning vehicles and employs three crews of two men each on a daily basis to clean the storm drains and pipes. Removing the material from the storm drain system reduces street flooding, a potential safety hazard, reduces the amount of trash and sediment from entering streams, and aids in the detection of illicit connections.

Each time a crew cleans an inlet or pipe the amount of debris removed is recorded on a data sheet that typically contains all cleaning records for that particular location. Completed data sheets are sent to EPS, where the data is entered into a database. The database facilitates reporting for NPDES purposes.

Storm Drain Cleaning Data Analysis

The data entered into the database are analyzed for a number of measures, including the amount of material removed per inlet, the amount of material removed per linear foot of pipe cleaned, total amount of material removed by watershed, and the amount of pollutants removed as a result of the program. Inlet data are reported as the average annual cubic feet of material removed per inlet, and pipe data are reported in cubic feet of material removed per linear foot of pipe.

Program Summary – Storm Drain Cleaning

In twenty years, the storm drain cleaning program has removed ~32,920 cubic yards of material from the Baltimore County storm drain system. At 331 pounds per cubic yard, that amounts to approximately 10.9 million pounds. Without intervention, this material would have eventually entered our waterways.

DRAFT
STANDARD OPERATING PROCEDURE
Tracking, Verification, and Pollutant Load Calculations:
Inlet Cleaning

Important Note: This is provided as a good example of an effective SOP for tracking storm drain cleaning, but the methods and equations may need to be adjusted to reflect the recommendations of this expert panel

Procedural Section

1.0 Definition

In order to keep the entire storm drain system clean of trash, debris, and sediment, the Department of Public Works maintains three storm drain cleaning vehicles and employs three crews of two men each on a daily basis to clean the storm drains and pipes. Removing the material from the storm drain system reduces street flooding, a potential safety hazard, reduces the amount of trash and sediment from entering streams, and aids in the detection of illicit connections.

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2.0 Tracking

2.1 Initial Inspection

2.1.1 Inspection Method

Each time a crew cleans an inlet or pipe the amount of debris removed is recorded on a data sheet that typically contains all cleaning records for that particular location.

2.1.2 Inspector and Qualifications

Staff from DPW Bureau of Utilities clean inlets and pipes using a VACCON truck.

2.1.3 Documentation

DPW completes a data sheet which is organized by work order.

2.2 Data Entry and QAQC

Data sheets are filled out by DPW and contain the following information for pipe cleaning: Starting address and closest intersection, upstream and downstream manhole number (if available), pipe size, debris type, length of pipe cleared, and applicable notes. For inlet cleaning the following information is recorded: starting address and closest intersection, length, width, and depth of inlet before and cleaning, debris type and odor before and after cleaning. Additional information is also recorded such as weather and arrival time. Completed data sheets are entered into a CASSWORKS database by DPW staff and copies of data sheets are sent to EPS where they are filed. The database facilitates reporting for NPDES purposes.

3.0 Pollutant Load Calculations

3.1 Data Retrieval and Processing

A summary table is prepared from the storm drain cleaning data sheets showing the debris collected (cubic yards and tons); TN, TP, TSS (pounds) removed; and equivalent impervious urban acres by watershed.

3.1.1 Export data for appropriate time period from CASSWORKS into an Excel file.

3.1.2 Transfer raw data from CASSWORKS in excel file to CASSWORKS import template available on S drive: file:///S:\EPS\WMM\Data\Chemical\Storm%20Drain%20Cleaning%20(Vaccon)\CASSWORKS\Template_ImportFromCASSWORKS.xlsx. Follow directions on the Description tab in order to get the data into the template.

3.1.3 Perform quality control on the import Excel file. Paper data sheets are compared to the information in Excel. Any missing inlet or pipe cleanings are entered by EPS in Excel. Dimensions are reviewed and are converted to inches if they are in a different unit.

3.1.4 Transfer the data from the import Excel file to this spreadsheet: file:///S:\EPS\WMM\Data\Chemical\Storm%20Drain%20Cleaning%20(Vaccon)\Vaccon_Data.xlsm which contains the formulas and macros to get the volumes.

For inlet cleaning, all dimensions are entered in inches. There are 36^3 cubic inches per cubic yard, or 2.14335×10^{-5} cubic yards per cubic inch. Formula 3.1 is used to calculate the volume of material removed in cubic yards:

$$V_{inlet\ debris} = L_i \times W_i \times \left(D_{i,post} - D_{i,pre}\right) \times 2.14335 \times 10^{-5} \qquad (3.1)$$

where $V_{inlet\ debris}$ = volume of debris removed from inlet in cubic yards,
L_i = length of inlet in inches,
W_i = width of inlet in inches,
$D_{i,post}$ = depth of inlet, in inches, after cleaning completed,
$D_{i,pre}$ = depth of inlet, in inches, before cleaning begins, and
2.14335×10^{-5} = cubic yards per cubic inch

3.1.5 Geocode the addresses and overlay the watersheds.

3.1.6 Transfer data to excel and use a pivot table to show the number of inlets cleaned and volume of debris removed per watershed.

3.1.7 Trash debris is not eligible for nutrient and sediment reductions. Using the volume of debris removed, estimate the weight of sediment and organic material, and the weight of trash, removed from inlets. A study of debris removed from inlets (Law, DiBlasi and Ghosh 2008) informs this estimation. Debris was weighed without drying, so we conservatively assume that all weights from this study are wet weight. The study found that the bulk density of the debris is 331 wet pounds per cubic yard (0.166 wet tons/cubic yard). The study also found that trash accounted for 8.9% of the weight of debris from inlets, while sediment and organic material made up 91.1% of the weight of debris. Formulae 3.2 and 3.3 are used respectively to estimate the weight of sediment and organic material, and the weight of trash:

$$W_{S+OM} = V_{inlet\ debris} \times D_b \times P_{S+OM}$$
$$W_{S+OM} = V_{inlet\ debris} \times 0.166 \times 0.911$$

where W_{S+OM} = wet weight of sediment and organic matter in tons, 3.2
$V_{inlet\ debris}$ = volume of debris removed from inlet in cubic yards,
D_b = bulk density of inlet debris in tons per cubic yard, and
P_{S+OM} = proportion sediment & $organic\ matter, by\ weight$

$$W_{trash} = V_{inlet\ debris} \times D_b \times P_{trash}$$
$$W_{trash} = V_{inlet\ debris} \times 0.166 \times 0.089$$

where W_{trash} = wet weight of trash in tons, 3.3
$V_{inlet\ debris}$ = volume of debris removed from inlet in cubic yards,
D_b = bulk density of inlet debris in tons per cubic yard, and
P_{trash} = proportion trash, by weight

3.2 TN Calculations

Nitrogen reductions per ton of sediment and organic matter removed via catch basin cleaning and storm drain vacuuming are provided in the document Accounting for Stormwater Wasteload Allocations and Impervious Acres Treated (MDE 2014). Reductions per ton of wet weight material are provided in Table 7 of that report, and are 3.5 pounds total nitrogen per wet ton (MDE 2014, 19). Reductions per ton of dry weight material are shown on page 46, and are 0.0025 pounds nitrogen per dry pound (5 pounds per dry ton) (MDE 2014, 46). Weight of wet material can be converted to dry weight by multiplying by 70% (MDE 2014, 46). Equation 3.4 is used to estimate nitrogen reductions from the wet weight of sediment and organic matter removed from inlets and storm drains.

$$TN = W_{S+OM} \times 3.5\ \text{lbs/ton}$$

where TN = total nitrogen removed in pounds, 3.4
W_{S+OM} = wet weight of sediment and organic matter in tons, and
3.5 lbs/ton = total nitrogen removal rate in pounds per wet ton

3.3 TP Calculations

Phosphorus reductions per ton of sediment and organic matter removed via catch basin cleaning and storm drain vacuuming are provided in the document Accounting for Stormwater Wasteload Allocations and Impervious Acres Treated (MDE 2014). Reductions per ton of wet weight material are provided in Table 7 of that report, and are 1.4 pounds total phosphorus per wet ton (MDE 2014, 19). Reductions per ton of dry weight material are shown on page 46, and are 0.001 pounds phosphorus per dry pound (2 pounds per dry ton) (MDE 2014, 46). Weight of wet material can be converted to dry weight by multiplying by 70% (MDE 2014, 46). Equation 3.5 is used to estimate phosphorus reductions from the wet weight of sediment and organic matter removed from inlets and storm drains.

$$TP = W_{S+OM} \times 1.4 \text{ lbs/ton}$$

where $TP =$ total phosphorus removed in pounds,
$W_{S+OM} =$ wet weight of sediment and organic matter in tons, and
$1.4 \text{ lbs/ton} =$ total phosphorus removal rate in pounds per wet ton

3.5

3.4 TSS Calculations

Sediment reductions per ton of sediment and organic matter removed via catch basin cleaning and storm drain vacuuming are provided in the document Accounting for Stormwater Wasteload Allocations and Impervious Acres Treated (MDE 2014). Reductions per ton of wet weight material are provided in Table 7 of that report, and are 420 pounds total suspended sediment per wet ton (MDE 2014, 19). Reductions per ton of dry weight material are shown on page 46, and are 30% of the dry weight (600 pounds per dry ton) (MDE 2014, 46). Weight of wet material can be converted to dry weight by multiplying by 70% (MDE 2014, 46). Equation 3.6 is used to estimate phosphorus reductions from the wet weight of sediment and organic matter removed from inlets and storm drains.

$$TSS = W_{S+OM} \times 420 \text{ lbs/ton}$$

where $TSS =$ total suspended sediment removed in pounds,
$W_{S+OM} =$ wet weight of sediment and organic matter in tons, and
$420 \text{ lbs/ton} =$ total suspended sediment removal rate in lbs per wet ton

3.6

Law, Neely L., Katie DiBlasi, and Upal Ghosh. 2008. *Deriving Reliable Pollutant Removal Rates for Municipal Street Sweeping and Storm Drain Cleanout Programs in the Chesapeake Bay Basin.* Research Report, Ellicott City, MD: Center for Watershed Protection. http://www.cwp.org/online-watershed-library/doc_download/577-deriving-reliable-pollutant-removal-rates-for-municipal-street-sweeping-and-storm-drain-cleanout-programs-in-the-chesapeake-bay-basin.

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APPENDIX G

Date: January 12, 2016

From: Tom Schueler
CBPO Stormwater Coordinator
Chesapeake Stormwater Network

To: Urban Stormwater Workgroup
Watershed Technical Workgroup

Re: Response to Comments on Street and Storm Drain Cleaning
Expert Panel Report (Revised)

The Expert Panel Report was released on September 18, and a webinar was held on September 29 in which more than 30 individuals participated. The required 30 day comment period under the new joint BMP expert panel review process recently established by the WQGIT expired on Monday, October 19.

The following individuals and organizations provided comments as of October 23:

- Tom Maguire, Justin Shafer and Neely Law (members of expert panel)
- Unidentified individual on webinar
- PA DEP
- MDE SSA
- Chesapeake Bay Foundation
- City of Chesapeake
- Anne Arundel County, MD

This memo summarizes the comments received by the deadline, and presents a technical response. It is organized in three sections:

Section 1: Applicability and Qualifying Conditions for the Practice

Comment No. 1. *Does the storm drain cleaning credit apply to sediment removal operations that occur during ditch maintenance along open section roads?*

Response: No, it does not. The storm drain cleaning credit only applies to sediment and/or organic matter removed from within the storm drain system (i.e., catch basins, storm drain pipes and/or stormwater outfalls). Given its charge, the panel did not evaluate any research on pollutant removal achieved during rural or agricultural ditch maintenance or retrofits. Other ongoing expert panels and research projects are investigating possible practices to enhance nutrient and sediment removal in agricultural and roadside ditch networks.

Comment No. 2. *Does the storm drain cleaning credit apply to sediment removal operations that occur in open, concrete-lined conveyance channels?*

Response: Yes, the practice is very similar to storm drain pipe or catch basin cleaning and should be credited in the same manner. These channels are located downstream of catch basins and provide an additional opportunity to capture pollutant loads before reaching the urban stream network.

Comment No. 3. *Can a community earn the street cleaning credit if it sweeps municipal or commercial parking lots, in addition to streets and roads?*

Response: Yes, but generally only when advanced street cleaning technology is used on the parking lot. In the past, most parking lots were swept using older mechanical broom sweepers that earn low or zero credit under this expert panel's recommendation.

Allowing parking lot cleaning will require two minor edits to Appendix E "Technical Requirements to Enter Practice into Scenario Builder". The first involves determining whether parking lots will be assigned to the new transport land use in the Phase 6 CBWM (or not). The second will involve additional text on how parking lot cleaning effort needs to be reported to get credit (e.g., report acres of parking lot swept, and then convert back to lane miles using the 1 acre = 1 curb lane mile rule).

Comment No. 4. Can the street cleaning credit be applied to roads and streets without curb and gutters?

Response: The expert panel explicitly considered this issue, and determined that there was insufficient monitoring data to determine whether it was effective to sweep streets without curb and gutters. The panel reviewed one study on the topic which is presented on page 21 of their report, and is excerpted below:

> In general, curbs and gutters create a trap that retains sediment and organic particles where they can be effectively swept. Streets without curb and gutters do not have a trap at the pavement edge, and the adjacent pervious area may actually become a net source of sediment when it is mobilized by contact with a sweeper broom (Smith, 2002).

The panel recommended more research be conducted on the effect of sweeping streets and highway shoulders that lack curb and gutters. Until that data becomes available, streets and parking lots without curb and gutter are eligible for credit.

Section 2: Technical Comments on the Panel Report

Comment No. 5. *The expert panel report should include a review of the limited monitoring data on the pollutant removal performance associated with storm drain and catch basin cleaning, as well as provide some standard definitions for the storm drain cleaning practice* (Maguire).

Response: Agreed. A new Section 4.7 has been added that summarizes storm drain cleaning research, and additional storm drain definitions have been added to Section 2. Tom Maguire provided draft text for both sections, which is shown in blue font in the revised expert panel report.

Comment No. 6. *Should the panel have applied a sediment delivery factor to reflect that not all street solids will ever reach the storm drain system?* (MDE)

Response: The expert panel strongly concurs that only a fraction of the street solids picked up by sweepers would ever reach the Chesapeake Bay, due to their large particle size. This is one of the reasons why the panel eliminated the hopper method for earning street cleaning credit (see also response to Comment 10).

The panel directly addressed the street solid delivery issue by using the WinSLAMM model to quantify the fraction of street solid mass that is actually conveyed from the street to the storm drain and ultimately discharged from the storm drain pipe. The documentation report prepared by Tetra Tech (2015) provides specific details on how the particle size of street solids was accounted in the simulation model. In general, the model simulates the particulate concentration for each storm event, based on the rainfall depth, runoff coefficient, street solid particle size distribution and street delivery factor for a defined street system.

Consequently, the WinSLAMM model provides a more fine-grained simulation of street solids and suspended sediment dynamics that occur in streets, gutters, storm drains and outfall pipes (and explains why the projected sediment removal rates associated with most street cleaning scenarios is so low).

The sediment loads that are discharged from storm drain pipes are still subject to the edge of field sediment delivery factor in the phase 5.3.2 CBWM. The panel references this in section 3.4 of the report (page 16).

> It should be noted that not all of the sediment load generated from urban impervious cover actually reaches the Chesapeake Bay in the watershed model. The sediment loads at the edge of pavement are adjusted downward by a sediment delivery factor in the current version of the CBWM. For a more thorough discussion of the sediment delivery factor, please consult the discussion in SR EP (2014).

The specific mechanics of how sediment delivery ratios are calculated may change in the next version of the CBWM (e.g., adding more impoundments and reservoirs), but these details go well beyond the charge of this expert panel report.

Comment No. 7. *Given the large particle size distribution for street solids, and the preferential pickup of large particles by sweepers, how does this square with the fine particle size (clay/silt) measured in the streams and rivers that flow to the Bay (MDE).*

Response: As noted the response to comment No. 6, the majority of medium and coarse-grained particles in street solids never reach the storm drain, stream network, or ultimately the Chesapeake Bay. The sediment reductions simulated by the WinSLAMM model primarily reflect the fine-grained particles that are observed at the river input monitoring stations further downstream (see also response to comment No. 10).

Comment No. 8. *Given the Figure 6 graphic showing poor pickup efficiency for regenerative air sweepers, why are they still considered an advanced cleaning technology ? (MDE)*

Response: MDE is correct when it notes that Figure 6 shows that regenerative air sweepers were not as effective as vacuum assisted sweepers in removing small sediment particles in the Selbig and Bannerman (2007) study. However, their study, as well as three other recent street cleaning studies, showed that regenerative air sweepers did have high sediment pick-up efficiencies which were generally comparable to those achieved by vacuum-assisted sweepers (Sorenson, 2013, SPU, 2009 and CSD, 2010). Consequently, the expert panel concluded that both qualify as Advanced Sweeper Technologies (AST) and thereby can earn higher pollutant removal rates than traditional mechanical broom sweepers.

Comment No. 9. *How did the panel evaluate street sweeping rates in the context of the role of downstream bank erosion in terms of the urban sediment load simulated by the Chesapeake Bay Watershed Model?*

Response: The panel acknowledges that downstream bank erosion in a major source of sediment loads in urban watersheds, as was established by the original Langland and Cronin (2003) report and validated more recently by a STAC research report (Sample et al, 2015). This important finding is implicitly addressed by the use of the Langland and Cronin curve relating urban sediment load to subwatershed impervious cover in the Version 5.3.2 CBWM (reproduced in Figure 1 of SR EP, 2013).

The USWG was recently updated on efforts to explicitly simulate how sediment loads might be allocated to upland areas versus the stream corridor in urban watersheds in the next version of the CBWM. The Center for Watershed Protection is testing several methods for doing so, and the decision to make any changes will be made by the Modeling Work Group, in conjunction with other stakeholders.

Predicting how these future modeling decisions will influence urban BMP removal rates (of any kind) is well beyond the scope of this or any other expert panel. The panel was not unduly concerned about how future modeling decisions might influence where urban sediment loads were generate, since they utilized an independent modeling approach to accurately define the upland sediment loads generated from streets.

Section 3: Panel Recommendations on Credits and Verification

Comment No. 10. *Could the panel document why the 2011 hopper credit for street cleaning was eliminated, since many communities would still like to report it?*

Response: The expert panel considered the hopper credit, but elected to eliminate it for both scientific and operational reasons.

Part of the scientific rationale for dropping the hopper credit can be found in response to comment No. 6, which describes how the particle size distribution of street solids influences how they are delivered to the storm drain system. This is also evident in Table 7, which shows the typical particle size distribution of street solids, based on a national data review. As can be seen, 90% of all street solids are either medium-grained (75 to 1000 microns) or coarse-grained (more than 1000 microns). Only 10% of the street solid particles are fine-grained silts and clays that can become entrained in the stormwater runoff and move easily through the watershed.

The panel felt the new street cleaning credit based on the WinSLAMM modeling was greatly superior to the hopper credit, since it has a stronger technically and empirical foundation, explicitly accounts for street solids delivery, and provides municipalities with a greater range of street cleaning practices in which they can earn credit. By contrast, the old hopper credit method is prone to errors, especially if users do not fully understand the importance of all of its qualifying conditions (e.g., applies only to streets that have curb and gutters, are swept bi-weekly or more frequently by advanced street cleaning technologies).

From an operational standpoint, the panel concluded it was poor practice to continue to offer two methods to calculate credit for the same practice. The existence of two methods creates confusion and could become a major source of reporting problems and submission errors.

The panel did recommend a two-year grace period before the mass loading method for earning street cleaning credit should be phased out. Additional justification for the phase out of the hopper credit is provided in Section 6.3.

Comment No. 11. *PA DEP is hesitant to accept the panel's endorsement of a new transport land use in the Phase 6 CBWM without additional documentation on how it might influence future urban loads and BMP efficiencies in the Commonwealth.*

Response: Section 8,4 was eliminated from the final text. The actual authority to make land use changes to the CBWM (or, for that matter, any other changes to the CBWM),is reserved by other management entities within the Chesapeake Bay Partnership, and not individual expert panels. The decision to proceed with a new transport IC land uses in Phase 6 of the CBWM was made earlier this year by the Land Use Working Group, Modeling Work Group and Water Quality Goal Implementation Team.

Comment No. 12. *PADEP does not support the panels proposed verification protocol involving a single annual sample for the street cleaning practice, as it too onerous and costly for small local governments to implement.*

Response: Verification is critical for annual operational practices such as street cleaning, since the degree of effort will change from year to year in response to budget resources, the size, age and technology of the local sweeper fleet and weather conditions.

The panel's street cleaning verification protocol (Section 7.2, page 47) recommends a single annual high quality sample of sweeper waste characteristics for each unique street cleaning practice (SCP) that is being claimed by the community. This verification approach was adopted in lieu of more stringent verification efforts that would involve measuring hopper loads or volumes after each daily street cleaning trip as originally suggested by some panel members.

The panel's verification protocol (a) provides greater transparency about what is actually being picked up off the streets within a community, (b) collects high quality data that can be shared among communities to further refine the street cleaning practice in the future and (c) requires limited resources in terms of costs for staff time and sweeper waste sampling.

Notes were added to the report to indicate that panel commendations on tracking and verification are advisory in nature, and are not binding on any state. Individual Bay states can provide alternate verification methods for street cleaning, as long as they satisfy the general verification principles agreed to by the Chesapeake Bay Program Partnership (CBP, 2014).

Comment No. 13. *Need to provide more technical support and sampling guidance on how to separate sediment from organic matter in the proposed verification method for the storm drain cleaning credit (e.g., sediment tends to stick to organic matter even when dried --Law).*

Response: The panel concurs that communities need more guidance on the sampling methods for the verification protocols for both street and storm draining cleaning, and has added some additional references. The panel recommended two initiatives to provide more technical guidance to help communities effectively implement the new credits. (Section 8.3, and excerpted below:)

- Develop more detailed sampling guidance and standard operating procedures to support the proposed verification protocols for street and storm drain cleaning.

- Establish a support website for MS4s across the Chesapeake Bay watershed on street cleaning, which provides updated guidance, standard reporting forms, a downloadable version of the spreadsheet, and list of sweeper models that are eligible for higher credit. The website might also include an interface for users and practitioners to share their verification samples.

Comment No. 14: *Suggest changing "may" to "should" when it comes to the list of street cleaning record-keeping requirements provided on page 47, and require MS4s to report the total number of street miles that could potentially be swept in their community at least once every permit cycle (Wood, CBF).*

Response: In general, the reporting, tracking and verification recommendations developed by the expert panel are advisory in nature. The Watershed Technical Work Group is the final arbiter of what is required to be reported in Scenario Builder to get credit for pollutant reductions in the CBWM. Likewise, the state stormwater regulatory agencies are the ultimate authority on what records MS4 must retain to substantiate their local street cleaning effort.

While the panel agrees that communities should evaluate their entire street network when analyzing which combination of street cleaning practices could maximize pollutant reduction credits, they did not want to impose this as a local requirement or permit condition. The panel also observes that measuring the total street mileage in a community is easier said than done, given that actual street ownership is split between many different federal, state, local and/or private entities.

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