Technical Memorandum

Selection of Event Mean Concentrations (EMCs)

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Consolidated TMDL Implementation Plan – Comprehensive Baseline Analysis

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DISTRICT DEPARTMENT OF THE ENVIRONMENT

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1 Introduction

The District Department of Environment (DDOE) is required to develop a Consolidated Total Maximum Daily Load (TMDL) Implementation Plan (IP) as established in the District's Municipal Separate Storm Sewer System (MS4) National Pollutant Discharge Elimination System (NPDES) permit (U. S. EPA 2011 and U. S. EPA 2012). The IP will define and organize a multi-year process centered on reducing pollutant loads originating within the District MS4. The level of pollutant control will be based on past TMDL studies performed to protect impaired water bodies in the District. The IP will include a summary of the regulatory compliance strategy to satisfy TMDL-related permit requirements, a summary of data and methods used to develop the IP, specific prioritized recommendations for stormwater control measures, a schedule for implementation and attainment of Waste Load Allocations (WLAs), and a method for tracking progress. Substantial public involvement will be sought in plan development.

This Technical Memorandum on the selection of event mean concentrations (EMCs) is one in a series of technical memoranda that provide detailed information on research, analysis, programs and procedures that support development of the Consolidated TMDL IP.

2 Purpose

EMCs are an essential component of most storm water pollutant load estimation procedures. In practice, EMCs are considered to be the flow proportional concentration of a given pollutant parameter during storm events. That is, the total mass discharged divided by the total runoff volume. The multiplication of observed or model simulated runoff (flow) by an EMC for a particular pollutant generates a pollutant load.

The selection and application of EMCs was instrumental in the development of TMDLs in the District. EMCs were used to estimate pollutant loads for conventional pollutants (e.g., TSS, nutrients, and bacteria) as well as metals and other toxic substances. In some instances the EMCs were applied to runoff at stormwater outfalls to develop MS4 stormwater loads. In other instances the EMCs were applied to runoff in watersheds to develop watershed loads. In addition, substantially dissimilar EMCs were often used to characterize the same pollutant in different TMDL studies.

The requirement to develop a Consolidated TMDL IP for the District provides an opportunity, if defensible, to identify and apply a consistent set of EMCs to support modeling of pollutant load estimations and pollutant reduction with BMPs and other non-structural control practices. In addition, comparisons of land use-based EMC values compiled from the scientific literature and MS4 outfall monitoring-derived EMCs to the EMCs used in the original TMDLs allows the evaluation of the feasibility of using updated EMCs in place of the EMCs used in the original TMDLs. Utilization of land use-based EMCs would confer the advantage of allowing different land uses to generate different loads, and this would help with targeting BMP practices to the land use types with the highest loads. Conversely, using EMCs derived from current MS4 outfall monitoring data would ensure that the EMCs used in the IP Modeling Tool were reflective of current pollutant concentrations in the District. This would contrast with the EMCs used in the original TMDLs, which are based on older data, and some of which was not collected within the District.

The purpose of this Technical Memorandum is to document the process that was used to develop a set of EMCs that can be applied on a city-wide basis across the District. The **Technical Approach** employed includes:

- A review of the EMCs used to develop TMDLs in the District.
- A review of EMCs reported in literature for various land use classes.

- An evaluation of District MS4 outfall monitoring data to develop DC-specific EMCs.

The **Results and Discussion** section of this Technical Memorandum presents the EMCs selected with commentary on the rationale for their selection and use of the EMCs in the IP.

3 Technical Approach

3.1 Review of EMCs used to develop the DC TMDLs

Most of the TMDLs done for the District used EMCs in conjunction with flow data to calculate loads for different wet weather flow types (i.e., stormwater and CSOs). EMCs used in District TMDLs were typically developed from local monitoring data, although in a few cases, other data (such as data from Maryland and/or literature values) were used. Several different sets of EMCs developed at different times for different purposes were used in the TMDLs. For example, some TMDLs used monitoring data specifically conducted for use in that TMDL, while others used historical MS4 outfall monitoring data, and still others used EMCs developed for the DC Water CSO Long Term Control Plan.

Because the EMCs were based on sampling from an entire watershed and they were applied to all flows from the entire watershed, these EMCs are referred to as "watershed-based EMCs." This contrasts with land use-based EMCs, which are derived for specific land use types.

Discussions of the EMCs developed for each pollutant type are presented below. A table summarizing the various EMCs used for the different TMDLs follows the discussions.

3.1.a Bacteria

Bacteria EMCs used in District TMDLs came from either the LTCP studies or MS4 monitoring data. The EMCs developed from the MS4 monitoring data was used in the DC Small Tributaries Model. The DC Small Tributaries Model was used for the Anacostia Tributaries, Oxon Run, C&O Canal, and Potomac tributaries bacteria TMDLs. Page 10 of the *DCST Model Report* (DC DOH, July 2003) states that "The average storm water concentration estimate for fecal coliform bacteria was obtained from District MS4 monitoring data (Nicoline Shelterbrandt [sic], private communication)." The bacteria EMCs developed by the LTCP studies to characterize separate storm sewer areas were used for the Anacostia, Potomac, and Rock Creek mainstem bacteria TMDLs, as well as for the Kingman Lake, Washington Ship Channel and Tidal Basin bacteria TMDLs. This EMC was developed through an analytical review of Nationwide Urban Runoff Program EMC data (U.S. EPA, 1983), and through the collection of stormwater samples taken at 6 sites by DDOE, and the collection of stormwater samples taken at 2 sites by DC Water. The original sample results are presented in *Study Memorandum LTCP 5-8 (Final), CSS and SSWS Event Mean Concentrations* (DC Water, October 2001), Table F-2.

Beginning in January 1, 2008, the District bacteriological WQS changed from fecal coliform to E. coli. The current Class A water standards are a geometric mean of 126 MPN. The District-specific bacteria translator was used to convert fecal coliform EMCs directly to E. coli EMCs (LimnoTech 2011) and 2012)[1]. This separate effort to develop a statistically valid bacteria translator involved extensive comparison of paired fecal coliform and E.Coli samples and development of a regression equation for translation of bacteria concentrations. No further analysis of District E. coli data is contained in this Technical Memorandum.

[1] Documentation related to development of the translator is in LimnoTech's 2011 Memorandum, Final Memo Summarizing DC Bacteria Data and Recommending a DC Bacteria Translator (Task 2) and LimnoTech's 2012 Memorandum, Update on Development of DC Bacteria Translators.

Paired Metals

The DC Small Tributaries Model was used for all of the metals TMDLs except the Rock Creek mainstem Metals TMDL. Table 2b in the DCST summarizes baseflow and stormflow EMCs for the Inorganic Chemicals Sub-Model. Copper, lead and zinc storm flow EMCs were calculated by averaging the DC WASA LTCP separate sewer system EMCs (DC WASA, 2002) with means of the recent DC MS4 monitoring results. This is explained in more detail in Section 2.2.4, *Other Tributaries and Separate Storm Sewer Loads* and Table 2-4 in *TAM/WASP Toxics Screening Level Model for the Tidal Portions of the Anacostia River, Final Report* (Behm, et.al., April, 2003). The original sample results for the LTCP EMCs are presented in *Study Memorandum LTCP 5-8 (Final), CSS and SSWS Event Mean Concentrations* (DC Water, October 2001), Table F-1 and consist of four composite samples from Suitland Parkway taken over four storms from September 1999 to February 200, plus four composites taken over the same four storms at Hickey Run, plus two additional grab samples from the November 1999 storm taken at Hickey Run. In contrast to the EMCs for copper, lead and zinc, the EMC for arsenic was based solely on MS4 monitoring data.

For the Rock Creek mainstem Metals TMDL EMCs, were based on sampling data performed by LimnoTech at five locations on Rock Creek over two storms in 2003 and sampling performed by DC Department of Health (DOH) at three locations over three storms in 1994 and 1995 (DC DOH, February 2004.

3.1.b Organics

The DC Small Tributaries Model was used for all of the organics TMDLs except the Potomac and Anacostia Tidal PCB TMDL. Table 2a in the DCST summarizes baseflow and stormflow EMCs for the Organic Chemicals Sub-Model. EMCs for chlordane, heptachlor epoxide and PAHs were calculated from data from the Northeast and Northwest Branches in Maryland because stormwater monitoring data for the tidal portion of the Anacostia River were not available and DC MS4 results for these contaminants are all non-detect (Behm, et.al., April, 2003, p. 143 for chlordane and heptachlor epoxide; p. 125 for PAHs). For chlordane, the original values for baseflow (which was calculated as the average of six baseflow samples collected in instream in 1995-1996 at the USGS gages on the Northeast and Northwest Branches) and stormflow (which was calculated as the average of four composite stormflow samples collected in instream in 1995-1996 at the USGS gages on the Northeast and Northwest Branches) were multiplied by 1.0 each to develop the individual baseflow and stormflow EMCs (Behm, et.al., April, 2003, Table 3-15; note that the sampling results summarized in the table do not support the EMC that is supposedly derived from them) (note that the load adjustment factors were used for each parameter to better calibrate modeled data to observed data; in the case of chlordane, that load adjustment factor was 1.0). For heptachlor epoxide, the original baseflow and stormflow values were multiplied by a load adjustment factor of 0.7 to develop the individual baseflow and stormflow EMCs (Behm, et.al., April, 2003, Table 3-22). The calibrated model incorporates this load reduction factor of 0.7 for heptachlor epoxide because bed sediment concentrations for heptachlor epoxide were over-estimated in the original model run (Behm, et.al., April, 2003, p. 144).

For the PAHs, the original values for baseflow and stormflow were multiplied by 1.5 to develop the individual baseflow and stormflow EMCs (Behm, et.al., April, 2003, Table 3-15). This 1.5 multiplier was used in the final calibrated model as a load adjustment factor to provide a better fit to bed sediment data (Behm, et.al., April, 2003, p. 127).

Dieldrin, DDD, DDE, and DDT EMCs were calculated from District MS4 monitoring data. For dieldrin, tidal sub-basin tributaries and separate storm sewer system EMCs were estimated at 0.00029 ug/L, based on MS4 monitoring data (Nicoline Shelterbrandt, private communication) of 20 samples with 18 non-detects, where non-detects were estimated as half the detection limit (Behm, et.al., April, 2003, p. 155).

The baseflow EMC for dieldrin for the tidal sub-basin tributaries and separate storm sewer systems was estimated as the average of the Northeast and Northwest Branch base flows. For DDD, DDE, and DDT, tidal sub-basin EMCs, including separate storm sewer system, and CSO are based on data from the District's MS4 storm water monitoring program, with an average minimum detection limit of 3E-04 ug/L (Nicoline Shelterbrandt, private communication) (Behm, et.al., April, 2003, p. 163). For DDD, the original sampling data value was multiplied by 20; for DDE, the original sampling data value was multiplied by 15; and for DDT, the original sampling data value was multiplied by 20. These adjustments were made for both baseflow and storm data.

For PCBs, tidal sub-basin tributaries storm flow, separate storm sewer system, and CSO Total PCB EMCs are based on data from the District's MS4 monitoring (Nicoline Shelterbrandt, private communication), where non-detects for each classification (PCB1, PCB2, and PCB3) were estimated to be 0.00025 ug/L, which is approximately half the reported minimum detection limit (Behm, et.al., April, 2003, p. 102). The baseflow EMC for each classification for the tidal sub-basin tributaries and separate storm sewer systems was estimated as the average of the Northeast and Northwest Branch base flows. For each PCB classification in the model, the original sampling data value was multiplied by 3 in order to better calibrate against observed monitoring data. These adjustments were made for both baseflow and storm data.

For the Potomac and Anacostia Tidal PCB TMDL, ICPRB looked at TSS vs. PCB regression relationships to set PCB concentrations, so no PCB EMCs were used.

3.1.c Nutrients

COG supplied the data and the methodology to calculate representative concentrations of nitrogen, phosphorus, and BOD5 for loads from the smaller tributaries, storm sewers, and the direct drainage to the tidal Anacostia River for the Anacostia Nutrients and BOD TMDL (2001). The methodology used storm flow composite samples collected from earlier studies of small urban watersheds in the District of Columbia. Representative storm flow concentrations were developed for closed systems (storm sewers) and open systems (watersheds with primarily free-flowing tributaries). For the direct drainage to the tidal Anacostia River, a weighted average of close and open system concentrations was calculated, depending on land use. Commercial, industrial, and high and medium density residential land uses were assigned close-system concentrations; the remaining land uses were assigned open-system concentrations. Representative stormwater TN and TP concentrations were then calculated for each modeling segment, as an average, weighted by land use, of the concentrations associated with the direct drainage and subwatersheds discharging to that model segment. Concentrations ranged from 2.34 to 3.9 mg/L for TN and 0.36 to 0.77 mg/L for TP. Only storm flow loads are calculated for the smaller tributaries, storm sewers and direct drainage. No attempt was made to estimate loads in base flow or groundwater discharge to the tidal Anacostia (Mandel and Schultz, 2000).

For the Anacostia Nutrients and BOD TMDL (2008), EMCs were calculated from monitoring data. For segments of the drainage area in Maryland, EMCs were calculated by land use type, but in the District, monitoring stations represented a mix of land use types, so EMCs were not calculated by land use type. EMCs were calculated for TKN (2.6 mg/L), Nitrate (1.1 mg/L), and TP (0.5 mg/L). The TN EMC can be calculated as the sum of the TKN and Nitrate EMCs: 2.6 mg/L TKN + 1.1 mg/L Nitrate = 3.7 mg/L TN (Mandel, et. al., 2008, p. 5).

Baseflow EMCs are provided in Table 2.6.3 and were also based on previous sampling data.

The Chesapeake Bay TMDL did not use EMCs for Total Nitrogen and Total Phosphorus because MS4 land areas are modeled by the Bay Watershed Model, which primarily uses loading rates (e.g.: pounds of pollutants per acre of land use). However, Chapter 10, pp. 15-16 of the Bay Watershed Model documentation (U.S. EPA 2010) discusses development of stormwater loads. Research had shown little variation in TN and TP between land uses in the Chesapeake Bay region. Therefore, the Phase 5.3 model used the same values to be reflective of both high and low density residential areas. For calculation of the developed land expected load, the overall median concentrations of 2.0 mg/L TN and 0.27 mg/L TP are used.

3.1.d TSS/Sediment

The Anacostia TSS TMDL (2002) used TSS storm concentrations of 227 mg/L to represent open-channel systems, including Nash Run, Fort Dupont, and Pope Branch. The storm concentration was based on previous COG sampling of Pope Branch. This TMDL uses storm concentrations of 94 mg/L to represent closed-channel systems, including Fort Chaplin, Fort Davis, Fort Stanton, Hickey Run, and Texas Avenue Tributary. Baseflow EMCs were either 0 or 2 mg/L depending on the specific sub-shed (Schultz, October 2001, revised April 2003, Table 2-5). Because no storm flow monitoring data for TSS is available for Watts Branch, a storm TSS concentration of 227 mg/L was used, based on the MWCOG Pope Branch open channel result. A non-storm TSS concentration of 6 mg/L for the Watts Branch was estimated from available DC DOH routine monitoring data for station TWB01 (time period 4/20/82 to 12/9/97) by computing the median value of the non-storm data (where the criteria for non-storm conditions was no precipitation recorded at National Airport on the day of and the day preceding the sampling event) (Schultz, October 2001, revised April 2003, p. 22). Output from the Prince Georges County HSPF model of Lower Beaverdam Creek was used to generate daily TSS loads from Lower Beaverdam Creek (Schultz, October 2001, revised April 2003, p. 22).

The Anacostia Sediment and TSS TMDL (2007) does not provide clear information as to the storm and baseflow EMCs used in the modeling. Therefore, it is assumed that the same storm and baseflow EMCs used in the 2002 Anacostia TSS TMDL were used in this TMDL.

The Watts Branch TSS TMDL (2003) does not identify overall stormflow EMCs, but it is assumed that the storm TSS concentration of 227 mg/L was used from the previous Anacostia TSS TMDL (2002) to calculate the total load, but a storm EMC of 60 mg/L was used after the stream erosion component was broken out of the equation (Watts Branch TSS TMDL, 2003, p. 20).

The Kingman Lake TSS, Oil & Grease, and BOD TMDL (2003) used data from three samples from the storm sewer collecting runoff from a residential area tributary to Kingman Lake to calculate EMCs. The location was selected to be representative of the commercial, industrial, residential, and recreational land use activities. Samples were collected over three storms (12/17/01; 4/9/02; and 4/18/02) and averaged to develop the EMCs. The EMC for TSS was 34.67 mg/L. The TMDL also shows a separate TSS EMC of 5.66 mg/L for grassed areas (p. 7).

The Chesapeake Bay TMDL did not use EMCs for TSS because MS4 land areas are modeled by the Bay Watershed Model, which primarily uses loading rates (e.g.: pounds of pollutants per acre of land use). The Bay Watershed Model Version 5.3 uses edge-of-field erosion rates for different land use types to establish loads from different land use types. This is documented in Chapter 9 of the Bay Watershed Model documentation (U.S. EPA, 2010). As a point of comparison, Maryland has used a TSS EMC of 80 mg/L in the past when addressing its allocations under the Chesapeake Bay TMDL (MDE, 2009).

3.1.e Other

COG supplied the data and the methodology to calculate representative concentrations of nitrogen, phosphorus, and BOD5 for loads from the smaller tributaries, storm sewers, and the direct drainage to the tidal Anacostia River for the Anacostia Nutrients and BOD TMDL (2001). According to Mandel and Schultz (2000), the methodology used storm flow composite samples collected from earlier studies of small urban watersheds in the District of Columbia. Representative storm flow concentrations were developed for closed systems (storm sewers) and open systems (watersheds with primarily free-flowing tributaries). For the direct drainage to the tidal Anacostia River, a weighted average of close and open system concentrations was calculated, depending on land use. Commercial, industrial, and high and medium density residential land uses were assigned close-system concentrations; the remaining land uses were assigned open-system concentrations. Representative storm-water BOD5 concentrations were then calculated for each modeling segment, as an average, weighted by land use, of the concentrations associated with the direct drainage and subwatersheds discharging to that model segment. However, while the document indicates that these BOD concentrations are to be found in Table 4.2-8 of Mandel and Schultz (2000), this table does not contain BOD information, so the actual EMCs are not documented. No attempt was made to estimate loads in base flow or groundwater discharge to the tidal Anacostia.

For the Anacostia Nutrients and BOD TMDL (2008), EMCs were calculated from monitoring data. For segments of the drainage area in Maryland, EMCs were calculated by land use type, but in the District, monitoring stations represented a mix of land use types, so EMCs were not calculated by land use type. The BOD EMC was calculated 42.9 mg/L (Mandel, et. al., 2008, p. 5). The baseflow EMC for BOD as provided in Table 2.6.3 is 1.2 mg/L. This EMC was also based on previous sampling data.

The Kingman Lake TSS, Oil & Grease, and BOD TMDL (2003) used data from three samples from the storm sewer collecting runoff from a residential area tributary to Kingman Lake to calculate EMCs. The location was selected to be representative of the commercial, industrial, residential, and recreational land use activities. Samples were collected over three storms (12/17/01; 4/9/02; and 4/18/02) and averaged to develop the EMCs. The EMC for BOD was 27 mg/L. The EMC for oil and grease was set at the method detection limit of 5 mg/L. No samples were actually measured over the method detection limit. The TMDL also shows a separate BOD EMC of 4.41 mg/L for grassed areas (p. 7).

No EMCs were used to model loads for the Anacostia Oil & Grease TMDL (2003), the Fort Davis BOD TMDL (2003) or the Hickey Run PCB, Oil and Grease, and Chlordane TMDL (1998).

Table 1: Summary of EMCs Used in District TMDLs

Pollutant	Units	Baseflow EMC	Stormflow EMC	TMDLs
Bacteria				
Fecal coliform bacteria	Number/100 mL	280	17,300	DC Small Tribs Model: Anacostia Tributaries; Oxon Run; C&O Canal; and Potomac Tributaries
Fecal coliform bacteria	Number/100 mL	N/A	28,265	CSO LTCP Approach: Anacostia, Potomac, and Rock Creek mainstems, as well as Kingman Lake, Washington Ship Channel and Tidal Basin
Metals				
Arsenic	ug/L (dissolved + particulate)	0.2	1.4	All of the metals TMDLs except the Rock Creek Mainstem Metals
Copper	ug/L (dissolved + particulate)	3.5	57	All of the metals TMDLs except the Rock Creek Mainstem Metals
Copper	ug/L	N/A	78	Rock Creek Mainstem Metals
Lead	ug/L (dissolved + particulate)	0.6	29	All of the metals TMDLs except the Rock Creek Mainstem Metals
Lead	ug/L	N/A	36	Rock Creek Mainstem Metals
Mercury	ug/L	N/A	0.19	Rock Creek Mainstem Metals

Table 1: Summary of EMCs Used in District TMDLs				
Pollutant	**Units**	**Baseflow EMC**	**Stormflow EMC**	**TMDLs**
Zinc	ug/L (dissolved + particulate)	7.5	173	All of the metals TMDLs except the Rock Creek Mainstem Metals
Zinc	ug/L	N/A	183	Rock Creek Mainstem Metals
Organics				
Chlordane	ug/L	0.000963	0.00983	DC Small Tributaries Model: all organics TMDLs except Potomac and Anacostia Tidal PCB TMDL
Heptachlor epoxide	ug/L	0.000641	0.000957	DC Small Tributaries Model: all organics TMDLs except Potomac and Anacostia Tidal PCB TMDL
PAH1	ug/L	0.0825	0.6585	DC Small Tributaries Model: all organics TMDLs except Potomac and Anacostia Tidal PCB TMDL
PAH2	ug/L	0.219	4.1595	DC Small Tributaries Model: all organics TMDLs except Potomac and Anacostia Tidal PCB TMDL
PAH3	ug/L	0.1065	2.682	DC Small Tributaries Model: all organics TMDLs except Potomac and Anacostia Tidal PCB TMDL
Dieldrin	ug/L	0.000641	0.00029	DC Small Tributaries Model: all organics TMDLs except Potomac and Anacostia Tidal PCB TMDL
DDD	ug/L	0.00462	0.003	DC Small Tributaries Model: all organics TMDLs except Potomac and Anacostia Tidal PCB TMDL
DDE	ug/L	0.00393	0.0133	DC Small Tributaries Model: all organics TMDLs except Potomac and Anacostia Tidal PCB TMDL
DDT	ug/L	0.01226	0.0342	DC Small Tributaries Model: all organics TMDLs except Potomac and Anacostia Tidal PCB TMDL
DDT (Watts Branch)	ug/L	0.00061	0.00171	DC Small Tributaries Model: all organics TMDLs except Potomac and Anacostia Tidal PCB TMDL
Total PCBs	ug/L	0.0115	0.0806	DC Small Tributaries Model: all organics TMDLs except Potomac and Anacostia Tidal PCB TMDL
Nutrients				
TN (winter)	mg/L	1.918	3.7	Anacostia Nutrients and BOD TMDL
TN (spring)	mg/L	1.418	3.7	Anacostia Nutrients and BOD TMDL
TN (summer)	mg/L	1.018	3.7	Anacostia Nutrients and BOD TMDL
TN (fall)	mg/L	1.318	3.7	Anacostia Nutrients and BOD TMDL

Table 1: Summary of EMCs Used in District TMDLs				
Pollutant	**Units**	**Baseflow EMC**	**Stormflow EMC**	**TMDLs**
TKN	mg/L	0.418	2.6	Anacostia Nutrients and BOD TMDL
NH4	mg/L	0.018	No Data	Anacostia Nutrients and BOD TMDL
NO3 (winter)	mg/L	1.5	1.1	Anacostia Nutrients and BOD TMDL
NO3 (spring)	mg/L	1.0	1.1	Anacostia Nutrients and BOD TMDL
NO3 (summer)	mg/L	0.6	1.1	Anacostia Nutrients and BOD TMDL
NO3 (fall)	mg/L	0.9	1.1	Anacostia Nutrients and BOD TMDL
Organic N	mg/L	0.4	No Data	Anacostia Nutrients and BOD TMDL
TP	mg/L	0.055	No Data	Anacostia Nutrients and BOD TMDL
Sediment				
TSS	mg/L	0 or 2	227	Anacostia TSS TMDL open channel tributaries
TSS	mg/L	0 or 2	94	Anacostia TSS TMDL closed channel sewersheds
TSS	mg/L	6	227	Anacostia TSS TMDL, Watts Branch
TSS	mg/L	No Data	227	Watts Branch TSS TMDL
TSS	mg/L	No Data	60 (after instream erosion was factored out)	Watts Branch TSS TMDL
TSS	mg/L	No Data	167 (instream erosion)	Watts Branch TSS TMDL
TSS	mg/L	No Data	34.67 (representative of the commercial, industrial, residential, and recreational land use activities)	Kingman Lake TSS, Oil & Grease, and BOD TMDL
TSS	mg/L	No Data	5.66 (grassed areas)	Kingman Lake TSS, Oil & Grease, and BOD TMDL

3.2 Review of Land Use-Based EMCs Reported in Literature

Different land use types have been shown to have significant variability in pollutant loads (Stein 2008). Many research institutions have conducted pollutant sampling of different land uses in order to establish land use-based EMCs (see Attachment 1). This research, along with the knowledge that the District of Columbia Office of the Chief Technology Officer (DC OCTO) has developed a very detailed GIS layer of land use and land cover (LULC) for the District, could provide a means to calculate pollutant loads for the MS4 area. This approach would be beneficial since it would identify areas in the city with higher pollutant load potential, which would in turn allow for targeted BMP implementation. A literature review was therefore undertaken to compile land use based EMC values for all of the pollutants which have a TMDL in the MS4 area. The following sections describe the methodology used to compile and analyze the EMCs reported in literature, as well as the results of the literature review.

3.2.a Methodology

The literature review was focused around the 23 pollutants for which DC has TMDLs. In addition, only land uses that are most predominant in the DC MS4 area (e.g.: residential, institutional), or land uses that potentially contribute a large proportion of a certain pollutant (e.g.: golf course, industrial) were targeted for the literature review. For non-conventional pollutants, such as organics, there was little information on EMCs by land use type, and published values were often lumped under the category "urban" land use, so urban was added to the list of land use categories to be researched. The full list of land uses is shown below.

- Commercial
- Forest
- Golf Course
- Highway
- Industrial
- Institutional
- Mixed Use
- Open
- Residential
- Residential, Low Density
- Residential, Medium Density
- Residential, High Density
- Residential, Multifamily
- Roadway
- Urban

The search method for the EMCs comprised of looking at keywords (e.g. EMC, event mean concentration, etc.). The sources of the literature consisted of peer-reviewed research papers and technical reports that were published by federal, state, or local agencies, or through scientific journals. The review was geographically comprehensive and includes data from international, national, and regional sources. Regional values included published data specific to DC, Virginia, and Maryland. Much of the regional data originates from local technical reports, watershed implementation plans (WIPs), and TMDL reports. To the extent possible, we attempted to find the original report and source data. An annotated bibliography is provided in Attachment 1. Both mean and median EMC values were compiled for further analysis.

3.2.b Results

For conventional pollutants, such as TSS, nutrients, and some metals, a significant amount of EMC data was found for all or most land use types. For some of the metals and all of the organics and toxics, very little EMC data was found by land use type. Table 2 provides a general overview of EMC data that was found for each pollutant and land use category.

After compiling the data into a spreadsheet, a statistical analysis of the data was undertaken to determine the min, Q1, median, Q3, and max values. The amount of data that was found for each land use and pollutant combination varied drastically. At least 10 data points per pollutant and land use combination were deemed necessary to conduct a meaningful statistical analysis. If there were not enough data points per land use and pollutant category, then similar land uses were lumped together into broader general land use category. For example, forest and open land uses were combined in some instances. After the compilation, nine land use categories were formed, including:

- Commercial
- Highway/Roadway
- Industrial
- Open/Forest
- Residential (total)
- Residential, Low Density
- Residential, Medium Density
- Residential, High Density
- Urban

The results of the statistical analysis are plotted using box and whisker plots and presented in Figures 1 through 11.

Table 2: EMC Data by Pollutant and Land Use Category

	TSS	TN	TP	BOD	FC	As	Cu	Pb	Hg	Zn	O&G	Chlordane	DDD	DDE	DDT	Dieldrin	Heptachlor Epoxide	PAH1	PAH2	PAH3	ΣPAH	TPCB
Commercial	x	x	x	x	x	x	x	x	x	x	x										x	
Forest	x	x	x	x	x		x	x		x												
Golf Course	x		x																			
Highway	x	x	x	x	x	x	x	x	x	x											x	
Industrial	x	x	x	x	x	x	x	x	x	x	x										x	
Institutional	x	x	x	x	x		x	x		x												
Mixed-Use	x	x	x	x			x	x		x												
Open	x	x	x	x	x		x	x		x											x	
Residential	x	x	x	x	x		x	x	x	x	x											
Residential, LD	x	x	x	x	x	x	x	x		x	x										x	
Residential, MD	x	x	x	x																		
Residential, HD	x	x	x	x	x		x	x		x	x										x	
Residential, Multifamily	x	x	x	x	x		x	x		x												
Roadway	x	x	x	x	x		x	x		x												
Urban	x		x	x	x	x	x	x	x	x	x	x	x	x	x		x				x	

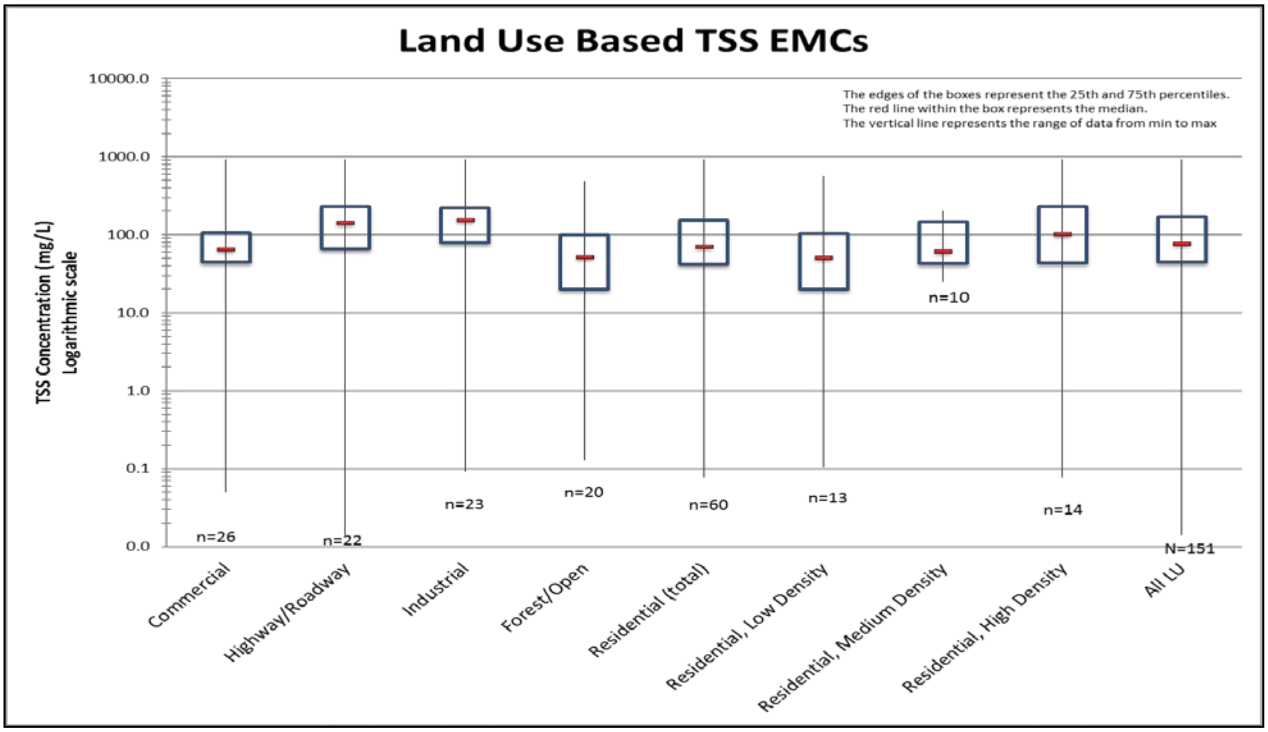

Figure 1: Land Use Based TSS EMCs

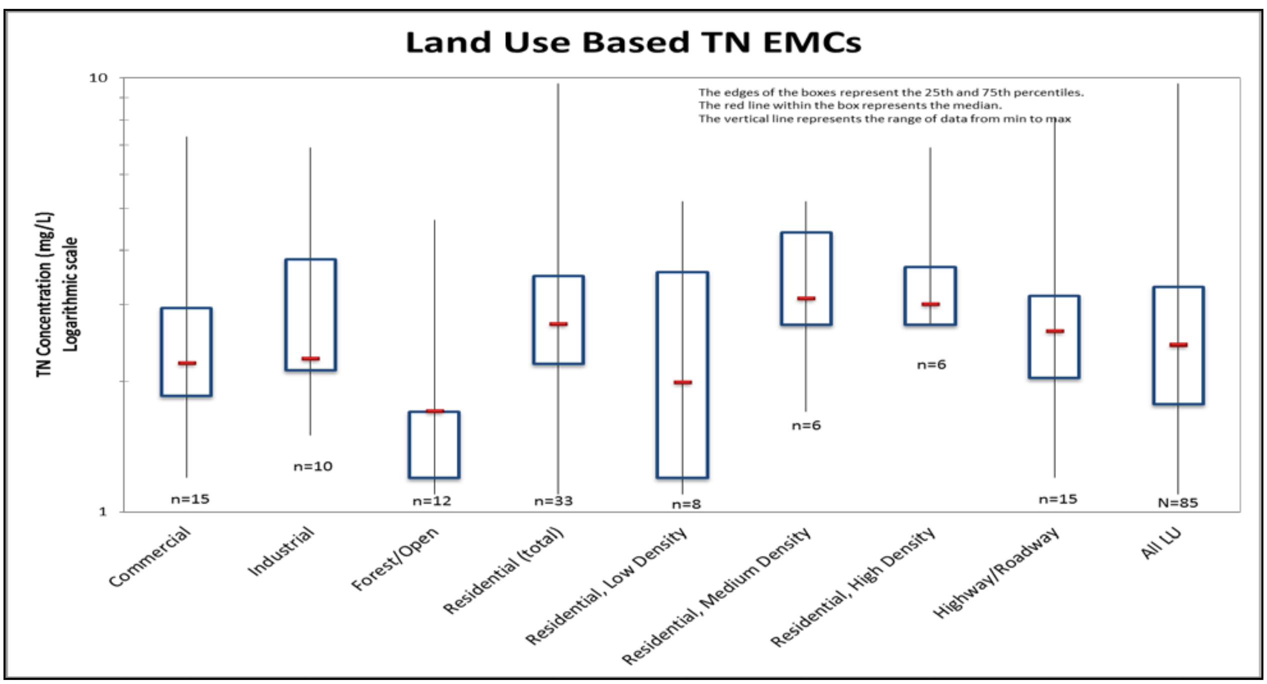

Figure 2: Figure Land Use Based TN EMCs

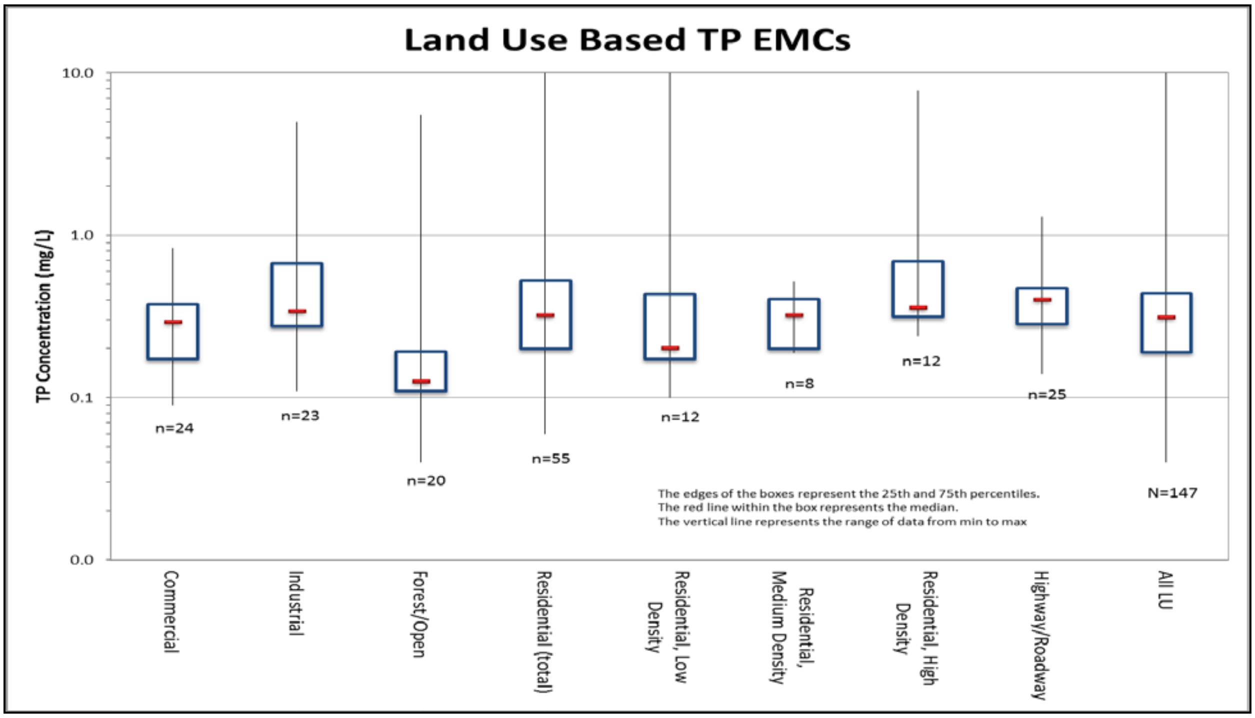

Figure 3: Land Use Based TP EMCs

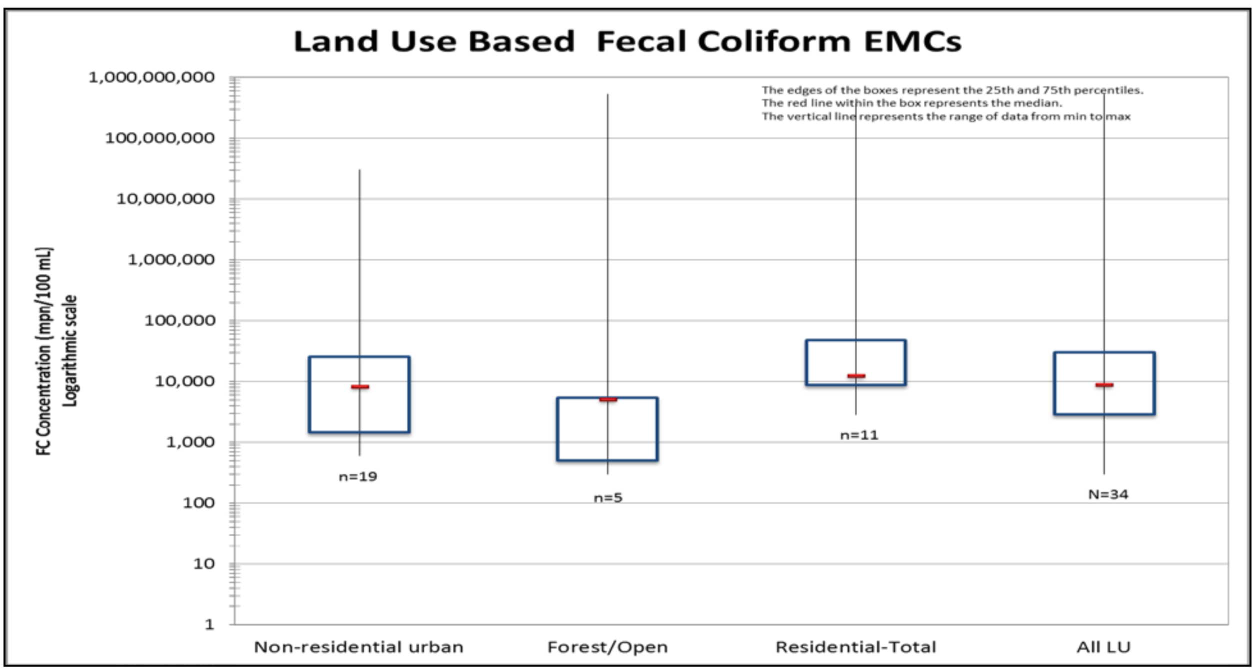

Figure 4: Land Use Based Fecal Coliform EMCs

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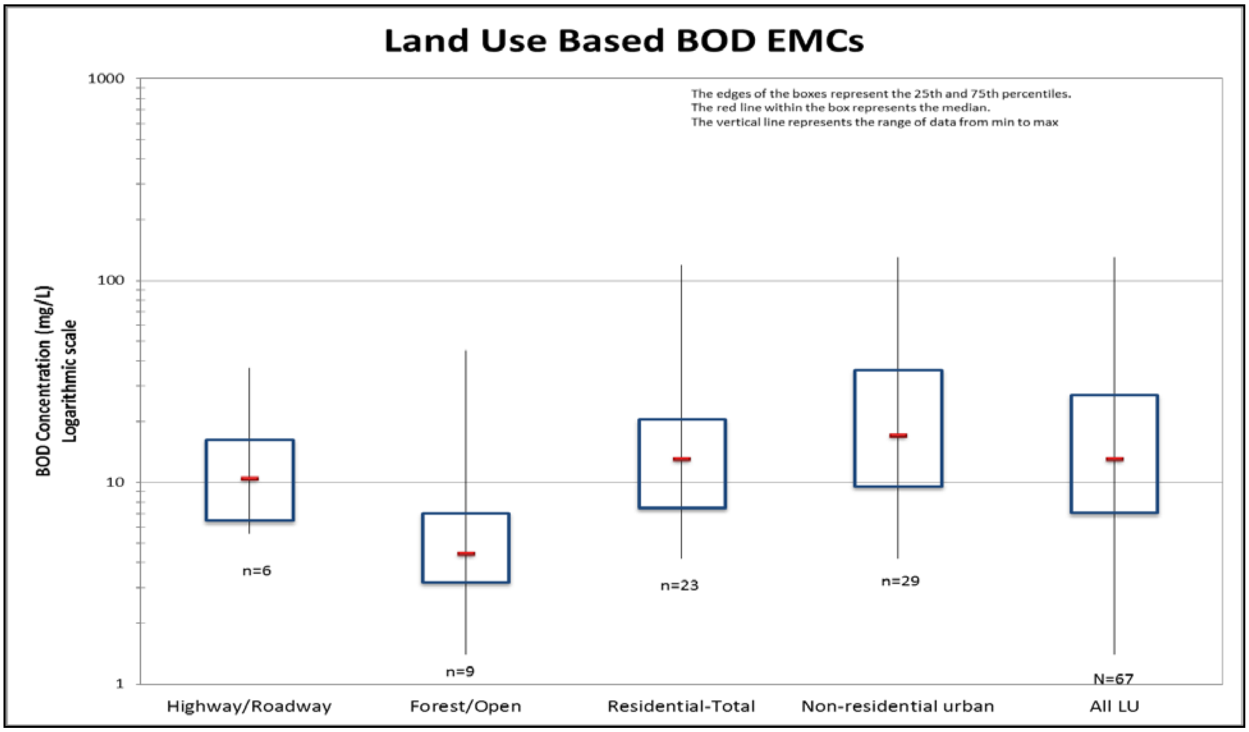

Figure 5: Land Use Based BOD EMCs

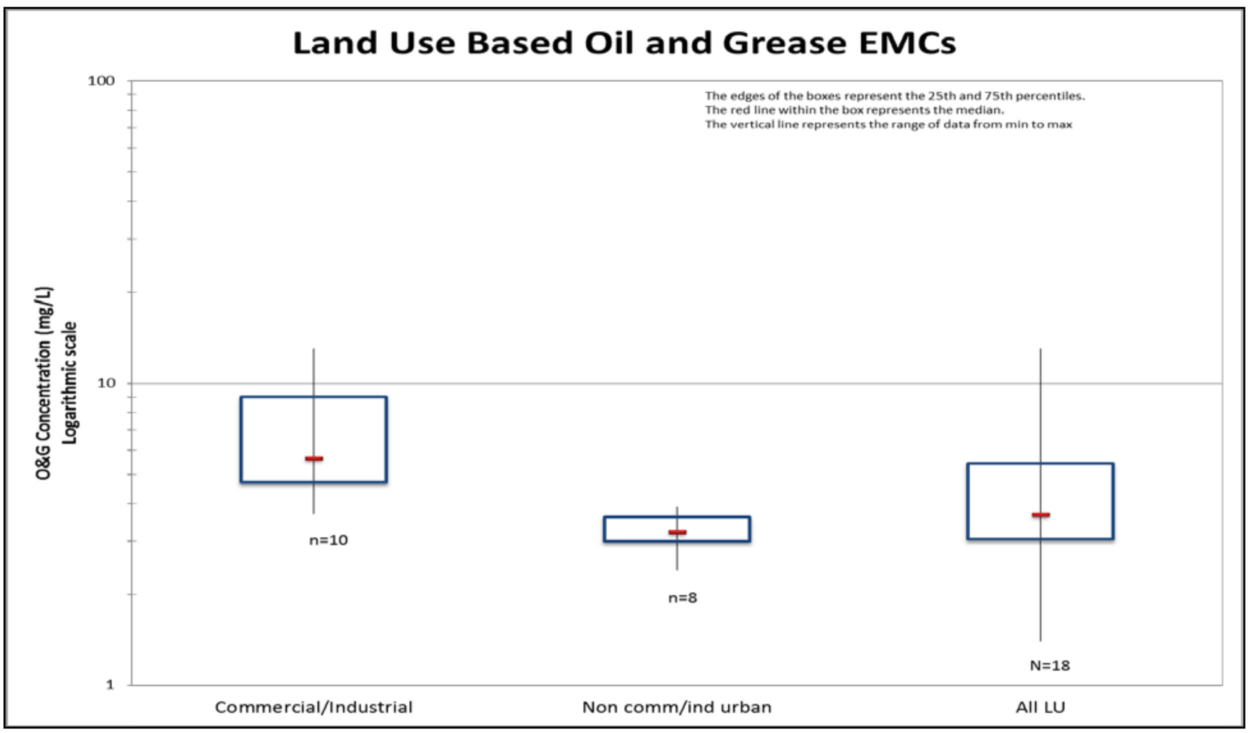

Figure 6: Land Use Based Oil and Grease EMCs

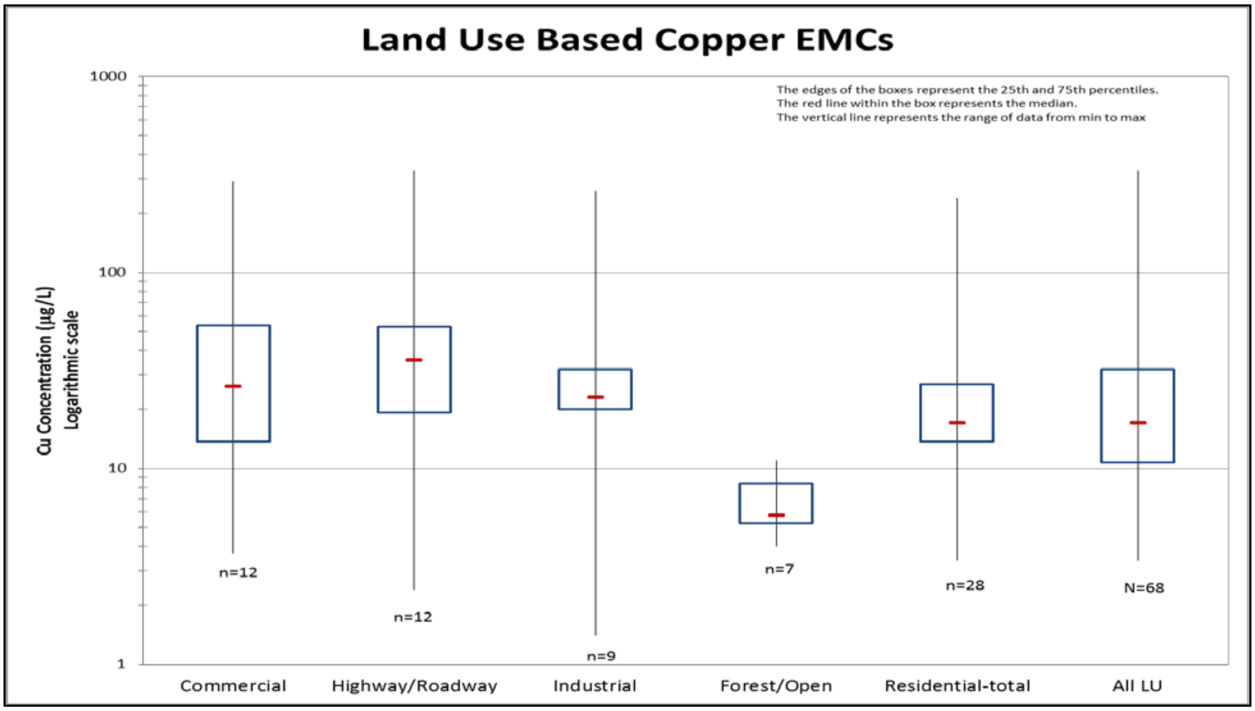

Figure 7: Land Use Based Copper EMCs

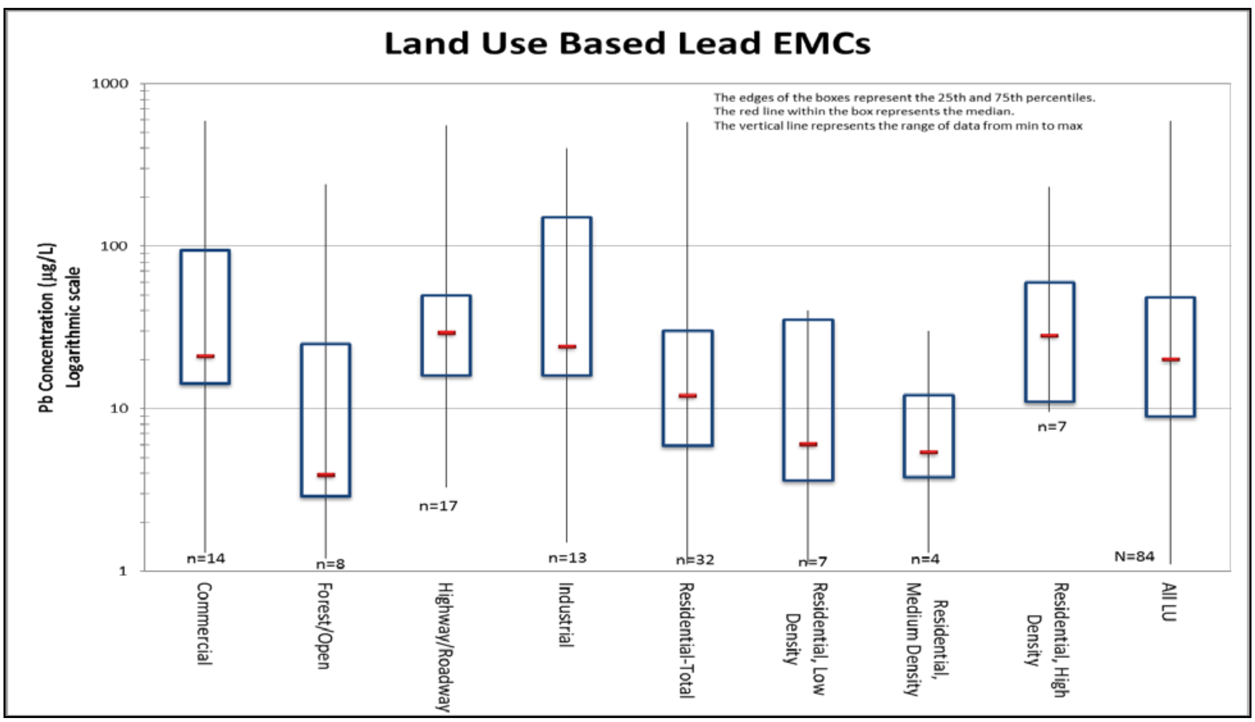

Figure 8: Land Use Based Lead EMCs

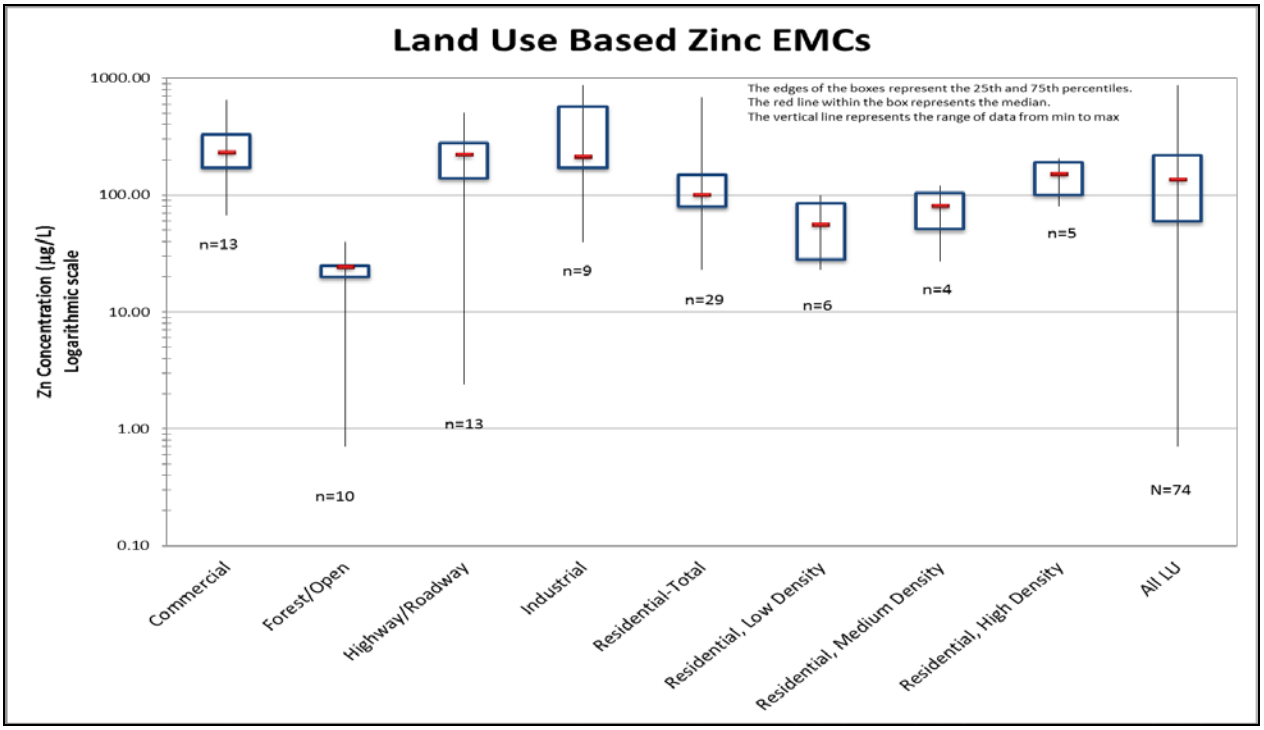

Figure 9: Land Use Based Zinc EMCs

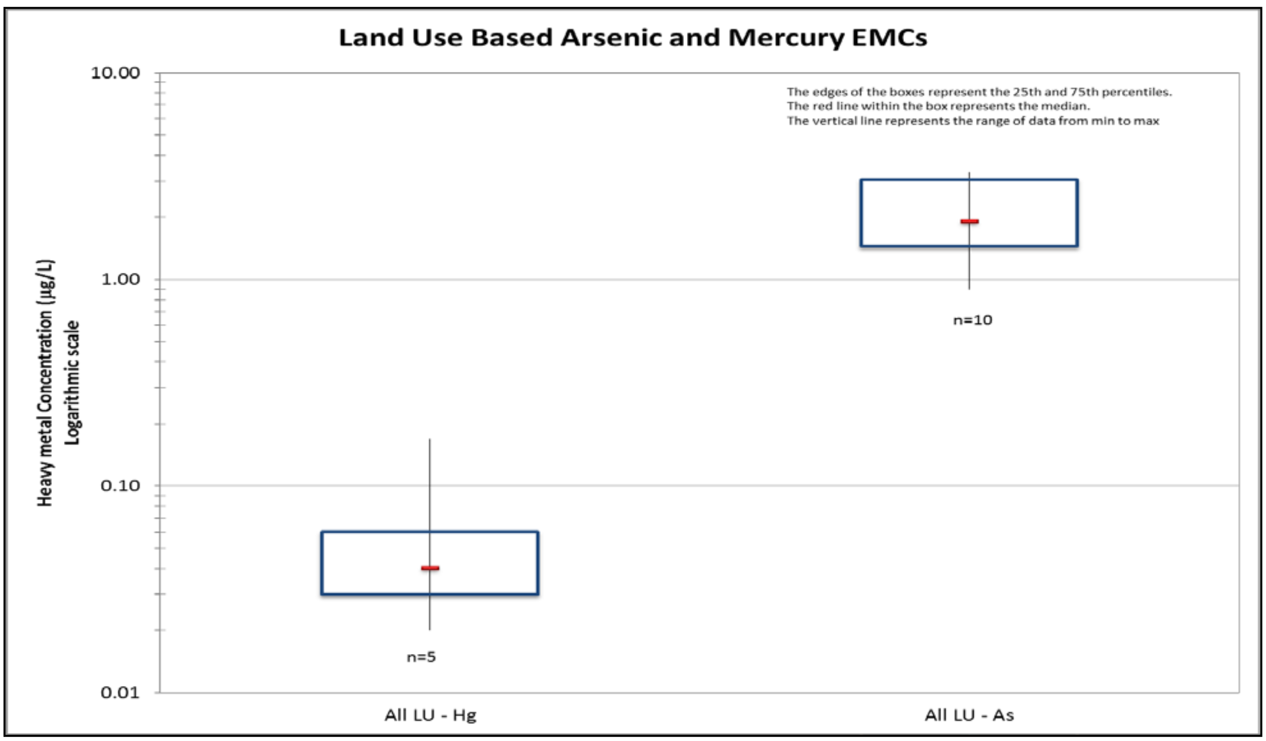

Figure 10: Land Use Based Arsenic and Mercury EMCs

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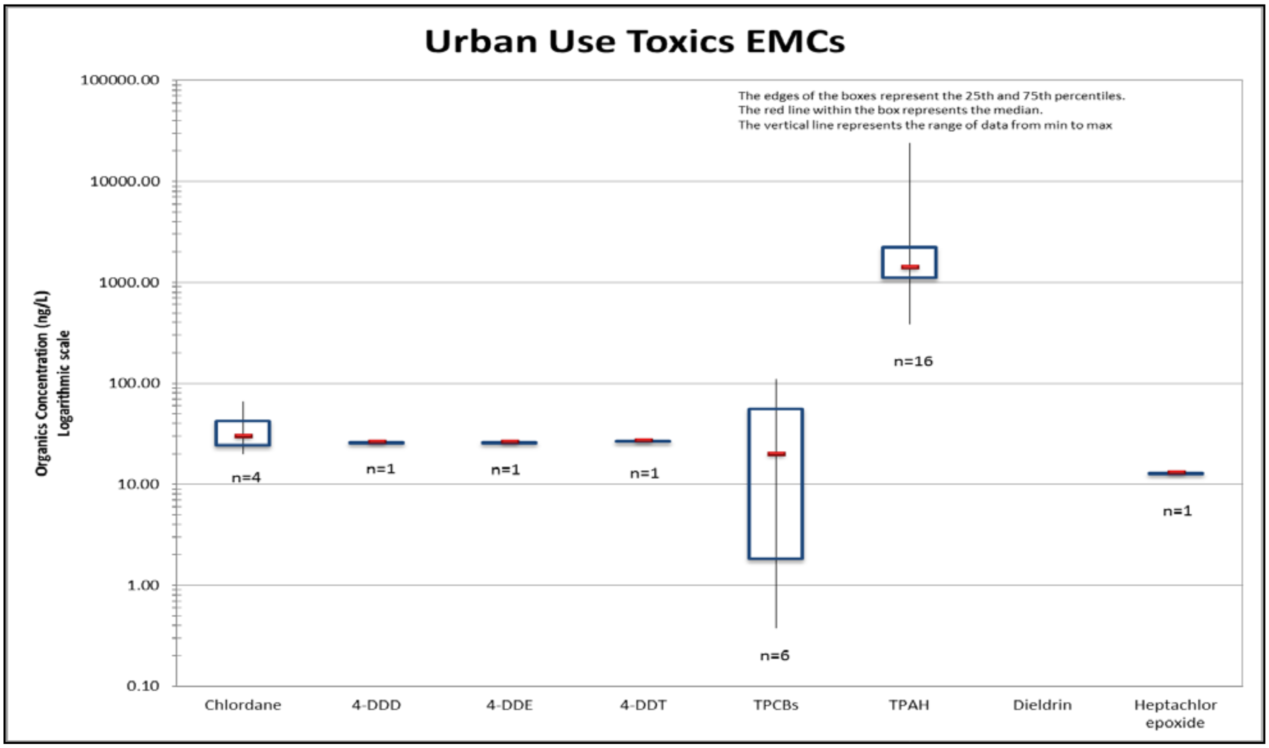

Figure 11: Urban Use Toxics EMCs

3.3 Evaluation of District MS4 Outfall Monitoring Data to Develop EMCs

3.3.a MS4 Monitoring Background

The District has been implementing wet weather monitoring programs in association with its municipal separate storm sewer (MS4) permit since 2000 when its first permit was issued. Within each watershed, DDOE has selected outfalls that are representative of the MS4. The outfall monitoring stations used since 2000 are shown in Table 3 and Figures 1-12 below. The District's 2004 MS4 permit established a rotating schedule for monitoring wet weather discharges to the Anacostia River, Rock Creek, and the Potomac River. Monitoring each year occurs only in one of the watersheds so that each watershed is monitored once every three years. Three wet events are sampled at all locations for the designated watershed each year. Storm events are chosen given the following criteria: at least 0.1 inch of precipitation, 72 hours since the last storm, and one month since the last collection at a specific site. From 2000 through 2011, samples were collected by grab method, except for those that could be analyzed in the field. From 2012 and on, time-composite samples were collected, except for those that could be analyzed in the field.

Table 3: Stormwater Outfall Monitoring Locations, 2000-2012 (Source: EDC 2006)
A. Anacostia River Sub Watershed Monitoring Sites
1. Stickfoot Sewer (Suitland Parkway)-2400 block of Martin Luther King, Jr. Ave., SE, near Metro bus entrance.
2. O St. Storm Water Pump Station - 125 O St., 125 O SE-just outside front gate at O St. Pump Station
3. Anacostia High School/Anacostia Recreation Center - corner of 17th St. and Minnesota Ave. SE
4. Gallatin & 14th St., NE-across from the intersection of 14th St. and Gallatin St. in a large outfall
5. Varnum and 19th Place,NE-2100 Block of Varnum St.
6. Nash Run-intersection of Anacostia Drive and Polk St., NE
7. East Capitol St.-200 Block of Oklahoma Ave., NE
8. Ft. Lincoln-Newtown BMP-in the brush along the side of New York Ave. West (coming into city) after the bridge
9. Hickey run-33rd and V Streets, NE
B. Rock Creek Subwatershed Monitoring Sites
1. Walter Reed (Fort Stevens Drive)
2. Military Road and Beach Drive
3. Soapstone Creek (Connecticut Avenue and Albemarle Street)
4. Melvin Hazen Valley Branch (Melvin Hazen Park and Quebec Street)
5. Klingle Valley Creek (Devonshire Place and 30th Street)
6. Normanstone Creek (Normanstone Drive and Normanstone Parkway)
7. Portal Dr. and 16th St.
8. Broad Branch
9. Oregon and Pinehurst
C. Potomac River Subwatershed Monitoring Sites
1. Battery Kemble Creek-49th and Hawthorne Streets, NW
2. Foundary Branch-at Van Ness and Upton Streets, NW in the park
3. Dalecarlia Tributary-Van Ness Street and Dalecarlia Parkway
4. Oxon Run-Mississippi Avenue and 15th Street, SE
5. Tidal Basin-17th Street and Constitution Avenue, NW
6. Washington Ship Channel-Washington Marina parking lot, SW
7. C and O Canal-Potomac Avenue and Foxhall Road, NW
8. Archbold Parkway

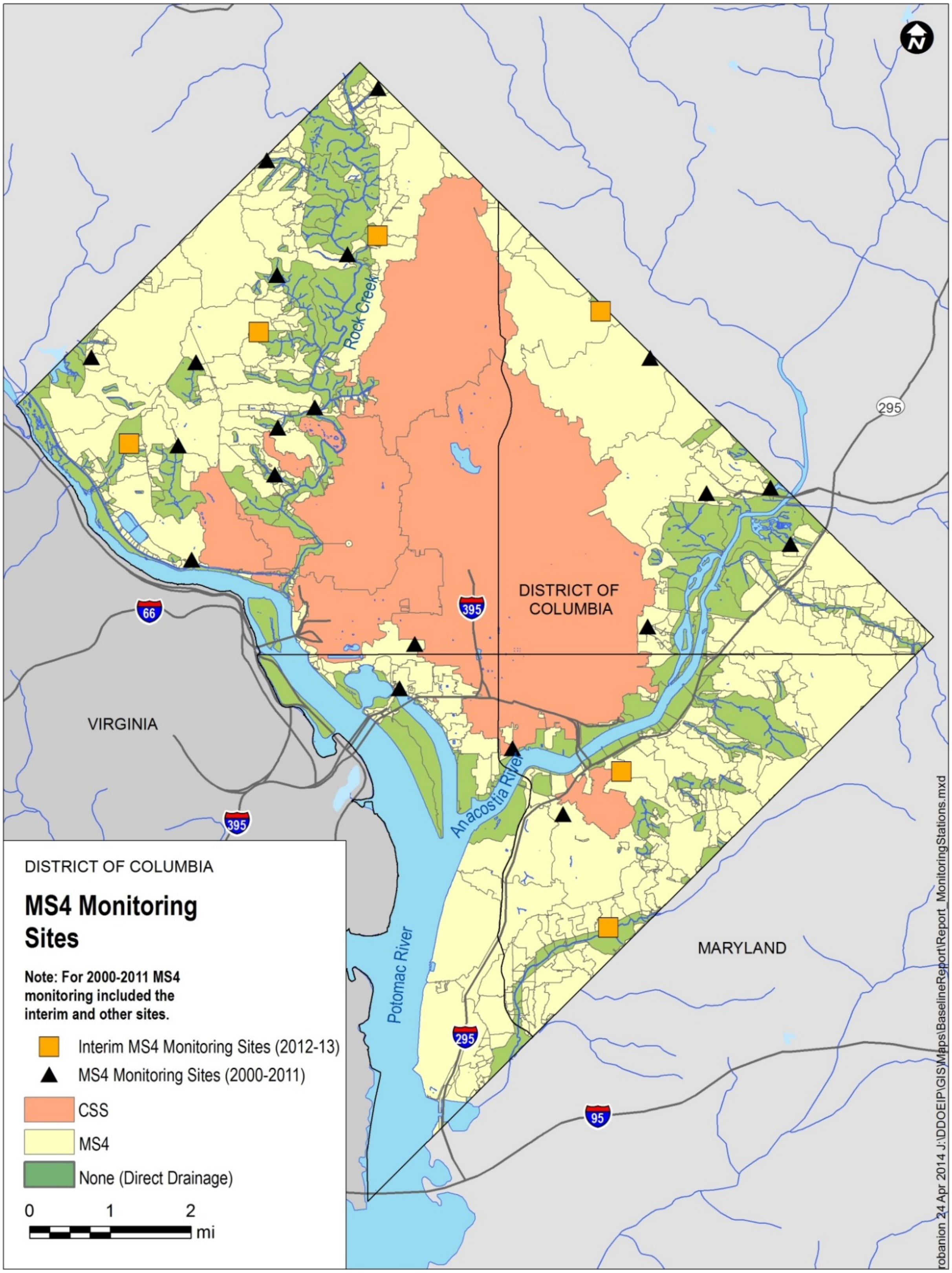

Figure 12: MS4 Monitoring Station 2000-2013

Table 4 shows the list of parameters that were analyzed from 2000 through 2011. Analytical methods and hold times are provided in Table 5.

Table 4: Parameters Analyzed Outfall Discharge Monitoring Samples, 2000-2011 (Source: Apex Companies 2012)

Grab Samples		Field Analysis
• VOCs	• SVOCs	• Residual Chlorine
• Cyanide	• Pesticides and PCBs	• Dissolved Oxygen
• Total Phenols	• Metals	• pH
• Oil & Grease	• Nutrients	• Temperature
• Fecal Coliform	• BOD5, Chlorophyll a	• Flow
• Fecal Streptococcus	• TSS, TDS, Hardness, TOC	
• E-Coli	• Dioxin	

Table 5: Analytical Methods and Hold Times for MS4 Monitoring 2004-2011 (Source: EDC 2006)

Parameters	Analytical Method	Hold Times
BOD5	EPA 405.1	
Chlorophyll a	Chlorophyll-a	
COD	EPA 410.4	
Dioxin	EPA 8280	
Dissolved Oxygen, pH, Temperature, Flow, Hardness	Field	
Dissolved phosphorus	SM 18 4500 P B + E	
Fecal Coliform	SM 18 9221 E	
Fecal streptococcus	SM 18 9230 B	
Mercury	EPA 245.1	
Metals, Cyanide and Phenols	EPA 200.8	
Nitrite plus nitrate	EPA 353.2	
Oil & Grease	EPA 1664 A	
Pesticides and PCBs	EPA 608	
Residual Chlorine		
SVOCs	EPA 625	
TKN, or total ammonia plus organic nitrogen	EPA 351.3	
Total dissolved solid	EPA 160.1	
Total phosphorus	EPA 160.1	7 days
TSS	EPA 160.2	7 days
VOCs	EPA 624	14 days

Starting in 2012, the wet weather discharge monitoring was implemented in a slightly revised format (the interim program) based on the revised MS4 permit (finalized in 2012). For the interim program, the sampling protocols changed to include time-composited samples for certain parameters (see Table 7 or which parameters are collected by each method) and the number of stations monitored was reduced to 2 per watershed (to be monitored each year) for efficiency's sake while a new monitoring program is being developed (Tables 6 and-7). Composite samples are taken every 15 minutes from the outfall discharge by automatic samplers equipped with 2.5 gallon glass jars supplied by the analytical laboratory. Grab samples are taken by field staff downstream of the outfall with laboratory-provided collection containers appropriate to the parameter being analyzed. Samples are preserved and packaged according to laboratory instructions and delivered to the lab within approximately 90 minutes of collection. Analytical methods are provided in Table 8.

Table 6: Required Interim Monitoring Stations (Source Table 5, MS4 Permit)
A. Anacostia River Sub Watershed Monitoring Sites
1. Gallatin Street & 14th Street N.E. across from the intersection of 14th St. and Gallatin St. in an outfall (MS-2)
2. Anacostia High School/Anacostia Recreation Center – Corner of 17th St and Minnesota Ave SE
B. Rock Creek Subwatershed Monitoring Sites
1. Walter Reed -- Fort Stevens Drive -- 16th Street and Fort Stevens Road, N.W. at an outfall (MS-6)
2. Soapstone Creek -- Connecticut Avenue and Albemarle Street N.W. at an outfall (MS-5)
C. Potomac River Subwatershed Monitoring Sites
1. Battery Kemble Creek-49th and Hawthorne Streets, N.W. at an outfall (MS-4)
2. Oxon Run-Mississippi Avenue and 15th Street, S.E. into Oxon Run via an outfall (MS-1)

Table 7: Parameters Analyzed in Outfall Discharge Monitoring Samples, 2012-2013 (Source: Apex 2012)		
GRAB SAMPLES	**COMPOSITE SAMPLES**	**FIELD ANALYSIS**
VOCs	SVOCs	Residual Chlorine
Cyanide	Pesticides/PCBs	Dissolved Oxygen
Coliform	Metals (As, Cu, Cr, Cd, Ni, Pb, Zn)	pH
E. coli, Fecal Coliform, Fecal Streptococcus	Nutrients	Temperature
Oil and Grease	BOD5, Chlorophyll a, COD	Flow
Total Phenols	TSS, TDS, Hardness, TOC	
	Dioxin	

Table 8: Wet Weather MS4 Sampling Analytical Methods and Hold Times (Source: Apex 2012)		
Parameters ***(to be Analyzed in Wet Weather Samples)***	**Method**	**Holding Times**
E. coli	SM (20) 9221E	6 hours
Total nitrogen	SM (20) 4500-NO3 E + SM 4500orgN	28 days
Total phosphorus	EPA 365.1	28 days
Total Suspended Solids	SM (2) 2540D	7 days

Table 8: Wet Weather MS4 Sampling Analytical Methods and Hold Times (Source: Apex 2012)		
Parameters **(*to be Analyzed in Wet Weather Samples*)**	**Method**	**Holding Times**
Cadmium	EPA 200.7	180 days
Copper	EPA 200.7	180 days
Lead	EPA 200.7	180 days
Zinc	EPA 200.7	180 days
pH	SM (20) 4500 H B	15 minutes
Fecal coliform	SM (20) 9221 E	6 hours
Dissolved Oxygen	SM (20) 4500 O-G	1 day
Hardness	SM (20) 2340 C	28 days
Chlorophyll a	SM 10200H	2 day s
Temperature	Field	Instant

Section 5.1 of DDOE's revised MS4 permit (first issued in 2011 and modified in 2012) includes the requirement to design a revised monitoring program. The permit requires a small set of parameters to be monitored (Table 9). The monitoring sites and protocols are currently in development (to be completed in 2015).

Table 9: Parameters to be Monitored for Outfall Discharge as Part of Revised Program, 2015 (Source: MS4 Permit, Table 4)		
E. coli	Lead	Total Suspended Solids
Total nitrogen	Zinc	Arsenic
Total phosphorus	Trash	Copper

3.3.b Methodology

Data from various documents and spreadsheets provided by DDOE was consolidated into a database of all available MS4 monitoring data 2001-13. The following quality control actions were taken with the data before analysis. First, all dry weather data and fecal coliform samples qualified with ">" were removed. When units of the minimum detection limit (MDL) and the result did not match, both units were checked the original sources and corrected. Those samples marked as non-detects ("ND") or below quantification limit ("BQL") were estimated to be one half the detection limit for analysis. The interquartile range (IQR) was established as the difference between the upper (Q3) and lower (Q1) values for each parameter, where

$$IQR = Q3 - Q1$$

Using the Interquartile Rule for the determination of outliers, outliers were identified as data values that are greater than Q3 + (3.0 * IQR). This analysis was applied o data sets that had sufficient data (i.e., data sets that did not contain large numbers of non-detects [NDs]), including conventional pollutants and all metals except mercury, most metals to identify outliers.

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3.3.c Results

Available wet weather data for the years 2001-2013 were analyzed for minimum, maximum, average, median, number of samples and number of non-detects (NDs) on a city-wide (Table 10) and watershed basis (Table 11). The following parameters had such a large number of NDs that they are excluded from this analysis due to lack of meaningful data: mercury, PAHs, PCBs, chlordane, dieldrin, DDT isomers, and heptachlor epoxide.

Table 10: Summary Statistics for Wet Weather MS4 Monitoring Data, City-Wide 2001-2013

	TSS	TN	TP	Fecal Coliform	BOD	Oil and Grease	Arsenic	Copper	Lead	Zinc
Units	mg/l	mg/l	mg/l	MPN/ 100ml	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Min	0.50	0.003	0.03	8.00	1.00	1.25	0.00013	0.00050	0.00012	0.00075
Max	290	11	1.2	92,000	120	13	0.01	0.23	0.07	0.34
Average	58.94	3.32	0.38	13,639	28.34	3.72	0.002	0.05	0.02	0.11
Median	42.5	3.1	0.33	4,600	18.5	2.5	0.001	0.04	0.012	0.0985
n	190	194	198	115	184	149	158	203	191	216
# NDs	5	18	0	1	13	103	109	7	11	7

Table 11: Summary Statistics for Wet Weather MS4 Outfall Monitoring Data by Watershed, 2001-2013

	TSS	TN	TP	Fecal Coliform	BOD	Oil and Grease	Arsenic	Copper	Lead	Zinc
Units	mg/l	mg/l	mg/l	MPN/ 100ml	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Anacostia River Watershed										
Min	8	0.0025	0.025	33	1	1.25	0.000302	0.0005	0.00012	0.0055
Max	290	9.1	1.2	90,000	110	11	0.0048	0.19	0.067	0.29
Average	73.33	3.39	0.42	12,512	35.93	3.65	0.002	0.04	0.02	0.12
Median	60	3.344	0.39	4,600	24.5	2.5	0.001	0.032	0.013	0.12
n	73	80	81	44	50	53	68	84	83	89
# NDs	0	8	0	0	1	38	45	3	2	0
Rock Creek Watershed										
Min	1	0.5	0.076	22	1	2.5	0.001	0.001	0.001	0.01
Max	210	11	1.05	90,000	100	12	0.0054	0.13	0.072	0.294
Average	59.50	3.24	0.33	16,295	23.67	4.15	0.00	0.05	0.02	0.10
Median	52	3.265	0.32	6,500	16.5	2.5	0.001	0.043	0.013	0.089
n	53	50	54	42	48	48	50	60	57	60
# NDs	2	4	0	1	9	30	38	1	3	4

Table 11: Summary Statistics for Wet Weather MS4 Outfall Monitoring Data by Watershed, 2001-2013										
	TSS	TN	TP	Fecal Coliform	BOD	Oil and Grease	Arsenic	Copper	Lead	Zinc
Units	mg/l	mg/l	mg/l	MPN/ 100ml	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Potomac River Watershed										
Min	0.5	0.0025	0.039	8	1	1.25	0.000125	0.00075	0.000115	0.00075
Max	220	9.7	1.06	92,000	120	13	0.004	0.234	0.062	0.344
Average	42.06	3.28	0.37	11,503	28.08	3.35	0.00	0.07	0.01	0.10
Median	33	2.8	0.3	3,000	16.5	2.5	0.001	0.05	0.011	0.083
n	64	64	63	29	40	48	40	59	51	67
# NDs	3	6	0	0	3	35	26	3	6	3

4 Results and Discussion

The review of EMCs in the previous section illustrates the complexity of EMC assignment. In particular,

- There are extremely broad differences in the EMCs used to establish TMDLs in the District, but these reasons for these differences may have as much to do with the data and sources used to develop the original EMCs as with actual differences in waterbody EMCs for different pollutants.
- The national and regional body of literature on EMCs is rich but highly variable with regard to land use classes, and relating these studies to local circumstances in the District is not straightforward.
- District MS4 outfall monitoring data offer some promise because the data are local and recent, and because the number of wet weather observations is fairly large for most of the parameters of interest.

Based upon this review it was determined that further analyses were needed before specific EMCs could be recommended. One analysis addressed the appropriateness of using land use-based EMCs in the District (Analysis 1). The second analysis addressed the adequacy of the District MS4 outfall monitoring data to support the derivation of EMCs (Analysis 2). A third analysis (an offshoot of Analysis 2) was undertaken to assess development of watershed based EMCs with District MS4 outfall monitoring data (Analysis 3).

The details of these three analyses are described in the following sub-sections. Conclusions and recommended EMCs are discussed and presented at the end of the section.

4.1 Analysis 1, Evaluation of Land Use-Based EMCs

The first analysis was to determine if the land use based EMCs from the literature could be used to predict the monitored EMCs. In other words, are the land use based EMCs from the literature, which are based on nationwide data, appropriate to characterize the site specific conditions of the District? If the analysis is favorable, then the land use-based EMC values could be used with a high degree of confidence to represent local pollutant load conditions.

To do this analysis, a subset of the monitored data was used and average EMCs were calculated for each pollutant of concern. The subset of District outfall monitoring data selected included the EMC data provided by the 2009 Stormwater Management Plan (DDOE, 2009), and the EMC data provided by the *Study Memorandum LTCP 5-8 (Final), CSS and SSWS Event Mean Concentrations* (DC Water, October 2001). The reason this subset of data was selected is because it was, at the time of the analysis, readily available in a useable format, and provided a good selection of monitoring sites across the MS4 area. A total of 16 sites were included in this subset of data, and each site was sampled during 3 to 5 storms over the course of a year. The drainage area of each site was delineated and the land use types within the drainage areas were defined using the 2005 DC OCTO existing land use GIS layer (DC OCTO, 2005). Then the land use based EMCs were applied and an overall area-weighted land use based EMC was calculated for each site. This calculated value was subsequently compared to the monitored value. The full table of comparison for each pollutant is available in Attachment 2. The results of this analysis showed that:

1. Not enough land use based EMC data exists in the literature for the organics and some of the metals to make land use based EMC predictions.
2. The calculated EMC values using the average values per land use type identified from the literature were, in most cases, lower than the monitored value. As a consequence, the average literature values were increased for each land use type by anywhere from 10% to 400% in order to produce a larger area-weighted land use based EMC value that was more aligned with the monitored value. Note that, even after increasing the average value of the individual land use based EMCs, the increased values were still within the observed ranges reported by the literature for each land use type.
3. Even after adjusting the average land use based values, it was practically impossible to match the monitored values in all locations. Only when comparing the calculated and monitored average and median EMC values for all the sites combined did the calculated values more closely match the monitored values. But on a site by site basis, the calculated EMCs would sometimes over-predict, and at other times under-predict the monitored values. No obvious trends in the data were observed on a site by site basis.
4. The monitored EMCs seem to be dependent on more than just land use, as watersheds with similar land use types do not always have similar EMC values. This is apparent in the results table shown in Attachment 2. Other factors that may affect EMC values include rain intensity, anthropogenic activities such as construction, the sampling protocol used, and other watershed characteristics such as slope.
5. The variability in the predictions did not provide the level of confidence needed to move forward with using the land use based EMC values.

4.2 Analysis 2, Updated EMCs from MS4 Monitoring Data

The second analysis that was undertaken was to determine if sufficient monitored EMC data exists to calculate EMC values for all of the TMDL pollutants. An additional line of inquiry was to compare the average monitored EMCs to the EMCs used to develop the TMDLs. The full table of comparison is available in Attachment 3. The results of this analysis showed that:

1. Sufficient monitoring data exists only for sediment, nitrogen, phosphorus, BOD, bacteria, oil and grease, arsenic, copper, lead, and zinc. For all other pollutants, many non-detects were found in the data, and this precluded any sort of meaningful interpretation of the monitoring data.
2. The EMCs for pollutants with sufficient data show that they are generally within the same range as the EMCs used to develop the TMDLs, but are typically slightly lower than the mainstem EMCs and slightly higher than the tributary and Chesapeake Bay EMCs.

4.3 Analysis 3, Evaluation of Watershed EMCs

Statistical analysis was undertaken to determine whether city-wide or watershed specific EMCs should be used for further modeling. The MS4 outfall monitoring data was grouped according to monitoring station location in either the Anacostia, Potomac or Rock Creek watershed. Standard EMC summary statistics and median values were calculated for each watershed. Analysis of variance (ANOVA) was used to examine differences in data collected in the three different watersheds. ANOVA is a standard statistical method used to test differences between two or more means (in this case EMCs) (See Attachment 4 for a summary of the ANOVA analysis). The relevant statistics and results are summarized in Table 12. These results show that a significant difference in EMCs at the watershed level was determined for four parameters: BOD, Oil & Grease, TSS and Zinc. Significance differences at the 0.05 level or lower mean that there is >95% confidence that the watershed EMCs are truly different and that this difference is not due to chance. No significant difference was found at the watershed level for the other parameters.

Table 12: Summary of ANOVA Analysis

Parameter	Transformation[1]	F-Statistic	Pr (>F)	Result
Arsenic	N/A	N/A	N/A	No Difference
Biological Oxygen Demand	Log	3.426	0.03463	Significant Difference at the 0.05 Level
Copper	Log	1.895	0.1530	No Difference
Fecal Coliform	Log	1.259	0.2878	No Difference
Lead	N/A	N/A	N/A	No Difference
Nitrogen	0.5454	0.036	0.9641	No Difference
Oil & Grease	-0.5858	4.379	0.0142	Significant Difference at the 0.05 Level
Phosphorus	0.3434	1.681	0.1889	No Difference
Total Suspended Solids	Log	6.315	0.0022	Significant Difference at the 0.01 Level
Zinc	0.4646	3.804	0.0238	Significant Difference at the 0.05 Level

[1] Numbers (ex. λ=0.5454) indicate a power transformation identified through a Box-Cox transformation analysis. N/A indicates that no suitable transformation for normality was identified and best professional judgment was used for difference analysis.

4.4 Conclusion

The results of the three analyses demonstrated that:

- Literature-derived land use-based EMCs cannot consistently predict EMCs from the monitoring data.
- District MS4 outfall monitoring data offered promise as a way to establish EMCs for conventional pollutants and metals. The average concentration of the pooled MS4 outfall monitoring data compared very well with the EMCs used in District TMDL studies.
- The District MS4 outfall monitoring data can be used to develop EMCs for TSS, nutrients, and some metals. For all other pollutants, insufficient monitoring data exists to develop EMCs.

- For some parameters for which updated EMCs can be developed from MS4 monitoring data, the monitoring data is sufficient to develop EMCs at the watershed/basin level (i.e., Anacostia, Rock Creek, and Potomac watersheds). For other parameters, updated EMCs can only be calculated at the District scale.

4.5 **Recommended EMCs**

An updated set of EMCs is recommended following a detailed review and analysis of:

- EMCs used to develop TMDLs in the District;
- EMCs reported in literature for various land use classes; and
- District MS4 outfall monitoring data.

The recommendation for organic compounds, arsenic and mercury is to use the original EMCs applied to develop TMDLs in the District. The recommendation for conventional pollutants and the other metals is to use average EMCs derived from the MS4 outfall monitoring data, with watershed-based EMCs for BOD, Oil & Grease, TSS and Zinc.

A summary of the recommended EMCs to be applied in the IP Modeling Tool is presented in Table 13.

Table 13: Recommended EMCs

Pollutant	Units	EMC Value	Source of EMC
TN	mg/l	3.32	From monitoring data
TP	mg/l	0.38	From monitoring data
TSS (Anacostia)	mg/l	73	From monitoring data
TSS (Rock Creek)	mg/l	60	From monitoring data
TSS (Potomac)	mg/l	42	From monitoring data
FC	MPN/100ml	13,639	From monitoring data
E. coli	MPN/100ml	5,474	From DC bacteria translator
BOD (Anacostia)	mg/l	35.93	From monitoring data
BOD (Rock Creek)	mg/l	23.67	From monitoring data
BOD (Potomac)	mg/l	28.08	From monitoring data
Oil&Grease (Anacostia)	mg/l	3.65	From monitoring data
Oil&Grease (Rock Creek)	mg/l	4.15	From monitoring data
Oil&Grease (Potomac)	mg/l	3.35	From monitoring data
Arsenic	ug/l	1.54	From monitoring data
Copper	ug/l	52.88	From monitoring data
Lead	ug/l	15.94	From monitoring data
Mercury	ug/l	0.19	From TMDL
Zinc (Anacostia)	ug/l	120.92	From monitoring data
Zinc (Rock Creek)	ug/l	101.73	From monitoring data
Zinc (Potomac)	ug/l	100.90	From monitoring data

Table 13: Recommended EMCs			
Pollutant	**Units**	**EMC Value**	**Source of EMC**
Chlordane	ug/l	0.00983	From TMDL
DDD	ug/l	0.003	From TMDL
DDE	ug/l	0.0133	From TMDL
DDT	ug/l	0.0342	From TMDL
Dieldrin	ug/l	0.00029	From TMDL
Heptachlor Epoxide	ug/l	0.000957	From TMDL
PAH1	ug/l	0.6585	From TMDL
PAH2	ug/l	4.1595	From TMDL
PAH3	ug/l	2.682	From TMDL
TPCB	ug/l	0.0806	From TMDL

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Attachment 1: Annotated Bibliography

Annotated Bibliography of the Land use Based EMC Literature Review

Currier, P., SB 1295 Stormwater Commission on Event Mean Concentration and Land Use; April 6, 2009

Summary: This brief report specifically discusses the event mean concentrations by varying land use. Data was collected from the Houston, TX area. Land uses consisted of residential, commercial, mixed urban, agricultural/pastures and herbaceous/open land. For this study, the focus is on urban areas and not rural areas. Parameters reviewed were total suspended solids (TSS), biological oxygen demand (BOD), total nitrogen (TN) and total phosphorus (TP). Fecal coliform was discussed on a national scale with another diagram showing the high fecal coliform count in urban areas. EMC values were calculated for the different land uses and were ranked in order from lowest to highest concentration. For TSS, the highest concentration rank was in the industrial land use and the lowest was in the water/wetland land use area. For TP, the highest concentration was in the medium density residential area and the lowest concentration was the water/wetland land use area. Total nitrogen had the highest concentration in agricultural/pasture and zinc had the highest concentrations in the industrial land use.

Flint, K., Water Quality Characteristics of Highway Stormwater Run-off from an Ultra-Urban Area, Thesis, University of Maryland-College Park, 2004

Summary: This is a thesis paper on water quality characterization of urban highway stormwater run-off. In the literature review, event mean concentrations were cited from several different sources in Sweden, North Carolina, and Texas. Conventional pollutants were documented such as TSS. Nitrate nitrogen, nitrite nitrogen, copper, lead, cadmium, zinc, total kjehldahl nitrogen and total phosphorus. Most of the land use area was rural, but there were some mixed used land uses that was beneficial to the project.

Lin, J., Review of Published Export Coefficient and Event Mean Concentration Data; Wetlands Regulatory Assistance Program, ERDC-TN-WRAP-04-3, September 2004

Summary: This review covers export coefficients and event mean concentration for various land use areas in different areas of the country. Export coefficients are designated for rural areas, while event mean concentrations (EMCs) are designated for urban land uses. Event mean concentrations are used to estimate pollutant loading and land use specific EMCs can help regulators determine the effects of the change of land uses on pollutant loads. Lin 2004 discusses “possible regional trends in export coefficient and EMCs”. Median and mean EMCs were sited from sources from Upper Neuse River Basin, NC; Dallas/Ft. Worth, TX; Colorado Springs, CO; Los Angeles, CA; Central and South Florida and the Twin Cities Metro area, MN.

The Upper Neuse River basin data was comprised from a study done in 2002 (Line 2002). The land use EMCs were attained from six small drainage areas that were monitored in east central North Carolina. The Dallas/Ft. Worth report was developed by Baldy 1998. This report contains EMCs from data collected at 26 sites in the Dallas/Ft. Worth area. The Colorado Springs report documents mean and median land use EMC values from five locations in the city. Land uses were not specifically given to the areas that were monitored, but the percentage of land use coverage for each area. Sites identified as commercial were 61.1 % commercial, industrial sites were 79.5% industrial and residential sites were 79.4% residential. Being a large city, Los Angeles County conducts their monitoring for stormwater. The Los Angeles County Department of Public Works published annually a stormwater monitoring report. The data for this report in Los Angeles originated from the LA report from 1998-1999. Lastly, the data from Florida is a summary of land use EMCs from 40 reports that was compiled from a summary report by Harper 1998. Pollutants identified included: NO_3, NO_3+NO_2, TKN, NH_3-N, TN, TP and TSS.

Stein, E.D. Comparison of Stormwater Pollutant Loading by Land Use Type; Southern California Coastal Water Research Project, AR08-015-027 2008. ftp://ftp.sccwrp.org/pub/download/DOCUMENTS/AnnualReports/2008AnnualReport/AR08_015_027.pdf

Summary: Stein did a comparison study on stormwater pollutant loading for different land use areas. Pollutant concentration and flows were measured over the entire storm duration from eight land use types in five Southern California watersheds. Land use types were being observed to determine patterns of pollutant loads in urban runoff and how varying land use types may affect them. The data was taken from the 2000-2001 to 2004-2005 storm seasons. There were 33 site events used for this study. Land use areas were homogeneous and comprised of: high density residential, low density residential, commercial, industry, agriculture, recreational, transportation and open space. Predicted stormwater loads are highly sensitive to land use designation and their associated EMC estimates. The greatest uncertainty to modeling efforts is inaccurate EMC data.

Environmental Assessment. USEPA.gov; water.epa.gov/scitech/.../2006_10_31_guide_stormwater_usw_b.pdf

Summary: This summary gives an overview of the effect of urban runoff on water quality when there is a change in perviousness due to urbanization. This report discusses the physical, chemical and biological effects of polluted urban run-off. Many studies of storm water runoff were conducted after the Water Quality Act of 1965. EPA's National Urban Runoff Program of 1983 was one of many programs that examined the effect of urban runoff on waterways. NURP was created to examine the characteristics of urban runoff to determine if there are differences between urban land uses. The program also examined whether urban runoff is a significant contributor to water quality problems nationwide and the performance characteristics and effectiveness of Best Management Practices (BMPs) to control pollution loads from urban runoff. Samples were taken from 28 NURP projects that included 81 specific sites and more than 2,300 separate storm events.

NURP focused on the following ten constituents:

- Total Suspended Solids (TSS)
- Biochemical Oxygen Demand (BOD)
- Chemical Oxygen Demand (COD)
- Total Phosphorus (TP)
- Soluble Phosphorus (SP)
- Total Kjehldahl Nitrogen (TKN)
- Nitrate + Nitrite (N)
- Total Copper (Cu)
- Total Lead (Pb)
- Total Zinc (Zn)

NURP also examined coliform bacteria and priority pollutants at a subset of sites. Median event mean concentrations (EMCs) for the ten general NURP pollutants for various urban land use categories are presented in this report (Table 4-1).

McKee, P.J. and H.C. McWreath, Computed and Estimated Pollutant Loads, West Fork Trinity River; Water-Resources Investigations Report 01–4253, U.S. GEOLOGICAL SURVEY, Fort Worth, Texas, 1997, Trinity River Authority, Austin, TX 2001

Summary: This report shows the EMC values for: total suspended solids (TSS) labeled as suspended solids in the table; total nitrogen (TN); ammonia and organic nitrogen (NH3 + org N-TKN); dissolved phosphorus (P^{3-}); total phosphorus (TP); biochemical oxygen demand (BOD); total recoverable copper (Cu); total recoverable lead (Pb); total recoverable zinc (Zn) and total recoverable diazinon. These values are median values and the table also shows the number of samples that were taken to find the median values.

Kieser & Associates, LLC; Urban Build-Out and Stormwater BMP Analysis in the Paw Paw River Watershed; Southwest Michigan Planning Commission, Benton Harbor, MI April 2008

Summary: This report addresses land uses, the reclassification of some of the land uses, future maps based on land uses and the analysis of BMPs for those areas. GIS and computer models were used to estimate the impact of stormwater BMPs. EMCs were estimated for each land use. Imperviousness was observed for each land use. They ranged from 0% to 90% imperviousness.

CDM, Temescal Canyon Park Stormwater Best Management Practices Project Pollutant Loading and Reductions; City of Los Angeles August 2009

Summary: This summary involves a pollutant loading model developed to estimate expected pollutant loads and concentrations from stormwater runoff within the Temescal Canyon watershed tributary to evaluate the underground cistern Best Management Practice (BMP). The pollutant loading model is based on four main equations that determine the runoff coefficient, the annual runoff, the annual pollutant loadings, and the resulting average annual pollutant concentrations adapted from the Simple Method. The model is used for estimating changes in runoff volumes, pollutant loads, and resulting pollutant concentrations that may occur as a result of property development or redevelopment. Concentrations observed total suspended solids (TSS), total phosphorus (Total P), dissolved phosphorus, total nitrogen (Total N), organic nitrogen, ammonia-nitrogen, nitrate + nitrite as nitrogen, total copper (Cu), dissolved Cu, total lead (Pb), dissolved Pb, zinc (Zn), dissolved Zn, and fecal coliform. EMCs from different land uses were used in the model.

Pitt, R., A. Maestre and R. Morquecho; Research Progress Report, Findings from the National Stormwater Quality Database (NSQD)

Summary: The University of Alabama and the Center for Watershed Protection have collected and evaluated stormwater data from a representative number of National Pollutant Discharge Elimination System (NPDES) municipal separate storm sewer system (MS4) stormwater permit holders. As of September 2003, data from 3,770 separate storm events from 66 agencies and municipalities from 17 states were collected and entered into NSQD. Data for individual storms, their geographic location and land use were documented. Median EMCs for individual land uses were recorded.

BETA Group, Inc.; Technical Memorandum Watershed Based Plan for the Chicopee Basin; Massachusetts Department of Environmental Protection September 2006

Summary: The Chicopee Basin, located in Central Massachusetts, covers several tributaries and the drainage area in the watershed is approximately 723 square miles. There are several documents that give data on pollutant loads in the basin:

- Chicopee River Watershed 1998 Water Quality Assessment Report
- Total Maximum Daily Load for Phosphorus for Selected Chicopee Basin Lakes
- Total Maximum Daily Load for Phosphorus for Quaboag Pond and Quacumquasit Pond
- EOEA Chicopee River Watershed Assessment Report 2003
- EOEA Chicopee River 5-Year Watershed Action Plan 2005-2010
- 2003 Chicopee Nonpoint Source Action Strategy
- Massachusetts Year 2004 Integrated List of Waters

The Watershed Management Model (WMM) was be used to offset any existing gap in the data from the other documents. The WMM estimates annual pollutant loads within each simulated sub watershed based on rainfall, overall pervious and impervious runoff coefficients within each sub watershed, land use-based pollutant event mean concentrations (EMCs), percent imperviousness for each land use category, and the sub watershed delivery ratios.

Ha, S.J., Predictive Modeling of Stormwater Runoff Quantity and Quality for a large Urban Watershed; a PhD Dissertation, University of California, Los Angeles

Abstract: In this research a predictive model for stormwater runoff volume was implemented in an ArcGIS platform based on the Rational Method and Browne's empirical relation for soil characteristics. Characterization of pollutant load contributions of land use types to total loads of the upper Ballona Creek watershed was achieved through zeroth-order regularization and L- BFGS-B optimization techniques. Relative form was used in the objective function to compensate for strong contributions of high magnitude variables. Model predictions showed reasonable agreement with total Zn, TKN, and TSS loadings measured at the mass emission site for the upper Ballona Creek watershed. Two additional categories, highways and local roads, which have not been routinely used as land use categories, were separately studied. Best Management Practices (BMP) strategies were evaluated a typical storm event, which exceeded total zinc TMDL by over 70%. The model was used to compare optimized BMP applications to the simplest application, which would treat all areas equally. Approximately 44 % removal efficiency with treatment of the entire runoff would be needed to meet the TMDL.

Wang, S., Pollutant concentrations and pollution loads in stormwater runoff from different land uses in Chongqing, Journal of Environmental Sciences 2013, 25(3) 502–510

Abstract: To investigate the distribution of pollutant concentrations and pollution loads in stormwater runoff in Chongqing, six typical land use types were selected and studied from August 2009 to September 2011. Statistical analysis on the distribution of pollutant concentrations in all water samples shows that pollutant concentrations fluctuate greatly in rainfall-runoff, and the concentrations of the same pollutant also vary greatly in different rainfall events. In addition, it indicates that the event mean concentrations (EMCs) of total suspended solids (TSS) and chemical oxygen demand (COD) from urban traffic roads (UTR) are significantly higher than those from residential roads (RR), commercial areas (CA), concrete roofs (CR), tile roofs (TRoof), and campus catchment areas (CCA); and the EMCs of total phosphorus (TP) and NH_3-N from UTR and CA are 2.35–5 and 3 times of the class-III standard values specified in the Environmental Quality Standards for Surface Water (GB 3838-2002). The EMCs of Fe, Pb and Cd are also much higher than the class-III standard values. The analysis of pollution load producing coefficients (PLPC) reveals that the main pollution source of TSS, COD and TP is UTR.

Lee, J.H. and Ki Woong Bang, Characterization of Urban Stormwater Runoff, Wat. Res. Vol. 34, No. 6, pp. 1773±1780, 2000

Abstract: The purpose of this study is to investigate the characteristics of pollutants overflow on storm events, relationships between pollutant load and runoff, and the first flush effect in urban areas. Nine watersheds in the cities of Taejon and Chongju, Korea were selected for sampling and study with different characteristics during the period from June 1995 to November 1997. Runoff and quality parameters such as BOD_5, COD, SS, TKN, NO_3-N, PO_4-P, TP, Pb, Fe, and n-Hexane extracts were analyzed for the development of relationships between runoff and water quality. From the hydrograph and pollutograph analysis, the peak of pollutant concentration preceded that of the flow rate in an area smaller than 100ha in which impervious area occupied more than 80%. The peak of pollutant concentration, however, was followed by that of flow rate in the watershed in an area larger than 100 ha in that the impervious area was less than 50%. In the storm event, the relative magnitude of the pollutants unit loading rate was in the following order; high density residential > low density residential > industrial > undeveloped watershed.

Yoon, S.W., Monitoring of non-point source pollutants load from a mixed forest land use; Journal of Environmental Sciences 2010, 22(6) 801–805

Abstract: The aim of this study was to determine the unit load of NPS (non-point source) pollutants including organic variables such as BOD (biochemical oxygen demand), COD (chemical oxygen demand) and DOC (dissolved organic carbon), nitrogen and phosphorus constituents, and suspended solids (SS) and their event mean concentration (EMC) of runoff flows from a water-shed of mixed forest land use by intensive field experiments. The EMCs of individual runoff event were estimated for each water quality constituent based on the flow rate and concentration data of runoff discharge. Affecting parameters on the EMCs were investigated by statistical analysis of the field data. As a result, significant correlations with precipitation, rainfall intensity, and total runoff flows were found in most constituents.

Event Mean Concentrations (EMCs) and Export Coefficients Appendix IV; www.water.epa.gov/scitech/datait/models/basin/upload/2002_05_10_BASINS; PLOAD version 3.0

Summary: The PLOAD model is a GIS based model designed to calculate pollutant loads from non-point sources for watersheds. The GIS model requires certain data sets to calculate pollutant loads such as GIS land use data, GIS watershed data, pollutant loading rate data tables, and impervious terrain factor data tables. Event mean concentrations and export coefficients from different parts of the US were obtained from literature. The EMCs values were obtained for different land uses from the Mid-Atlantic; Coastal Texas; Atlanta, GA; Florida, Washington State, North Carolina and Milwaukee, Wisconsin. Pollutants examined included: TSS, TDS, BOD, COD, phosphorus, nitrogen, nitrate plus nitrite, TKN, Ammonia, fecal coliform, lead and zinc.

Urban Stormwater Runoff Loadings; Chesapeake Bay Basin Toxics Loading and Release Inventory; Chesapeake Bay Program; May 1999

Summary: The Chesapeake Bay Basin Toxics Loading and Release Inventory is designed to identify sources of pollutants and develop source reduction and pollution prevention goals for the Chesapeake Bay. Reducing chemical loads will require looking at point sources and non-point sources. One of the ways to reduce loads is to incorporate the Clean Water Act's TMDL program that "complements and enhances traditional approaches of controlling chemical concentrations exiting pipes by addresses the ambient concentration of contaminants from all sources." Event mean concentrations are used to estimate pollutant loads in urban areas. Descriptive statistics and EMCs for inorganic and organic pollutants were documented:

- ***Oil and grease***
- Cyanide
- Total phenol
- Chloroform
- ***Benzo(a)anthracene***
- ***Benzo(a)pyrene***
- 3,4-benzofluoranthene
- Benzo(k)fluoranthene
- Bis(2-chloroethoxy)methane
- 1,4-dichlorobenzene
- ***Fluoranthene***
- ***Fluorene***
- ***Phenanthrene***
- ***Pyrene***
- Antimony
- ***Arsenic***
- Beryllium
- Cadmium
- Chromium
- ***Copper***
- ***Lead***
- ***Mercury***
- Nickel
- Selenium
- Silver
- Thallium
- ***Zinc***

CSN Technical Bulletin No. 9 Stormwater Nutrient Accounting; Local Stormwater Load Reduction in the Chesapeake Bay Watershed version 1.0, Review Draft; August 15, 2011

Summary: This technical bulletin has incorporated several sections on nutrients in the Chesapeake Bay as a result of stormwater. It summarizes the impact of eutrophication on waterbodies, the TMDLs and the WIPs implemented to reduce nutrient loads, sources of nutrients in urban stormwater, models used to estimate loads and pollutant removals by BMPs. Table 6 of this report lists event mean concentrations for total nitrogen and total phosphorus for different urban land uses such as highways, streets, parking lots, rooftops and general urban land cover.

Impacts of Impervious cover on Aquatic Systems; Watershed Protection Research Monograph No. 1; Center for Watershed Protection, March 2003

Summary: This research monograph explores the impacts of urbanization on small streams and receiving waters. These impacts are categorized as changes in hydrologic, physical, water quality or biological indicators. Impervious cover has been identified as a significant factor as an indicator of stream quality. The Impervious Cover Model (ICM) is designed to predict stream quality indication by the imperviousness of the area. Chapter four discusses the water quality impacts of impervious cover. The information in this chapter contains urban stormwater data from national and regional data for nine categories of pollutants. EMC data included sediments, nutrients, metals, hydrocarbons, bacteria, organic carbon and pesticides. There was data for EMCs according to land use areas: commercial (parking lot, rooftop), street (high, medium, low), residential (rooftop, driveway, lawn).

Pitt, R., A. Maestre and R. Morquecho; Evaluation of NPDES Phase I Municipal Stormwater Monitoring Data, Center for Watershed Protection 2001

Summary: The University of Alabama and the Center for Watershed Protection collected data from various NPDES permit across the United States. This NPDES database provides detailed descriptions of the test areas and sampling conditions are also being collected, including aerial photographs and topographic maps for many locations, which we are collecting from public sources. The land use information used is as supplied by the communities submitting the data, although aerial photographs and maps are also used to clarify any questions. Most of the sites have homogeneous land uses, although many are mixed. Constituents analyzed included typical conventional pollutants (TSS, TDS, COD, BOD_5, oil and grease, fecal coliforms, fecal strep, pH, Cl, TKN, NO_3, TP, and PO_4), plus many heavy metals (including total forms of arsenic, chromium, copper, lead, mercury, and zinc, plus others), and numerous listed organic toxicants (including PAHs, pesticides, and PCBs). Our database includes information for about 125 different stormwater quality constituents, although the database is mostly populated with data from 44 of the commonly analyzed pollutants.

Chesapeake Stormwater Network Biohabitats, Montgomery County Implementation Guidance Memo; Montgomery County DEP, April 2010

Summary: The Montgomery County IP Guidance Document provides a schedule for the watershed analyses to be conducted over the next year and through the permit cycle. Watershed Implementation Plans (WIPs) are prepared for the County that has to meet certain parts of the MS4 permit requirements, including watershed restoration; EPA approved TMDLs and trash and litter management for the Potomac. These measures have to be cost effective and gain regulatory approval. Part three of the memorandum discusses the estimation of pollutant load reductions. The WTM (Watershed Treatment Model) will be used to estimate pollutant loads for the watershed. Where there are TMDLs, modeling information from the TMDL will be used for calibration of the WTM model, including event mean concentrations and total load allocations. For each major watershed in the County, one of the outcomes for the pollutant load analysis will be to assign EMCs and runoff volume coefficients for each land use/cover type for computation of an annual pollutant from primary sources. Pollutants include nitrogen (lbs/yr), phosphorus (lbs/yr), sediment (lbs/yr) and fecal coliform (billion/yr). In Appendix B, the table (1) presents recommended event mean concentrations for urban land uses in Montgomery County based on literature from Pitt (2008).

NPDES 18th Annual Update (MD0068322/00-DP-3318); Howard County Department of Public Works June 2013

Summary: National Pollutant Discharge Elimination System permits have to be renewed at least every five years. Howard County with a population of just over 290,000, is one of five medium and five large jurisdictions in Maryland that is regulated by a NPDES permit. The large NPDES MS4 permits serve populations greater than 250,000, which includes Howard County. The conditions of the permit condition are to identify sources of pollutants in stormwater runoff and linked to specific water quality impacts on a watershed basis. Based on this information, watershed restoration plans are developed to improve water quality. Howard County's municipal NPDES management program effectiveness is evaluated through chemical, biological and physical assessments through monitoring and sampling analysis. For chemical monitoring, eight storm events are monitored per year at each monitoring location with at least two [storm events] occurring per quarter. At least three samples representative of each storm event shall be evaluated and EMCs are calculated for:

- BOD
- TKN
- Nitrate + nitrite
- TSS
- TPH
- F.Coli/E.Coli
- Pb
- Cu
- Zn
- TP
- Oil and grease

EMC information is included in the annual report under Section C.

Anne Arundel County NPDES Annual Report; Anne Arundel County Department of Public Works; Sept 2 2013

Summary: The annual report for the NPDES MS4 permit was designed to detail the activities in Anne Arundel County from November 2011 through September 2012 that demonstrates compliance with the MS4 permit. It details the stormwater management program, the implementation status and proposed revisions. The report also summarizes the monitoring programs employed by Anne Arundel County, including data collection and analysis. As part of the County's watershed studies, Event Mean Concentration (EMC) data for the Anne Arundel County urban land covers were compiled for various studied pollutants. The EMC data are weighted mean values derived from statistical assessment of pollutant concentrations measured for multiple storm events. The data are currently utilized for assessing pollutant loadings using the EPA Simple Method. During the 2011 Phase II Watershed Implementation Plan (WIP) development, the County reconciled its EMCs for various land covers with those used in the Chesapeake Bay Program's (CBP) Watershed Model (Version 5.3). Table 7 identifies the adjustments made to reconcile the concentrations with those used in the Bay Program's Watershed Model. Beginning with the 2011 assessment for the Patapsco Tidal and Bodkin Creek watersheds, EMCs based on the CBP Watershed Model have been used to characterize pollutant loading and develop watershed restoration projects.

Patapsco Tidal and Bodkin Creek Watershed Assessment Comprehensive Summary Report; Anne Arundel County, Department of Public Works, Bureau of Engineering Watershed Ecosystem and Restoration Services Division Watershed Assessment and Planning Program, in association with LimnoTech and Versar; August 2012

Summary: The Anne Arundel County, Maryland, Watershed Assessment and Planning Program initiated a comprehensive assessment of the Patapsco Tidal and Bodkin Creek Watersheds in the spring of 2010. The main purpose of the assessment was to characterize current stream and upland conditions in the watershed to support and prioritize watershed management and planning activities. The scope of the Patapsco Tidal and Bodkin Creek Watersheds study encompassed collection of field and stream assessment data and supporting Geographic Information System (GIS) data, followed by analysis and modeling using the County's customized watershed assessment and modeling tools. The WTM was just one of the models used to forecast results from data being collected. Pollutant loads are the product of the annual runoff, the drainage area and the event mean concentrations for each land use category. EMC values according to each land use are listed in Table 3.3 of the WTM. These values were either found in literature of calculated from export coefficients used by the Chesapeake Bay Program.

Watershed Management Plan; Dept. of Environmental Services, Environmental Planning Office; Virginia Dept. of Environmental Quality; Arlington County, Arlington, VA; January 2001

Summary: With a grant from the Virginia Dept. of Environmental Quality, Arlington County developed a watershed management to address growing issues of stormwater flows and pollution in the heavily urban and impervious area. For Arlington County, the Watershed Management program analyzes existing water sources and runoff management practices; sets management goals for subwatersheds based current stream conditions, current land uses and future land use changes; provides management recommendations for subwatersheds and provides an implementation plan. One of the conditions of Arlington's MS4 permit and section one of the watershed management plan is for DES collects samples from four storm sewer outfalls in the County. Each outfall drains a land use and the data is beneficial to determine pollutant loads in different land uses. From laboratory analysis, event mean concentrations are calculated for each pollutant.

A User's Guide to Watershed Planning in Maryland: A Maryland DNR Guide; Center for Watershed Protection for Maryland Department of Natural Resources; December 2005. www.dnr.maryland.gov

Summary: This guide gives an overview of how to create a watershed plan that meets federal funding, regulatory programs such as TMDLs the Chesapeake Bay 2000 Agreement and address current land issues. Watersheds and sub-watersheds are geographical scales used to develop these plans. Watershed planning steps include: developing watershed goals; classifying and screening priority subwatersheds; identifying watershed planning opportunities; conducting detailed assessments; assemble recommendations into a plan; determining if watershed plan meets goals; developing methods to implement the plan and implementing and measuring improvements over time. The Watershed Treatment Model (WTM) estimates pollutant loads for watersheds. EMCs of sediment, phosphorus and nitrogen for various land uses are provided in the WTM as defaults, but CBP Watershed Model data should be substituted when available. EMCs for nutrients and sediment for three urban land uses are in Table 4.14 of the Maryland DNR Guide.

Howell, N.L, Lakshmanan, D., Rifai, H.S., and Koenig, L.; PCB dry and wet weather concentration and load comparisons in Houston-area urban channels; Science of the Total Environment 409 (2011) 1867-1888

Abstract: All 209 PCB congeners are quantified in water in both dry and wet weather urban flows in Houston, Texas, USA. Total water PCBs ranged from 0.82 to 9.4 ng/L in wet weather and 0.46 to 9.0 ng/L in dry. Wet weather loads were 8.2 times higher (by median) than dry weather with some increases of over 100-fold. The majority of the PCB load was in the dissolved fraction in dry weather while it was in the suspended fraction in wet weather. Dissolved PCB loads were correlated with rain intensity and highly developed land area, and a multiple linear regression (MLR) equation was developed to quantify these correlations. PCA generated five PCB components with nearly all positive loadings. The PCB 11 component was statistically higher in wet versus dry weather when no other component showed such clear distinctions.

Smullen, J., Ksyniak, D., Blair, D., and J. Wetherington; A Watershed Runoff Loading Methodology for Polychlorinated Biphenyls; CDM, Philadelphia Water Dept; Dupont Company; 2005

Abstract: For the initial stage of the Delaware Estuary TMDL for Polychlorinated Biphenyls (PCBs), estimates were needed for watershed runoff loads of PCBs delivered to the Delaware River and Bay from tributaries for which no monitoring data were available. For these tidewater tributary basins, an alternative approach was developed to estimate Polychlorinated Biphenyl (PCB) loads using data available from existing international stormwater databases and from some locally collected stream discharge water quality databases. The approach is based on studies conducted both in the region and elsewhere in the United States, and is used to estimate average daily PCB loadings for comparisons with other pollutant sources in the total maximum daily load assessments. To estimate yields of PCBs from urban areas in the basins, event mean concentrations of PCBs in urban runoff were derived through the retrieval and careful review of over 200 references that yielded 12 investigations with EMC results for PCBs.

The literature search for PCB EMCs yielded no information suitable for estimating loads from rural areas. To provide estimates for PCB contributions from rural areas, a simple USEPA indirect loading methodology was employed. For this application, the atmospheric deposition rates were taken from the published and unpublished works of researchers at Rutgers University, who have conducted atmospheric deposition monitoring in the Delaware Estuary drainage (Van Ry, et al., 2002)

Schiff, K., Watershed Monitoring and Modeling in Switzer, Chollas and Paleta Creek Watersheds; Southern California Coastal Water Research Project in conjunction with Tetra Tech; May 15, 2007. www.sccwrp.org

Summary: San Diego Bay was listed in California's impaired waterbodies due to contaminated sediments and impaired benthic communities. Chollas Creek (North and South forks), Switzer Creek, and Paleta Creek are three of the creek mouth areas listed as impaired, therefore having TMDLs allocated to them. The purpose of this study is to help gather technical information for the TMDL. Pollutants of potential concern are copper, polynuclear aromatic hydrocarbons (total PAHs), polychlorinated biphenyls (total PCBs), and chlordane. This study tackled two primary data gaps: 1) estimates of pollutant loading to San Diego Bay from each of the three watersheds; and 2) estimate relative pollutant contributions from various land uses within each watershed.

Watershed Model Development for the LA/LB Harbors: October 2010

Summary: This report describes the model used to estimate metals and organic pollutant loads from the Los Angeles River, the San Gabriel River, and other near shore watershed areas. These models, in addition to the Dominguez Channel model, were used to determine the pollutant loadings to Dominguez Channel and Greater Los Angeles and Long Beach Harbor Waters. Pollutants of interest include metals such as copper, lead, and zinc, and several organic pollutants (PAHs, DDT, PCBs, and chlordane). Separate approaches were used to represent dry- and wet-weather conditions. The wet weather analyses

are based on an eleven-year simulation using the LSPC watershed model. Stormwater total PAH concentrations for each model subwatershed were predicted using weighted averages of land use EMCs based on area and runoff potential of each land use in each subwatershed. For DDT, PCBs, and chlordane, a different approach was required because no detectable levels of these pollutants were found in the mass emissions monitoring stations (DDT was only detected in stations associated with agricultural runoff). Sediment concentrations from Bight 03 monitoring data were applied to predicted sediment loads to estimate loads of these pollutants.

Bannerman, R.T., Legg, A.D., and S.R. Greb; Quality of Wisconsin Stormwater, 1989-94; U.S. Geological Survey Open-File Report 96-458, Wisconsin Department of Natural Resources, Madison, WI 1996

Abstract: Water-quality data were compiled from four urban stormwater monitoring projects conducted in Wisconsin between 1989 and 1994. These projects included monitoring in both storm-sewer pipes and urban streams. A total of 147 constituents were analyzed for in stormwater sampled from 10 storm-sewer pipes and four urban streams. Land uses represented by the storm-sewer watersheds included residential, commercial, industrial, and mixed. For about one-half the constituents, at least 10 percent of the event mean concentrations exceeded the laboratory's minimum reporting limit. Detection frequencies were greater than 75 percent for many of the heavy metals and polycyclic aromatic hydrocarbons in both the storm sewer and stream samples, whereas detection frequencies were about 20 percent or greater for many of the pesticides in both types of samples. Stormwater concentrations for conventional constituents, such as suspended solids, chloride, total phosphorus, and fecal coliform bacteria were greater than minimum reporting limits almost 100 percent of the time. Concentrations of many of the constituents were high enough to say that stormwater in the storm sewers and urban streams might be contributing to the degradation of the streams.

Attachment 2: Results Analysis 1, Evaluation of Land Use-Based EMCs

The following sets of tables show the results from Analysis 1. Evaluation of Land Use-Based EMCs, as explained in Section 4. This analysis was conducted to determine if the land use based EMCs from the literature could be used to predict the monitored EMCs. In other words, are the land use based EMCs from the literature, which are based on nationwide data, appropriate to characterize the site specific conditions of the District?

To do this analysis, a subset of the monitored data was used and average EMCs were calculated for each pollutant of concern. The subset of monitored data selected included the EMC data provided by the 2009 Stormwater Management Plan (DDOE, 2009), and the EMC data provided by the *Study Memorandum LTCP 5-8 (Final), CSS and SSWS Event Mean Concentrations* (DC Water, October 2001). The reason this subset of data was selected is because it was, at the time of the analysis, readily available in a useable format, and provided a good selection of monitoring sites across the MS4 area. A total of 16 sites were included in this subset of data, and each site was sampled during 3 to 5 storms over the course of a year. A map of the sites is provided in Figure 1. The drainage area of each site was delineated and the land use types within the drainage areas were defined using the 2005 DC OCTO existing land use GIS layer (DC OCTO, 2005). Then the land use based EMCs were applied and an overall area-weighted land use based EMC was calculated for each site. This calculated value was subsequently compared to the monitored value. The full table of comparison for each pollutant is presented below.

The results of this analysis showed that:

1. The amount of land use based EMC data that exists in the literature for the organics and some of the metals not sufficient to make land use based EMC predictions.
2. The calculated EMC values using the average values per land use type, identified from the literature, were in most cases lower than the monitored value. As a consequence, the average literature values were increased for each land use type by anywhere from 10% to 400% in order to produce a larger area-weighted land use based EMC value that was more aligned with the monitored value. Note that, even after increasing the average value of the individual land use based EMCs, the increased values were still within the observed ranges reported by the literature for each land use type.
3. Even after adjusting the average land use based values, it was practically impossible to match the monitored values in all locations. Only when comparing the calculated and monitored average and median EMC values for all the sites combined did the calculated values more closely match the monitored values. But on a site by site basis, the calculated EMCs would sometimes over-predict, and at other times under-predict the monitored values. No obvious trends in the data were observed on a site by site basis.

It should be noted that Analysis 1 will be further refined to include all data from all sites and time periods. The refined analysis will be included in the Comprehensive Baseline Report.

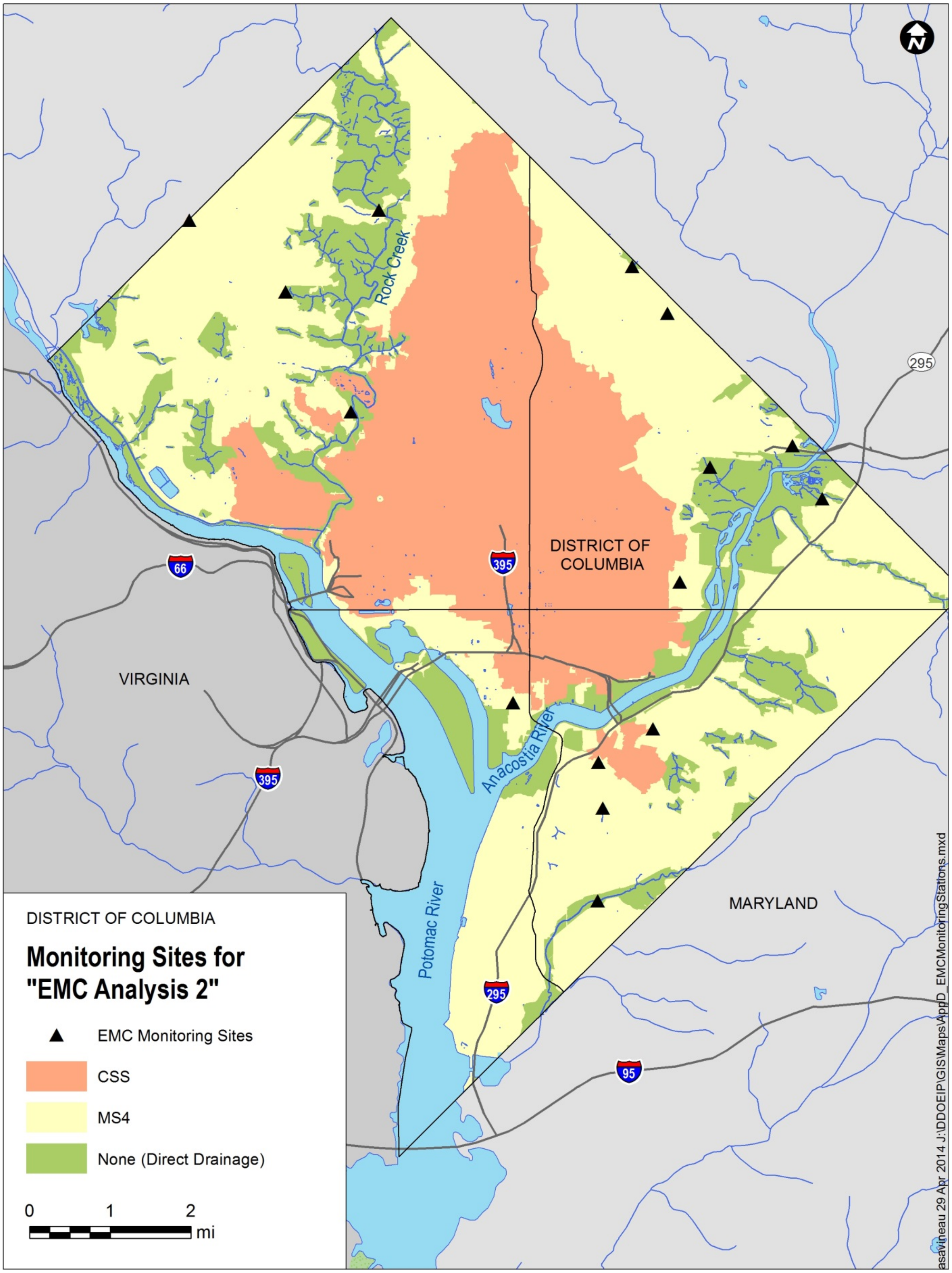

Figure 1: Location of Sampling Sites Used in Analysis 1

Table 1: TSS EMC Comparison Between Reported and Calculated Values Calculated Values					
Catchment	**Range of Reported EMCs (mg/L)**	**Average of Reported EMCs (mg/L)**	**Calculated LU-Based EMC (mg/L)**	**Percent Difference**	**LU Description**
Anacostia High	Not In Report	4.0	4.7	17.3%	Low/med residential, parks, commercial
East Capitol	Not In Report	6.7	5.9	-11.4%	Low/med residential
Fort Lincoln	Not In Report	5.4	2.8	-47.4%	Parks, mixed use
Gallatin	Not In Report	3.0	4.5	47.1%	Low/med residential, institutional
Nash Run	Not In Report	4.1	4.9	19.9%	Low/med residential, parks
O Street	Not In Report	3.2	3.4	4.7%	Mixed, commercial
Stickfoot	Not In Report	6.7	6.0	-10.9%	Low/med residential
Varnum	Not In Report	3.6	4.8	33.4%	Low/med residential, institutional, mixed
Oxon Run	3.1 - 7.21	5.0	5.5	8.7%	Low/med residential, institutional
Rock Creek, Military	3.22 - 6.47	4.5	2.6	-42.7%	Parks, institutional
Hickey	6.74 - 8.32	7.6	5.9	-22.1%	Industrial, low-/med residential
Rock Creek, Cathedral	1.07 - 8.58	4.4	5.5	25.4%	Low/med residential, med/high residential
Soapstone	2.22 - 8.49	5.5	3.1	-44.1%	Institutional, federal, commercial
Potomac Trib	4.01 - 5.23	4.8	4.9	2.5%	Low/med residential, mixed use
Suitland Pkwy (DCWASA)	2.2 - 3.05	2.5	4.4	71.9%	Low/med residential, institutional, parks
Hickey Run (DCWASA)	1.37 - 3.08	2.4	5.1	112.4%	Low/med residential, industrial
	Average	4.6	4.6	0.6%	
	Median	4.4	4.8	9.1%	
	Maximum	7.6	6.0	-21.4%	
	Minimum	2.4	2.6	7.3%	

Table 2: TN EMC Comparison Between Reported and Calculated Values					
Catchment	**Range of Reported EMCs (mg/L)**	**Average of Reported EMCs (mg/L)**	**Calculated LU-Based EMC (mg/L)**	**Percent Difference**	**LU Description**
Anacostia High	Not In Report	4.0	4.7	17.3%	Low/med residential, parks, commercial
East Capitol	Not In Report	6.7	5.9	-11.4%	Low/med residential
Fort Lincoln	Not In Report	5.4	2.8	-47.4%	Parks, mixed use
Gallatin	Not In Report	3.0	4.5	47.1%	Low/med residential, institutional
Nash Run	Not In Report	4.1	4.9	19.9%	Low/med residential, parks
O Street	Not In Report	3.2	3.4	4.7%	Mixed, commercial
Stickfoot	Not In Report	6.7	6.0	-10.9%	Low/med residential
Varnum	Not In Report	3.6	4.8	33.4%	Low/med residential, institutional, mixed
Oxon Run (MS1)	3.1 - 7.21	5.0	5.5	8.7%	Low/med residential, institutional
Rock Creek, Military (MS2)	3.22 - 6.47	4.5	2.6	-42.7%	Parks, institutional
Hickey (MS3)	6.74 - 8.32	7.6	5.9	-22.1%	Industrial, low-/med residential
Rock Creek, Cathedral (MS4)	1.07 - 8.58	4.4	5.5	25.4%	Low/med residential, med/high residential
Soapstone (MS5)	2.22 - 8.49	5.5	3.1	-44.1%	Institutional, federal, commercial
Potomac Trib (MS6)	4.01 - 5.23	4.8	4.9	2.5%	Low/med residential, mixed use
Suitland Pkwy (DCWASA)	2.2 - 3.05	2.5	4.4	71.9%	Low/med residential, institutional, parks
Hickey Run (DCWASA)	1.37 - 3.08	2.4	5.1	112.4%	Low/med residential, industrial
	Average	4.6	4.6	0.6%	
	Median	4.4	4.8	9.1%	
	Maximum	7.6	6.0	-21.4%	
	Minimum	2.4	2.6	7.3%	

Table 3: TP EMC Comparison Between Reported and Calculated Values					
Catchment	**Range of Reported EMCs (mg/L)**	**Average of Reported EMCs (mg/L)**	**Calculated LU-Based EMC (mg/L)**	**Percent Difference**	**LU Description**
Anacostia High	Not In Report	0.3	0.4	17.7%	Low/med residential, parks, commercial
East Capitol	Not In Report	0.7	0.5	-29.9%	Low/med residential
Fort Lincoln	Not In Report	0.5	0.2	-67.7%	Parks, mixed use
Gallatin	Not In Report	0.3	0.4	15.4%	Low/med residential, institutional
Nash Run	Not In Report	0.4	0.4	7.9%	Low/med residential, parks
O Street	Not In Report	0.2	0.3	29.9%	Mixed, commercial
Stickfoot	Not In Report	0.8	0.5	-29.4%	Low/med residential
Varnum	Not In Report	0.1	0.4	199.9%	Low/med residential, institutional, mixed
Oxon Run (MS1)	0.03 - 130.0	65.0	0.5	-99.3%	Low/med residential, institutional
Rock Creek, Military (MS2)	0.01 - 0.08	0.0	0.1	175.3%	Parks, institutional
Hickey (MS3)	0.01 - 0.05	0.0	0.4	1620.2%	Industrial, low-/med residential
Rock Creek, Cathedral (MS4)	0.03 - 0.05	0.0	0.5	1065.6%	Low/med residential, med/high residential
Soapstone (MS5)	0.03 - 0.05	0.0	0.3	676.1%	Institutional, federal, commercial
Potomac Trib (MS6)	0.06 - 0.25	0.1	0.4	249.7%	Low/med residential, mixed use
Suitland Pkwy (DCWASA)	0.28 - 1.5	0.6	0.4	-40.3%	Low/med residential, institutional, parks
Hickey Run (DCWASA)	0.2 - .56	0.4	0.4	0.4%	Low/med residential, industrial
	Average	0.4	0.4	-5.3%	
	Median	0.4	0.4	6.7%	
	Maximum	0.8	0.5	-29.4%	
	Minimum	0.1	0.1	2.4%	

Table 4: Fecal Coliform EMC Comparison Between Reported and Calculated Values					
Catchment	**Range of Reported EMCs (MPN/100mL)**	**Average of Reported EMCs (MPN/100mL)**	**Calculated LU-Based EMC (MPN/100mL)**	**Percent Difference**	**LU Description**
Anacostia High	Not In Report	8890.8	20264.7	127.9%	Low/med residential, parks, commercial
East Capitol	Not In Report	8897.3	22810.0	156.4%	Low/med residential
Fort Lincoln	Not In Report	105046.4	16000.0	-84.8%	Parks, mixed use
Gallatin	Not In Report	19815.9	19216.4	-3.0%	Low/med residential, institutional
Nash Run	Not In Report	104937.5	20894.9	-80.1%	Low/med residential, parks
O Street	Not In Report	210.0	16015.3	7526.3%	Mixed, commercial
Stickfoot	Not In Report	20187.1	22994.8	13.9%	Low/med residential
Varnum	Not In Report	930.0	20020.0	2052.7%	Low/med residential, institutional, mixed
Oxon Run (MS1)	Not Sampled	Not Sampled	21759.0	N/A	Low/med residential, institutional
Rock Creek, Military (MS2)	Not Sampled	Not Sampled	16000.0	N/A	Parks, institutional
Hickey (MS3)	Not Sampled	Not Sampled	18352.6	N/A	Industrial, low-/med residential
Rock Creek, Cathedral (MS4)	Not Sampled	Not Sampled	22445.9	N/A	Low/med residential, med/high residential
Soapstone (MS5)	Not Sampled	Not Sampled	16276.6	N/A	Institutional, federal, commercial
Potomac Trib (MS6)	Not Sampled	Not Sampled	20120.3	N/A	Low/med residential, mixed use
Suitland Pkwy (DCWASA)	100-13,000	36546.0	19416.8	-46.9%	Low/med residential, institutional, parks
Hickey Run (DCWASA)	100-90,000	19985.0	19846.6	-0.7%	Low/med residential, industrial
	Average	32544.6	19747.9	-39.3%	
	Median	19900.5	19933.3	0.2%	
	Maximum	105046.4	22994.8	-78.1%	
	Minimum	210.0	16000.0	7519.0%	

Table 5: BOD EMC Comparison Between Reported and Calculated Values					
Catchment	**Range of Reported EMCs (mg/L)**	**Average of Reported EMCs (mg/L)**	**Calculated LU-Based EMC (mg/L)**	**Percent Difference**	**LU Description**
Anacostia High	Not In Report	39.5	34.6	-12.4%	Low/med residential, parks, commercial
East Capitol	Not In Report	94.5	34.9	-63.1%	Low/med residential
Fort Lincoln	Not In Report	20.4	36.6	79.5%	Parks, mixed use
Gallatin	Not In Report	31.9	37.7	18.2%	Low/med residential, institutional
Nash Run	Not In Report	45.8	33.5	-26.9%	Low/med residential, parks
O Street	Not In Report	36.0	47.0	30.5%	Mixed, commercial
Stickfoot	Not In Report	43.9	35.0	-20.2%	Low/med residential
Varnum	Not In Report	17.0	37.9	122.7%	Low/med residential, institutional, mixed
Oxon Run (MS1)	Not Sampled	Not Sampled	35.7	N/A	Low/med residential, institutional
Rock Creek, Military (MS2)	Not Sampled	Not Sampled	31.5	N/A	Parks, institutional
Hickey (MS3)	Not Sampled	Not Sampled	52.1	N/A	Industrial, low-/med residential
Rock Creek, Cathedral (MS4)	Not Sampled	Not Sampled	37.9	N/A	Low/med residential, med/high residential
Soapstone (MS5)	Not Sampled	Not Sampled	40.2	N/A	Institutional, federal, commercial
Potomac Trib (MS6)	Not Sampled	Not Sampled	39.4	N/A	Low/med residential, mixed use
Suitland Pkwy (DCWASA)	6.0 - 28.0	15.8	35.8	127.2%	Low/med residential, institutional, parks
Hickey Run (DCWASA)	5.0 - 37.0	23.0	40.6	76.3%	Low/med residential, industrial
	Average	36.8	37.3	1.6%	
	Median	33.9	36.2	6.6%	
	Maximum	94.5	47.0	-50.3%	
	Minimum	15.8	33.5	112.7%	

Table 6: Oil and Grease EMC Comparison Between Reported and Calculated Values					
Catchment	**Range of Reported EMCs (mg/L)**	**Average of Reported EMCs (mg/L)**	**Calculated LU-Based EMC (mg/L)**	**Percent Difference**	**LU Description**
Anacostia High	Not In Report	Not In Report	13.2	N/A	Low/med residential, parks, commercial
East Capitol	Not In Report	13.3	12.9	-3.0%	Low/med residential
Fort Lincoln	Not In Report	109.8	11.6	-89.4%	Parks, mixed use
Gallatin	Not In Report	Not In Report	13.8	N/A	Low/med residential, institutional
Nash Run	Not In Report	37.8	12.1	-68.0%	Low/med residential, parks
O Street	Not In Report	7.6	16.2	113.1%	Mixed, commercial
Stickfoot	Not In Report	Not In Report	13.0	N/A	Low/med residential
Varnum	Not In Report	7.3	14.0	92.3%	Low/med residential, institutional, mixed
Oxon Run (MS1)	Not Sampled	Not Sampled	13.5	N/A	Low/med residential, institutional
Rock Creek, Military (MS2)	Not Sampled	Not Sampled	10.9	N/A	Parks, institutional
Hickey (MS3)	Not Sampled	Not Sampled	17.6	N/A	Industrial, low-/med residential
Rock Creek, Cathedral (MS4)	Not Sampled	Not Sampled	13.1	N/A	Low/med residential, med/high residential
Soapstone (MS5)	Not Sampled	Not Sampled	16.9	N/A	Institutional, federal, commercial
Potomac Trib (MS6)	Not Sampled	Not Sampled	14.2	N/A	Low/med residential, mixed use
Suitland Pkwy (DCWASA)	Not Sampled	Not Sampled	13.3	N/A	Low/med residential, institutional, parks
Hickey Run (DCWASA)	Not Sampled	Not Sampled	15.0	N/A	Low/med residential, industrial
	Average	35.2	13.8	-60.6%	
	Median	13.3	13.4	0.7%	
	Maximum	109.8	17.6	-83.9%	
	Minimum	7.3	10.9	49.2%	

Table 7: Copper EMC Comparison Between Reported and Calculated Values					
Catchment	**Range of Reported EMCs (µG/L)**	**Average of reported EMCs (µG/L)**	**Calculated LU-based EMC (µG/L)**	**Percent Difference**	**LU Description**
Anacostia High	Not In Report	125.0	52.8	-57.8%	Low/med residential, parks, commercial
East Capitol	Not In Report	96.0	40.0	-58.3%	Low/med residential
Fort Lincoln	Not In Report	82.1	59.7	-27.4%	Parks, mixed use
Gallatin	Not In Report	31.2	65.0	108.4%	Low/med residential, institutional
Nash Run	Not In Report	36.8	40.0	8.7%	Low/med residential, parks
O Street	Not In Report	25.0	106.7	326.8%	Mixed, commercial
Stickfoot	Not In Report	35.0	40.1	14.5%	Low/med residential
Varnum	Not In Report	73.0	64.1	-12.2%	Low/med residential, institutional, mixed
Oxon Run (MS1)	15.1 - 50.2	32.7	50.1	53.3%	Low/med residential, institutional
Rock Creek, Military (MS2)	44.2 - 73.2	58.0	48.9	-15.7%	Parks, institutional
Hickey (MS3)	26.1 - 144.0	68.6	114.4	66.8%	Industrial, low-/med residential
Rock Creek, Cathedral (MS4)	12.4 - 186.0	84.1	50.9	-39.4%	Low/med residential, med/high residential
Soapstone (MS5)	55.3 - 201.0	105.8	106.1	0.3%	Institutional, federal, commercial
Potomac Trib (MS6)	45.5 - 76.1	63.0	66.1	4.8%	Low/med residential, mixed use
Suitland Pkwy (DCWASA)	0.0 - .0	45.5	58.8	29.1%	Low/med residential, institutional, parks
Hickey Run (DCWASA)	60.78 - 60.78	73.0	75.8	3.8%	Low/med residential, industrial
	Average	64.7	65.0	0.4%	
	Median	65.8	59.2	-10.0%	
	Maximum	125.0	114.4	-8.4%	
	Minimum	25.0	40.0	60.0%	

Table 8: Lead EMC Comparison Between Reported and Calculated Values					
Catchment	**Range of Reported EMCs (µG/L)**	**Average of reported EMCs (µG/L)**	**Calculated LU-based EMC (µG/L)**	**Percent Difference**	**LU Description**
Anacostia High	Not In Report	46.0	24.9	-45.9%	Low/med residential, parks, commercial
East Capitol	Not In Report	88.0	21.8	-75.2%	Low/med residential
Fort Lincoln	Not In Report	16.8	18.3	9.0%	Parks, mixed use
Gallatin	Not In Report	25.0	27.5	10.0%	Low/med residential, institutional
Nash Run	Not In Report	21.4	19.9	-7.0%	Low/med residential, parks
O Street	Not In Report	17.0	33.0	93.9%	Mixed, commercial
Stickfoot	Not In Report	39.0	22.0	-43.5%	Low/med residential
Varnum	Not In Report	9.0	27.6	206.2%	Low/med residential, institutional, mixed
Oxon Run (MS1)	20.0 - 22.9	17.9	25.0	39.5%	Low/med residential, institutional
Rock Creek, Military (MS2)	30.9 - 33.2	19.2	18.7	-2.8%	Parks, institutional
Hickey (MS3)	34.7 - 64.6	27.1	51.4	89.3%	Industrial, low-/med residential
Rock Creek, Cathedral (MS4)	15.4 - 18.8	34.8	27.3	-21.5%	Low/med residential, med/high residential
Soapstone (MS5)	0.0 - 0.0	47.0	43.6	-7.2%	Institutional, federal, commercial
Potomac Trib (MS6)	0.0 - 0.0	20.9	26.6	26.9%	Low/med residential, mixed use
Suitland Pkwy (DCWASA)	59.25 - 59.25	17.8	25.9	45.7%	Low/med residential, institutional, parks
Hickey Run (DCWASA)	35.11 - 35.11	49.0	34.6	-29.3%	Low/med residential, industrial
	Average	31.0	28.0	-9.7%	
	Median	23.2	26.2	13.0%	
	Maximum	88.0	51.4	-41.6%	
	Minimum	9.0	18.3	103.1%	

Table 9: Zinc EMC Comparison Between Reported and Calculated Values					
Catchment	Range of Reported EMCs (µG/L)	Average of reported EMCs (µG/L)	Calculated LU-based EMC (µG/L)	Percent Difference	LU Description
Anacostia High	Not In Report	101.0	180.7	78.9%	Low/med residential, parks, commercial
East Capitol	Not In Report	396.0	136.4	-65.5%	Low/med residential
Fort Lincoln	Not In Report	146.5	225.4	53.9%	Parks, mixed use
Gallatin	Not In Report	131.3	205.5	56.5%	Low/med residential, institutional
Nash Run	Not In Report	111.9	140.2	25.3%	Low/med residential, parks
O Street	Not In Report	143.0	385.3	169.4%	Mixed, commercial
Stickfoot	Not In Report	261.0	136.2	-47.8%	Low/med residential
Varnum	Not In Report	187.0	197.7	5.7%	Low/med residential, institutional, mixed
Oxon Run (MS1)	27.13 - 176.0	147.1	158.2	7.5%	Low/med residential, institutional
Rock Creek, Military (MS2)	34.8 - 183.0	193.0	164.8	-14.6%	Parks, institutional
Hickey (MS3)	47.0 - 139.0	270.1	347.8	28.8%	Industrial, low-/med residential
Rock Creek, Cathedral (MS4)	20.93 - 309.0	218.7	165.9	-24.1%	Low/med residential, med/high residential
Soapstone (MS5)	27.84 - 27.84	213.3	296.9	39.2%	Institutional, federal, commercial
Potomac Trib (MS6)	0.0 - 0.0	263.3	223.2	-15.2%	Low/med residential, mixed use
Suitland Pkwy (DCWASA)	33.38 - 33.38	120.0	179.7	49.8%	Low/med residential, institutional, parks
Hickey Run (DCWASA)	202.22 - 202.22	268.0	239.7	-10.6%	Low/med residential, industrial
	Average	198.2	211.5	6.7%	
	Median	190.0	189.2	-0.4%	
	Maximum	396.0	385.3	-2.7%	
	Minimum	101.0	136.2	34.9%	

Attachment 3: Results of Analysis 2, Updated EMCs from MS4 Monitoring Data

The following two tables show the results from Analysis 2, Updated EMCs from MS4 Monitoring Data, as explained in section 4. This analysis was undertaken to determine if sufficient monitored EMC data exists to calculate EMC values for all of the TMDL pollutants. An additional line of inquiry was to compare the average monitored EMCs to the EMCs used to develop the TMDLs.

A statistical analysis was undertaken of the monitored data to calculate the average and median values of the EMCs, on a city-wide basis (i.e.: all sites aggregated). The statistical analysis was only possible for sediment, nitrogen, phosphorus, BOD, bacteria, oil and grease, copper, lead, and zinc. The statistical results for these pollutants are shown in Table 1. For all other pollutants, many non-detects were found in the data, and this precluded any sort of meaningful statistical analysis of the monitoring data (Table 2).

The results of this analysis showed that:

1. Sufficient monitoring data exists only for sediment, nitrogen, phosphorus, BOD, bacteria, oil and grease, copper, lead, and zinc. For all other pollutants, many non-detects (over 2/3) were found in the data, and this precluded any sort of meaningful interpretation of the monitoring data.
2. The EMCs for pollutants with sufficient data show that they are generally within the same range as the EMCs used to develop the TMDLs, but are typically slightly lower than the mainstem EMCs and slightly higher than the tributary and Chesapeake Bay EMCs.

It should be noted that additional statistical analysis are currently being undertaken on the District MS4 monitoring program results to determine if further refinement of the EMCs on a watershed or waterbody level is possible. The additional analysis will be included in the Comprehensive Baseline Report.

Table 1: Statistical Analysis of MS4 monitoring Data for conventional pollutants and some metals

	TSS	TN	TP	Fecal Coliform Bacteria	BOD	Oil and Grease	Copper	Lead	Zinc
Units	mg/l	mg/l	mg/l	MPN/100ml	mg/l	mg/l	mg/l	mg/l	mg/l
City Wide Statistical Results of reported EMCs									
Min	0.50	0.0025	0.03	8.00	1.00	1.25	0.00050	0.00012	0.00075
Max	1100	22.00	2.60	500,000	200.00	116.00	0.68	0.31	0.89
Average	81.25	3.7	0.41	22,963	29.3	5.2	0.065	0.025	0.118
Median	44	3.2	0.35	5,000	19.0	2.5	0.042	0.013	0.103
n	198	200	203	121	185	156	212	205	220
# NDs	5	18	0	1	13	103	7	11	7
EMC values used in TMDLs									
Ranges	34.67 (Kingman) 60 (Watts Branch) 80?? (CB TMDL) 94 (Mainstem) 227 (Tribs)	3.7 (DC TMDLs) 2 (CB TMDL)	0.5 (DC TMDLs) 0.27 (CB TMDL)	28,265 (Mainstem) 17,300 (Tribs)	27 (Kingman) 42.9 (all other)	3.65 (Kingman) 10 (all other)	0.078 (RC Mainstem) 0.057 (all others)	0.036 (RC Mainstem) 0.029 (all others)	0.183 (RC Mainstem) 0.173 (all others)

Table 2: Statistical Analysis of MS4 monitoring Data for organics, toxics, and some metals												
	Arsenic	**Mercury**	**Chlordane**	**DDD**	**DDE**	**DDT**	**Dieldrin**	**Heptachlor Epoxide**	**PAH1**	**PAH2**	**PAH3**	**TPCB**
Units	**mg/l**	**mg/l**	**ug/l**	**ug/l**	**ug/l**	**ug/l**	**ug/l**	**ug/l**	**ug/l**	**ug/l**	**ug/l**	**ug/l**
City Wide Statistical Results of reported EMCs												
Min	TOO MANY NON-DETECTS TO DO MEANINGFUL STATISTICS											
Max												
Average												
Median												
n	162	137	134	133	134	133	135	133	136	123	137	90
# NDs	109	130	132	132	128	123	129	132	136	123	137	90
EMC values used in TMDLs												
Ranges	0.0014	0.0019 (RC Mainstem)	0.00983	0.003	0.0133	0.0342	0.00029	0.000957	0.6585	4.1595	2.682	0.0806

Attachment 4: Analysis of EMC Differences

Memorandum

From: R. O'Banion and B. Crary

To: A. Savineau
37T

Date: 6/27/2014
Project: DDOEIP
CC: 37T

SUBJECT: EMC Watershed Difference Analysis

Watershed EMC Analysis

Water quality sampling data were collected by DDOE from 2001 to 2013. These data were used to develop event mean concentrations (EMC) at both the city wide and watershed (Anacostia, Potomac, Rock Creek) scales. A statistical analysis was completed to determine whether the city wide or watershed specific EMCs should be used for further modeling.

Analysis of Variance

An analysis of variance (ANOVA) is a test of significance that measures between population difference and within population variance to test the null hypothesis of no difference (Qian 2010). In other words, ANOVA tests that:

$$H_0: \mu_1 = \ldots \mu_k$$

where H_0 is the null hypothesis

μ is the population mean

k is the number of experimental groups

If the null hypothesis is accepted, we expect the different watershed means to be similar to the citywide mean. However, if the null hypothesis is rejected, we expect the watershed means to be different from the citywide mean.

In order to appropriately apply ANOVA, it is necessary to make underlying assumptions about the data. The assumptions and relation to the data being analyzed are discussed below:

- Data are independent – All data in this analysis are independent.
- Data are normally distributed- The data in this analysis are not normally distributed. To account for this, the data have been transformed as needed (Table 1).
- Data have equal variance- As long as the sample sizes, *n*, between the groups are equal or nearly equal, ANOVA is a very robust test regardless of variance (Zar 1999). Since the sample sizes are similar, for this analysis, the data were assumed to have equal variances.

Tests of Significance

Analysis of variance was calculated on the EMC values of ten different pollutants. All analyses were run with R statistical software (R 2010). Table 1 provides all results from the analysis, including the f-statistic. Significant differences (indicated by the p-value) at the 0.05 level or lower means that there is >95% confidence that the watershed EMCs are truly different and that this difference is not due to chance.

Table 1: Summary of ANOVA Analysis							
Parameter	**Potomac Sample Size (n)**	**Rock Creek Sample Size (n)**	**Anacostia Sample Size (n)**	**Transformation**	**F-statistic**	**P-value**	**Result**
Arsenic	40	50	68	N/A	N/A	N/A	No Difference
Biological Oxygen Demand	61	48	75	Log	3.426	0.03463	Significant Difference at the 0.05 Level
Copper	59	60	84	Log	1.895	0.1530	No Difference
Fecal Coliform	29	42	44	Log	1.259	0.2878	No Difference
Lead	51	83	57	N/A	N/A	N/A	No Difference
Nitrogen	64	50	80	0.5454	0.036	0.9641	No Difference
Oil & Grease	53	48	48	-0.5858	4.379	0.0142	Significant Difference at the 0.05 Level
Phosphorus	63	54	81	0.3434	1.681	0.1889	No Difference
Total Suspended Solids	64	53	73	Log	6.315	0.0022	Significant Difference at the 0.01 Level
Zinc	67	60	89	0.4646	3.804	0.0238	Significant Difference at the 0.05 Level

A discussion of each EMC ANOVA is found below.

Arsenic

The arsenic EMC data are independent, but no appropriate transformation was identified to meet the assumption of normal distribution. Based on this, a formal ANOVA was not run. However, by looking at box and whisker plots (Figure 1), it is possible to see that the mean values are similar across the watersheds. Therefore, based on best professional judgment, a citywide EMC should be used. It is also worth noting that the arsenic data contains a large amount of non-detect values (109 out of 158 total data points). Non-detect values were estimated to be ½ the detection limit for the analysis.

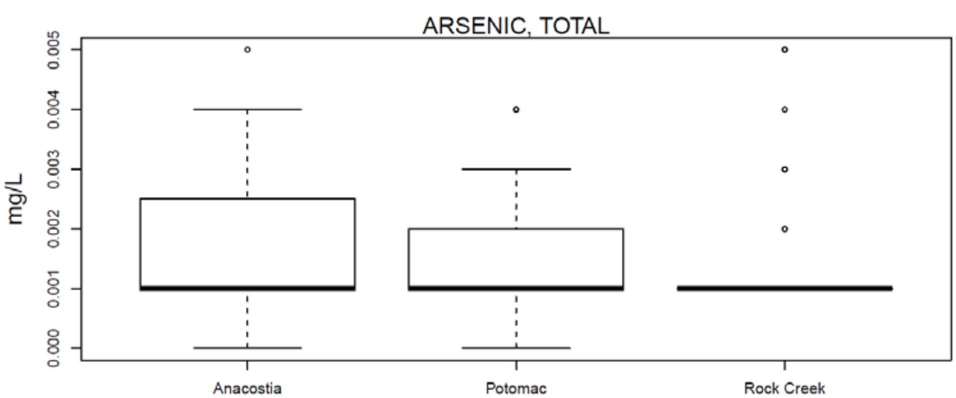

Figure 1: Box and Whisker plot of Arsenic data

Biological Oxygen Demand

The BOD EMC data were found to be log normal. The ANOVA indicated that the difference between the watershed means is significant at the 0.05 level. Therefore, the null hypothesis can be rejected. Further statistical tests should be used to identify pairwise differences. Watershed specific EMC values for BOD should be used for further modeling efforts.

Copper

The copper EMC data were found to be log normal. The ANOVA indicated that the difference between the watershed means is not significant. Therefore, the null hypothesis is accepted. Citywide copper EMCs should be used for further modeling efforts.

Fecal Coliform

The fecal coliform EMC data were found to be log normal. The ANOVA indicated that the difference between the watershed means is not significant. Therefore, the null hypothesis is accepted. Citywide fecal coliform EMCs should be used for further modeling efforts.

Lead

The lead EMC data are independent, but no appropriate transformation was identified to meet the assumption of normal distribution. Based on this, a formal ANOVA was not run. However, by looking at box and whisker plots (Figure 2), it is possible to see that the mean values are similar across the watersheds. Therefore, based on best professional judgment, a citywide EMC should be used.

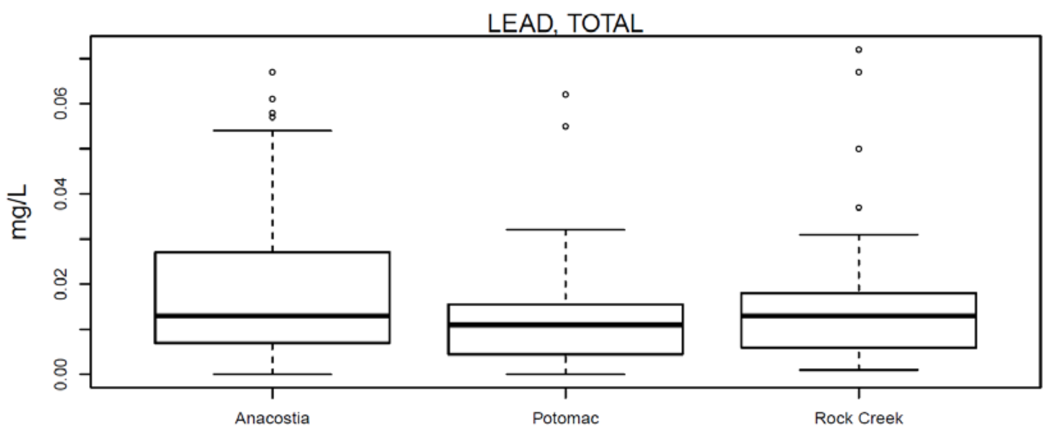

Figure 2: Box and Whisker plot of Lead data

Total Nitrogen

The total nitrogen EMC data were found to be normal with a power transformation (λ=0.5454). The ANOVA indicated that the difference between the watershed means is not significant. Therefore, the null hypothesis is accepted. Citywide total nitrogen EMCs should be used for further modeling efforts.

Oil and Grease

The oil and grease EMC data were found to be normal with a power transformation (λ=-0.5858). The ANOVA indicated that the difference between the watershed means is significant at the 0.05 level. Therefore, the null hypothesis can be rejected. Further statistical tests should be used to identify pairwise differences. It is worth noting that the Oil and Grease data contains a large amount of non-detect values (103 out of 149 total data points). Non-detect values were estimated to be ½ the detection limit for the analysis.

Total Phosphorus

The total nitrogen EMC data were found to be normal with a power transformation (λ=0.3434). The ANOVA indicated that the difference between the watershed means is not significant. Therefore, the null hypothesis is accepted. Citywide total phosphorus EMCs should be used for further modeling efforts.

Total Suspended Solids

The total suspended solids EMC data were found to be log normal. The ANOVA indicated that the difference between the watershed means is significant at the 0.01 level. Therefore, the null hypothesis can be rejected. Further statistical tests should be used to identify pairwise differences.

Zinc

The zinc EMC data were found to be normal with a power transformation (λ=0.4646).The ANOVA indicated that the difference between the watershed means is significant at the 0.05 level. Therefore, the null hypothesis can be rejected. Further statistical tests should be used to identify pairwise differences.

Tukey Honestly Significant Differences Test

The rejection of a null hypothesis with an ANOVA test does not imply that all groups are different from each other, nor does it provide information as to which and how many differences exist. Thus, it is common practice to perform subsequent statistical tests to determine which groups are significantly different from each other. If multiple pairwise t-tests are performed on a single data set, then it is more likely that an incorrect rejection of the null hypothesis occurs (Zar 1999). In other words, with an increasing number of logical tests on the same data, we are increasingly likely to falsely determine that any two groups are different.

A common solution to this issue is the Tukey Honestly Significant Differences Test. This method conducts all t-tests, but uses a significance level which represents the probability of encountering at least one Type-1 error across all pairwise comparisons (Zar 1999). The null hypothesis for each pairwise test is that the compared groups have equal means, or:

$H_0: \mu_1 = \ldots \mu_k$

where H_0 is the null hypothesis

μ_1 is the mean of group 1

μ_2 is the mean of group 2

Multiple Comparisons

There were four pollutants in which watershed means were found to be different than citywide means (BOD, Oil and Grease, TSS, and Zinc) using the ANOVA test. The Tukey HSD test was performed on these pollutants to determine which watershed means differed. Table 2 shows the 95% confidence interval for difference in group means and the corresponding significance value for rejecting the null hypothesis.

Table 2 Summary of Tukey HSD test

Parameter	Watershed 1	Watershed 2	Difference in mean	Lower Bound (95% CI)	Upper Bound (95% CI)	p	Result
BOD	Potomac	Rock Creek	0.3481	-0.1413	0.8374	0.2153	No difference
	Potomac	Anacostia	0.1699	-0.2674	0.6072	0.6296	No difference

Table 2 Summary of Tukey HSD test							
Parameter	**Watershed 1**	**Watershed 2**	**Difference in mean**	**Lower Bound (95% CI)**	**Upper Bound (95% CI)**	**p**	**Result**
	Anacostia	Rock Creek	0.5180	0.0491	0.9868	0.0264	Significant Difference
Oil and Grease	Anacostia	Rock Creek	0.0462	-0.0255	0.1178	0.2819	No difference
	Potomac	Rock Creek	0.0918	0.0183	0.1652	0.0100	Significant Difference
	Potomac	Anacostia	0.0456	-0.0261	0.1172	0.2910	No difference
TSS	Rock Creek	Potomac	0.3369	-0.1211	0.7950	0.1940	No difference
	Anacostia	Potomac	0.6353	0.2129	1.0576	0.0014	Significant Difference
	Anacostia	Rock Creek	0.2984	-0.1467	0.7435	0.2552	No difference
Zinc	Rock Creek	Potomac	0.0073	-0.0374	0.0521	0.9208	No difference
	Anacostia	Potomac	0.0437	0.0030	0.0845	0.0319	Significant Difference
	Anacostia	Rock Creek	0.0364	-0.0057	0.0785	0.1046	No difference

Biological Oxygen Demand

The only statistical difference found for BOD EMC values was between the means of Anacostia and Rock Creek. The results suggest that while these two means are significantly different, the mean of Potomac is not significantly different from the mean of either Anacostia or Rock Creek. Thus the test results are ambiguous and fail to distinguish between the three EMC 'populations' in a way that is applicable to watershed loading.

Oil and Grease

The only statistical difference found for Oil and Grease EMC values was between the means of Potomac and Rock Creek. The results suggest that while these two means are significantly different, the mean of Anacostia is not significantly different from the mean of either Potomac or Rock Creek. Thus the test results are ambiguous and fail to distinguish between the three EMC 'populations' in a way that is applicable to watershed loading.

Total Suspended Solids

The only statistical difference found for TSS EMC values was between the means of Anacostia and Potomac. The results suggest that while these two means are significantly different, the mean of Rock Creek is not significantly different from the mean of either Anacostia or Potomac. Thus the test results are ambiguous and fail to distinguish between the three EMC 'populations' in a way that is applicable to watershed loading.

Zinc

The only statistical difference found for BOD EMC means was between the means of Anacostia and Rock Creek. The results suggest that while these two means are significantly different, the mean of Potomac is not significantly different from the mean of either Anacostia or Rock Creek. Thus the test results are ambiguous and fail to distinguish between the three EMC 'populations' in a way that is applicable to watershed loading.

Tukey Recommendations

The Tukey HSD test failed to identify coherent set of EMC relationships for the four pollutants that the ANOVA identified as having significant differences. This is not an uncommon result for Tukey tests, particularly because the ANOVA is a more powerful test (Zar 1999). Given the ambiguous results, it is recommended that watershed specific EMC values should be used for modeling purpose.

References

Qian, Song. 2010. Environmental and Ecological Statistics with R. CRC Press.

Zar, Jerrold H. 1999. Biostatistical Analysis, Fourth Edition. Prentice Hall.

R Development Core Team (2010). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org/.

Appendix A

Boxplots of all pollutants sampled if wanted

"J:\DDOEIP\Task 1-2 Modeling\ModelDevelopment\EMC\WW_outfall_analyses\StatisticalAnalysis\EMC_BoxplotHistograms.pdf"

Appendix B

Transformed boxplots and histograms if wanted

"J:\DDOEIP\Task 1-2 Modeling\ModelDevelopment\EMC\WW_outfall_analyses\StatisticalAnalysis\EMC_BoxplotHistograms_Transformed_Arsenic.pdf"

Each pollutant has its own pdf.