8.0 Permit Requirements

D. <u>Discharge Characterization</u>

Baltimore County and 10 other municipalities in Maryland have been conducting discharge characterization monitoring since the early 1990's. From this expansive monitoring, a statewide database has been developed that includes hundreds of storms across numerous land uses. Summaries of this dataset and other research performed nationally effectively characterize stormwater runoff in Maryland for NPDES municipal stormwater purposes. These data shall be used by Baltimore County for guidance to improve stormwater management programs and develop watershed restoration projects. Monitoring required under this permit is now designed to assess the effectiveness of stormwater management programs and watershed restoration projects developed by the County. Details about this monitoring can be found in PART III. H.

H. <u>Assessment of Controls</u>

Assessment of controls is critical for determining the effectiveness of the NPDES stormwater management program and progress toward improving water quality. Therefore, Baltimore County shall use chemical, biological, and physical monitoring to document work toward meeting the watershed restoration goals identified above. Additionally, the County shall continue physical stream monitoring in the Windlass Run to assess the implementation of the *2000 Maryland Stormwater Design Manual* or other innovative stormwater management technologies approved by MDE. Specific monitoring requirement are described below.

1. <u>Watershed Restoration Assessment</u>

The County shall monitor the Scotts Level Branch, or, select and submit for MDE's approval a new watershed restoration project for monitoring. Ample time shall be provided so that pre-restoration monitoring, or characterization monitoring can take place. Priority will be given to new practices where little monitoring data exist or where the cumulative effects of watershed restoration activities can be assessed. An outfall and associated in-stream station, or other locations based on an approved study design shall be monitored. The minimum criteria for chemical, biological, physical monitoring are as follows:

a. <u>Chemical Monitoring</u>

i. Twelve (12) storm events shall be monitored per year at each monitoring location with at least three occurring per quarter. Quarters shall be based on the calendar year. If extended dry weather periods occur, baseflow samples shall be taken at least once per month at the monitoring stations if flow is observed;

ii. Discrete samples of stormwater flow shall be collected at the monitoring stations using automated or manual sampling methods. Measurements of pH and water temperature shall be taken;

iii. At least three (3) samples determined to be representative of each storm event shall be submitted to a laboratory for analysis according to methods listed under 40 CFR Part 136 and event mean concentrations (EMC) shall be calculated for:

Biochemcial Oxygen demand (BOD_5)	Total Lead
Total Kjeldahl Nitrogen (TKN)	Total Copper
Nitrate plus Nitrite	Total Zinc
Total Suspended Solids	Total Phosphorus
Total Petroleum Hydrocarbons (TPH)	Oil and Grease*
Fecal Coliform or E. coli	(*Optional).

iv. Continuous flow measurements shall be recorded at the in-stream monitoring station or other practical locations based on an approved study design. Data collected shall be used to estimate annual and seasonal pollutant loads and for the calibration of the watershed assessment models.

b. Biological Monitoring

i. Benthic macroinvertebrate samples shall be gathered each Spring between the outfall and in-stream stations or other practical locations based on an approved study design; and

ii. The County shall use the U.S. Environmental Protection Agenciy's (EPA) Rapid Bioassessment Protocols (RBP), Maryland Biological Stream Survey (MBSS), or other similar method approved by MDE.

c. Physical Monitoring

i. A geomorphologic stream assessment shall be conducted between the outfall and in-stream monitoring locations or in a reasonable area based on an approved study design. This assessment shall be include an annual comparison of permanently monumented stream channel cross-sections and the stream profile;

ii. A stream habitat assessment shall be conducted using techniques defined by the EPA's RBP, MBSS, or other similar method approved by MDE; and

iii. A hydrologic and/or hydraulic model shall be used (e.g., TR-20, HEC-2, HSPF, SWMM, etc.) to analyze the effects of rainfall discharge rates; stage; and if necessary, continuous flow on channel geometry.

d. Annual Data Submittal: The County shall describe in detail its monitoring activities for the previous year and include the following:

i. EMCs submitted on MDE's long-term monitoring database as specified in PART IV below;

Chemical, biological, and physical monitoring results and a combined analysis for the Scotts Level Branch or other approved monitoring

ii. locations; and

iii. Any requests and accompanying justifications for proposed modification to the monitoring program.

2. Stormwater Management Assessment

The County shall continue monitoring the Windlass Run for determining the effectiveness of the *2000 Maryland Stormwater Design Manual* for stream channel protection. Physical stream monitoring protocols shall include:

a. An annual stream profile and survey of permanently monumented cross-sections in the Windlass Run to evaluate channel stability in conjunction with the implementation of the *2000 Maryland Stormwater Design Manual*.

b. A comparison of the annual stream profile and survey of the permanently monumented cross-sections with baseline conditions for assessing areas of aggradation and degradation; and

c. A hydrologic and/or hydraulic model shall be used (e.g., TR-20, HEC-2, HEC-RAS, HSPF, SWMM, etc.) to analyze the effects of rainfall discharge rates; stage; and, if necessary, continuous flow on channel geometry.

8.1 Introduction

The third term of the Baltimore County – NPDES MS4 Permit that became effective June 15, 2005 resulted in a change in the long-term monitoring location. The long-term monitoring site was moved from Spring Branch in the Loch Raven watershed to Scotts Level Branch in Gwynns Falls watershed. This report will present the research design and monitoring data for Scotts Level Branch (8.2, 8.3), and the data for Windlass Run (8.4).

8.2 Scotts Level Branch Long-Term Monitoring

The Baltimore County NPDES Municipal Stormwater Discharge Permit requires monitoring of restoration effectiveness. For the first two rounds of the 5-year permit, the Spring Branch subwatershed had been monitored to determine the effectiveness of the stream restoration in promoting stream stability, reduction in pollutant loads, and improvement in the benthic macroinvertebrate community. Using the experience gained in monitoring Spring Branch, a more effective monitoring program has been designed for the Scotts Level Branch subwatershed, as detailed below.

Scotts Level Branch is located in the Gwynns Falls watershed in the Patapsco/Back River Basin. The 303(d) lists these waters as being impaired by nutrients, suspended sediments, and fecal coliform bacteria. In addition, Scotts Level Branch is listed as impaired for biology. The TMDLs for nutrients and bacteria have been completed. The TMDL for nutrients has identified a reduction of 15% nitrogen and phosphorus loads from urban non-point sources as needed to meet water quality standards in Baltimore Harbor. The TMDL for bacteria has identified a ~98% reduction for human and domestic pet sources.

While the Spring Branch study monitored the effectiveness of one large restoration project, the Scotts Level Branch monitoring is designed on the basis that a number of restoration projects will be implemented within the subwatershed over a period of time. The ability to detect effects of individual restoration projects will be dependent on the size of the restoration project in relation to the total subwatershed size. Therefore each restoration project will be monitored for project effectiveness, dependent on staff availability. The cumulative effects of restoration will be measured at the long-term in-stream monitoring site.

In order to assess restoration progress in the Scotts Level Branch subwatershed, a paired watershed, before-after design concept will be used. Two additional subwatersheds within Gwynns Falls, Powder Mill Run and Upper Gwynns Falls (above Gwynnbrook Road) have been selected as the "paired" subwatersheds (Figure 8-1).

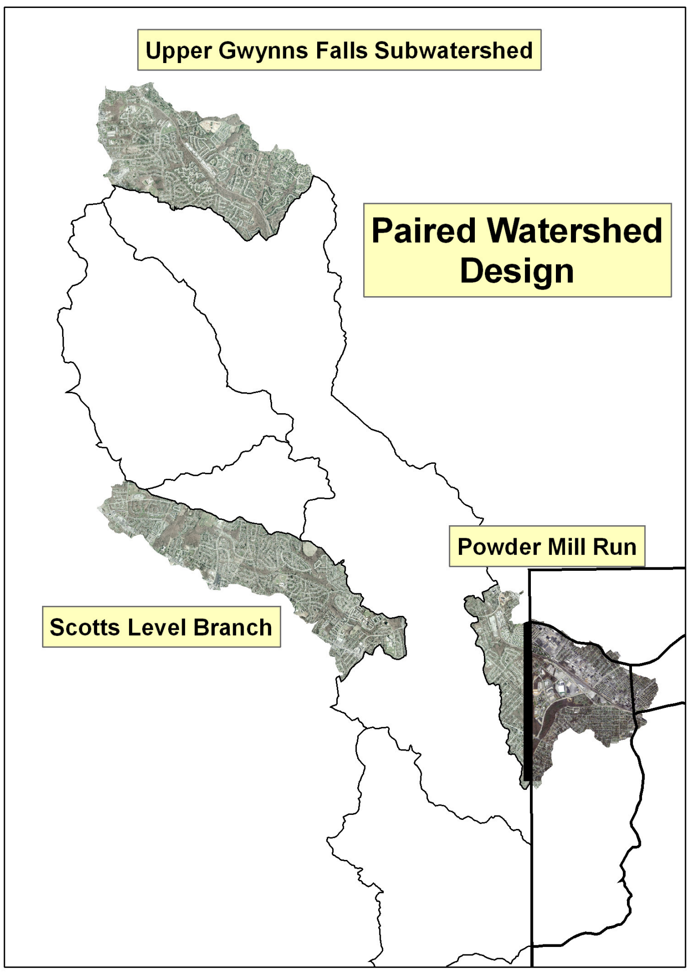


Figure 8-1: Subwatersheds to be used in the Paired Watershed Monitoring Design.

Table 8-1 presents a comparison between the three subwatersheds in relation to overall size, land use composition, percent impervious cover, and stream length. The third subwatershed (Upper Gwynns Falls) was added due to the fact that Baltimore City will be doing stream restoration work in the Powder Mill Run subwatershed. Restoration work will also be conducted in the Upper Gwynns Falls subwatershed in the future, with restoration work in Scotts Level Branch beginning in a few years.

Table 8-1: Scotts Level Branch, Powder Mill Run, and Upper Gwynns Falls Information

Parameter	Scotts Level Branch	Powder Mill Run	Upper Gwynns Falls
Area (acres)	2,186	2,436	2,637
Land Use			
% Residential	91.1	63.4	74.9
% Commercial/Ind	6.0	32.5	6.3
% Forest	2.9	4.1	11.6
Impervious Cover (%)	23.7	33.8	21.4
Stream Miles	8.0	5.9	11.1

The monitoring will consist of flow monitoring, chemical monitoring, geomorphological monitoring, and biological monitoring as described below.

8.2.1 Monitoring Design

8.2.1.1 Flow Monitoring

Each of the three subwatersheds has had a gage installed and operated by the US Geological Survey (Table 8-2) with funding provided in total for the Powder Mill Run and Scotts Level Branch gages and in part for the Upper Gwynns Falls gage (Delight). USGS is providing the rating curves for the gages and annual data. A 36" outfall near the headwater of Scotts Level Branch is being monitored for discharge and chemistry. A weir was installed to permit continuous flow monitoring with a water level sensor installed and operated by Baltimore County. Due to a malfunction in the continuous flow meter, the data for the outfall will not be included in this report. This outfall has a drainage area of 15.0 acres with ~35% impervious cover. The land use is ~88% medium residential and therefore representative of the major land use in each of the subwatersheds.

Table 8-2: USGS Gage Information

Gage Number	Location	Measurements			Real Time	Period of Record
		Stage	Discharge	Precipitation		
01589197	Upper Gwynns Falls	X	X	X	Yes	October, 1998 - Current
01589305	Powder Mill Run	X	X		Yes	November, 2005 – Current
01589290	Scotts Level Branch	X	X		Yes	November, 2005 – Current

The flow monitoring will be used in conjunction with the chemical monitoring (described below) to determine pollutant loads and in relation to the geomorphological monitoring. Over time the flow data will be assessed for any changes in relation to restoration work that is conducted in the subwatersheds.

8.2.1.2 Chemical Monitoring

The chemical monitoring will include both storm event and baseflow monitoring components. The standard list of chemicals detailed in the permit requirements will be analyzed. Figure 8-2 displays the location of the chemical monitoring sites in Scotts Level Branch by type.

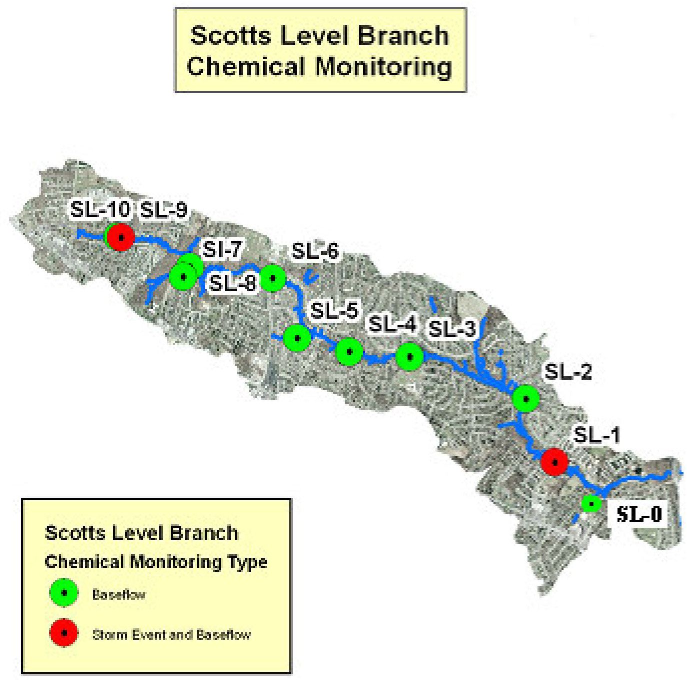


Figure 8-2: Scotts Level Branch Chemical Monitoring Locations

Storm Event Monitoring

Storm event monitoring will occur at each of the three USGS gages and at the outfall. The two Scotts Level Branch storm event monitoring sites (SL-1 in-stream, and SL-9 outfall) will be monitored for 12 storms each calendar year seeking to acquire samples for the entire hydrograph. At the other USGS gage at the Upper Gwynns Falls storm event grab samples will be collected to represent a range of stage discharges. The data for the Powder Mill site will come from Baltimore City. The data from all four sites will be analyzed using regression analysis to determine the relationship between discharge and pollutant concentration. These relationships will then be used in conjunction with the flow data collected from the USGS operated gages and the water level sensor operated by DEPRM. The results and subsequent analysis following restoration will be used to determine annual loads and any load reductions due to restoration activities.

The pollutant load data collected from the Scotts Level Branch outfall will be used to estimate the wash load (the load derived from the land surface). While the pollutant load estimate derived from the Scotts Level Branch in-stream site will estimate the watershed load, which includes both the wash load and the load derived from stream bank erosion. The geomorphological analysis (see below) will attempt to determine the stream channel erosion component via changes in the channel cross-section and analysis of the pollutant concentration of the stream bank and bed. Thus the wash load (derived from the outfall data) plus the stream erosion load (derived from the geomorphological data) should equal the watershed load (derived from the in-stream monitoring data). These data should provide an estimate of the relative proportions of pollutants derived from the land surface and the stream corridor. This will have important implications for restoration efforts in urban settings. If, as the literature suggests, a large component of the sediment and total phosphorus load is derived from the stream channel, then in order to meet sediment and phosphorus load reduction requirements for TMDLs and the Chesapeake Bay Program additional effort will need to be focused on stream restoration.

Baseflow Monitoring

Scotts Level Branch baseflow monitoring will occur at the outfall (SL-9), three tributary locations, and six mainstem locations for a total of 11 baseflow monitoring sites (Figure 8-2). The site below SL-01 was added last year in order to collect some information on what may be coming from the tributary below the gage. Within Powder Mill Run baseflow monitoring will take place at the USGS gage and two up-stream sites that are representative of each major branch (one in the County and one in the City). Baseflow monitoring in Upper Gwynns Falls will occur only at the USGS gage site. The baseflow sites in Scotts Level Branch, Powder Mill Run, and Upper Gwynns Falls will be monitored quarterly during baseflow conditions (preceded by a minimum of 72 hours dry weather).

Analysis of baseflow pollutants is especially important in relation to nitrogen. Research work conducted by the County, indicates that ~50% of the nitrogen load occurs during dry weather conditions. The baseflow sampling will be used in conjunction with the storm event sampling to partition the annual discharge and pollutant load between baseflow (dry weather) conditions and storm event conditions.

8.2.1.3 Geomorphological Monitoring

The geomorphological monitoring is intended to provide an estimate of stream erosion and deposition rates, and an estimate of the pollutant load derived from stream channel erosion. In addition, it is intended over time to provide an estimate of the effects of restoration on stream stability on both a project basis and over the entire subwatershed.

In order to assure unbiased selection of cross-section locations, Scotts Level Branch and Powder Mill Run were divided into 30 equal length stream segments, 20 in Scotts Level Branch (Figure 8-3) and 10 in Powder Mill Run (Figures 8-4). Within each segment a point was randomly selected, using a GIS subroutine, for location of permanent cross sections. These cross sections will be monitored annually with the results overlaid to provide an assessment of the amount of channel change. Three longitudinal profile reaches will be selected in Scotts Level Branch for annual assessment.

Stream bank and bed core samples will be collected in the vicinity of the permanent cross sections for laboratory analysis of bulk density, particle size distribution, total nitrogen, and total phosphorus. These will be one-time sample collections, with 10% of the sites, randomly selected, for a second round of sample collection to provide an analysis of annual variability.

Based on the annul and long term change, and the results of the core samples, the estimated annual sediment, total nitrogen, and total phosphorus loads will be calculated for comparison with the chemical monitoring results derived from the in-stream monitoring site.

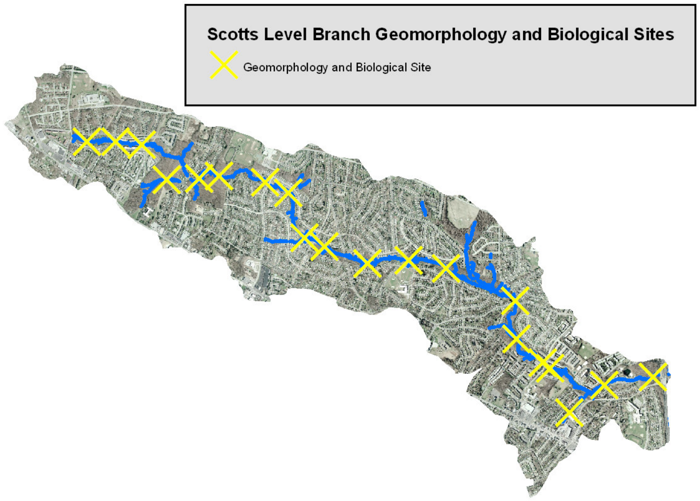


Figure 8-3: Scotts Level Branch Geomorphological and Biological Monitoring Site Locations

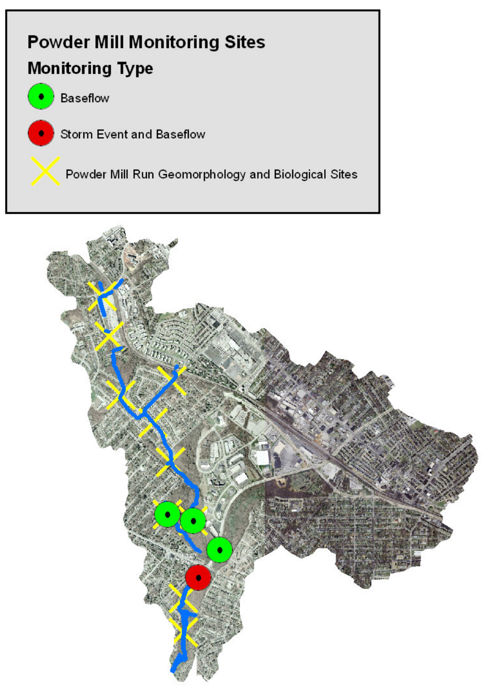


Figure 8-4: Powder Mill Run Geomorphological and Biological Monitoring Sites

8.2.1.4 Biological Monitoring

Benthic macroinvertebrate and fish sampling is conducted annually at five fixed stations on Scotts Level Branch and three fixed stations on Powder Mill Run, during the appropriate index periods (March-April for macroinvertebrates, June-September for fish). Maryland Biological Stream Survey (MBSS) methods are followed. Macroinvertebrate identification is to the Genus taxonomic level or the lowest practical identification level. At the time of sample collection, the appropriate MBSS stream habitat assessment is conducted.

The biological monitoring data are integrated with the cross sectional and habitat data to produce an overall assessment of conditions in the subwatersheds. In addition, the results will be compared between the two subwatersheds and to reference sites within Baltimore County. Inter-annual comparisons and changes in the biological community will be related to restoration progress within Scotts Level Branch.

8.3 Scotts Level Branch Long-Term Site Monitoring Results

8.3.1 Flow Monitoring

The U.S. Geological Survey under an agreement with Baltimore County installed a continuous gage on Scotts Level Branch where it crosses Rolling Road on September 29, 2005. This site is designated as SL-01. They also installed a continuous gage on Powder Mill Run below Liberty Road. In the fall of 2007, a weir with a continuous gage was installed at the outfall in Scotts Level Branch to provide a continuous discharge record. Issues involving rating curve development and recording water depth data need to be resolved prior to reporting data from the outfall. Only the data for Scott's Level Branch instream site are analyzed in this report.

Precipitation Data: Hourly and daily precipitation data used were acquired from the Department of Public Works rain gage located on Carlson Lane. These data were recorded in conjunction with the Scotts Level Branch discharge data discussed below. Calendar year 2009 had one hundred forty-six days of recorded measurable precipitation. The daily data were analyzed for precipitation amount (Table 8-3). As can be seen from Table 8-3, 35% of the days recorded less than a 0.1 inch of precipitation. Precipitation over one inch occurred on only 9% of the days, but accounted for about 37% of the total amount of the precipitation in 2009. The maximum daily rainfall was 3.28 inches, recorded on September 11, 2009. A total of 51.36 inches of precipitation, more than the long-term average (~42 inches), was recorded at the Department of Public Works Carlson Lane rain gauge for 2009.

Table 8- 3: Precipitation Data Analysis for Calendar 2009

Precipitation Category	# of Days	% Days	Total Amount	% of accumulation
<.1	51	35%	1.83	3.56%
.1-<.5	59	40%	13.47	26.23%
.5-<1.0	23	16%	17.15	33.39%
1.0-<1.5	9	6%	10.37	20.19%
1.5-<2.0	3	2%	5.26	10.24%
2.0-<2.5	0	0%	0	0.00%
2.5-<3.0	0	0%	0	0.00%
3.0-3.5	1	1%	3.28	6.39%
Total	**146**		**51.36**	

Often storms span more than one day. The hourly precipitation data were used to delimit individual storms. All precipitation was counted as a storm, and the end of the storm event defined as about thirty-six hours with no rainfall recorded. A total of 65 distinct storms were identified during 2009. These storms were analyzed for amount of precipitation, intensity (inches/hour), and duration. The results of this analysis are presented in Table 8-4.

Table 8-4: 2009 Precipitation Amount, Intensity, and Duration by Category

Precipitation Category (Inches)	Accumulation Amount				Intensity (inches/hour)			Duration (hours)		
	# Storms	% Storms	Total Acc.	% Acc.	Intensity Category	# Storm	% storms	Duration Category	# storms	% storms
< .1	11	16.9	0.42	0.8	< .1	57	87.7	<1	11	16.9
.1 - <.25	18	27.7	2.44	4.8	.1 - <.25	4	6.2	1 – <3	7	10.8
.25 - <.50	7	10.8	2.81	5.5	.25 - <.50	4	6.2	3 – <6	4	6.2
.50 - <.75	4	6.2	2.58	5.0	.50 - <.75	0	0.0	6 – <9	4	6.2
.75 – <1.00	6	9.2	5.03	9.8	.75 – <1.00	0	0.0	9 – <12	4	6.2
1.00 – <1.50	6	9.2	7.66	14.9	1.00 – <1.50	0	0.0	12 – <15	0	0.0
1.50 – <2.00	5	7.7	8.47	16.5	1.50 – <2.00	0	0.0	15 – <18	2	3.1
2.00 – <3.00	5	7.7	11.55	22.5	2.00 – <3.00	0	0.0	18 – <21	1	1.5
3.00 – 4.00	2	3.1	6.39	12.4	3.00 – 4.00	0	0.0	21 – 24	1	1.5
>4.00	1	1.5	4.01	7.8	>4.00	0	0.0	>24	31	47.7
Total	**65**		**51.36**			**65**			**65**	

45% of the storms were less than 0.25 inches in total amount of precipitation, but these storms accounted for only 5.6% of the total amount of rainfall. Only 29.2% of the storms at SL-01 were over one inch in total amount of rainfall and but these storms accounted for almost three-quarters (74.1%) of the total amount of precipitation in 2009. The largest storm for 2009 recorded 4.1 inches of precipitation over about a three and a half day period. The highest intensity recorded was 0.4 inches per hour (four storms). The majority of storms (87.7%) highest recorded hourly intensity were less than one-tenth inch per hour. About half of the storms (47.5%) were greater than 24 hours in duration.

Flow Data: The Scotts Level Branch gage data includes 15-minute discharge readings from the period of October 1, 2005 to December 31, 2009. The entire record was analyzed for storm events. The data were visually scanned to determine the inception of each storm event. The termination of the event was based on comparison of discharge to the daily baseflow developed from the USGS Part program, a computerized method of baseflow record estimation. A total of 249 storm events for the period of record were identified, of which, 59 occurred in the calendar year 2009. Figure 8-5 displays the daily discharge and precipitation for calendar year 2009. The correlation coefficient was determined to be r = 0.999. The database was further coded to reflect the concurrence of storms as indicated by the increase in discharge and the precipitation from recorded at the DPW Carlson Lane gage. This resulted in 66 storms that had an overlap of both precipitation and storm discharge, and an increase in the correlation coefficient to r = 0.998, during 2009.

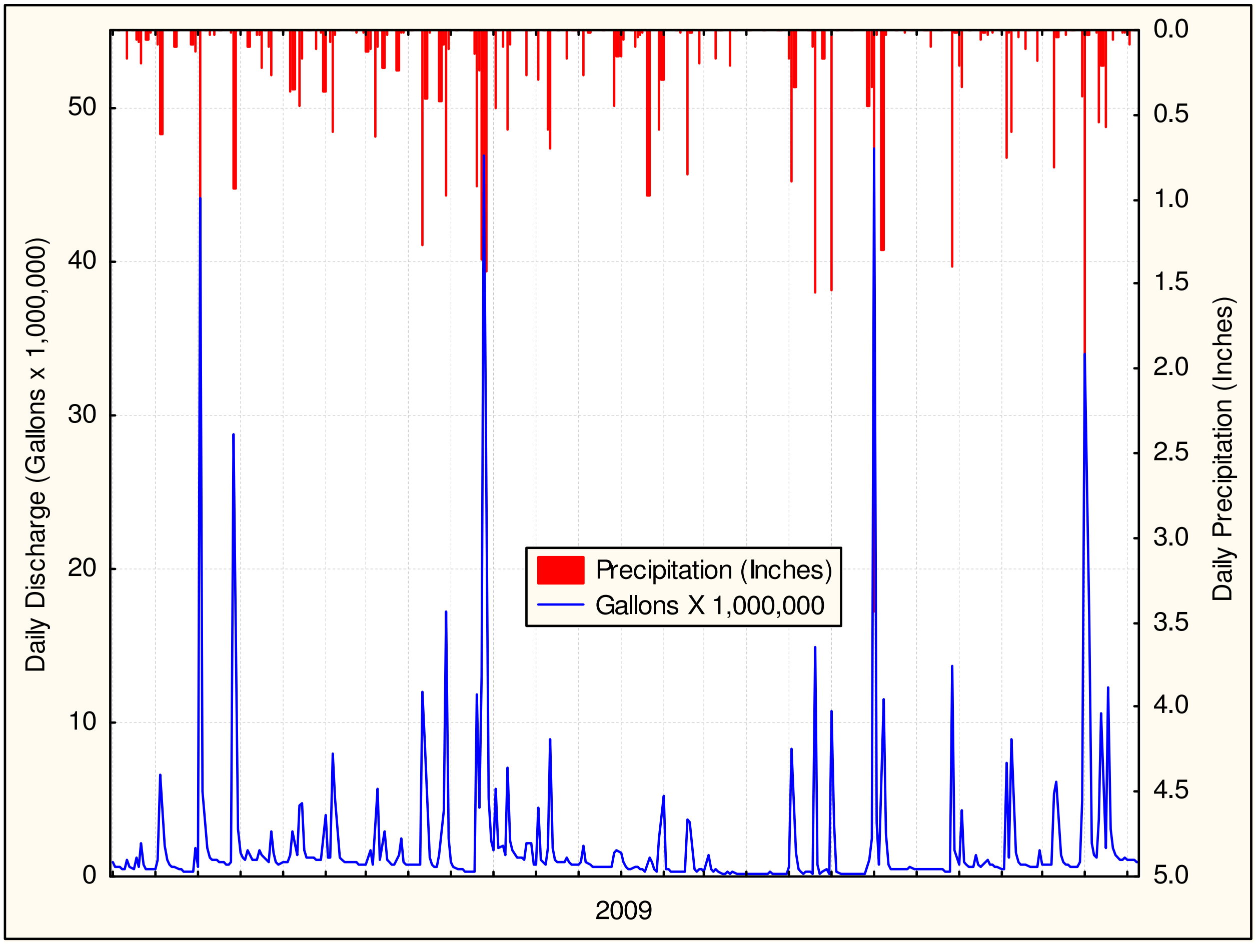


Figure 8-5: Calendar year 2009 Daily Precipitation and Discharge

Using this set of data for the 66 storms, the runoff coefficient was calculated for each storm. The average runoff coefficient was 0.250, with a maximum of 0.729 and a minimum of 0.042. The storm data sets were further analyzed to determine the proportion of runoff to total precipitation, and the relative proportions of baseflow and storm event runoff. These data were analyzed by season for calendar year 2009. The results are presented in Table 8-5.

Table 8-5: Seasonal Precipitation and Runoff Characteristics

Parameter	Fall	Winter	Spring	Summer	Total
Precipitation Amount	16.50	4.25	19.67	10.94	51.36
Precipitation %	32.1 %	8.3 %	38.3%	21.3 %	---
% of precipitation volume accounted for by Runoff	35.1%	78.6%	33.3%	24.2%	35.7%
% of precipitation volume accounted for by Evapotranspiration	64.9 %	21.4%	66.7%	75.8%	64.3 %
% of stream flow accounted for by Storm flow	81.2%	66.1%	88.5%	74.6%	80.1%
% of stream flow accounted for by Baseflow %	18.8%	33.9%	11.5%	25.4%	19.9%

Table 8.5 shows the fall and spring exhibited higher precipitation than the spring and summer. About thirty-six percent of the precipitation was accounted for by stream flow, while the balance was assumed to be evapotranspiration. The evapotranspiration is the result of the evaporation of water, which is temperature dependant and the transpiration of water due to plants. Thus the expectation is that winter should exhibit the lowest evapotranspiration rates and summer the highest rate. The results bear this out with 21.4% and 75.8% evapotranspiration rates for winter and summer, respectively. As is characteristic of urban watersheds, there is a shift in runoff from baseflow dominated to storm flow dominated. For 2009, 80.1% of the flow was determined to be storm flow using the criteria described above, while only 19.9% was characterized as baseflow.

8.3.2 Chemical Monitoring

The data analysis for chemical monitoring includes three components, storm event monitoring (8.3.2.1), baseflow monitoring (8.3.2.2), and the calculation of pollutant loads (8.3.2.3)

8.3.2.1 Storm Event Monitoring Results

The chemical results from the storm event monitoring at the Scotts Level Branch in-stream monitoring site was analyzed in conjunction with the discharge data. Both the chemical and the discharge data were $\log_{10}$ transformed prior to regression analysis. The data for the regression equations was censored by removing any chemical data that was below the detection limit for any constituent. Regression equations were determined for Total Suspended Solids, TKN, Nitrate/Nitrite, Total Nitrogen, and Total Phosphorus, Total Copper, Total Lead, Total Zinc, Chloride and Sodium. The results are displayed in Table 8-6 and graphically in Appendix 1.

Table 8-6: Regression Equations Relationship Between Discharge (CFS) and Pollutant Concentrations

Parameter	Regression Equation
Total Suspended Solids	0.9968+0.4159*(log cfs)
Total Kjeldahl Nitrogen	-0.337+0.1721*(log cfs)
Nitrate/Nitrite	-0.2515-0.1019*(log cfs)
Total Nitrogen	-0.0308+0.1016*(log cfs)
Total Phosphorus	-1.2024+0.2531*(log cfs)
Total Copper	-2.2425+0.1424*(log cfs)
Total Lead	-3.0883+0.369*(log cfs)
Total Zinc	-2.1506+0.3104*(log cfs)
Chloride	1.6898-0.1409*(log cfs)
Sodium	1.5724-0.0852*(log cfs)

Total Suspended Solids, Total Phosphorus, Total Lead and Total Zinc exhibited strong positive relationships with discharge, while no parameters displayed a strong negative relationship with discharge. The TKN, TN (TKN+Nitrate/Nitrite Nitrogen) and Total Copper relationship with discharge was relatively weak and positive. Nitrate/Nitrite, Chloride, and Sodium displayed a weak and negative relationship.

The regression equations were used to calculate the chemical concentrations for each 15-minute interval for recorded discharge. The log chemical concentrations were then back transformed. This permitted the calculation of the flow weighted Event Mean Concentrations for the 2009 storms. Results are shown graphically in Appendix 2.

8.3.2.2 Baseflow Monitoring Results

Scotts Level Branch baseflow monitoring occurred at the outfall (SL-9), three tributary locations, and six mainstem locations for a total of 11 baseflow monitoring sites (Figure 8-2). Within Powder Mill Run baseflow monitoring will take place at the USGS gage and two up-stream sites that are representative of each major branch (one in the County and one in the City). Baseflow monitoring in Upper Gwynns Falls will occur only at the USGS gage site. The baseflow sites in Scotts Level Branch, Powder Mill Run, and Upper Gwynns Falls will be monitored quarterly during baseflow conditions (preceded by a minimum of 72 hours dry weather).

Analysis of baseflow pollutants is especially important in relation to nitrogen. Research conducted by the County indicates that ~50% of the nitrogen load occurs during dry weather conditions. The baseflow sampling will be used in conjunction with the storm event sampling to partition the annual discharge and pollutant load between baseflow (dry weather) conditions and storm event conditions.

Pollutant loads were examined for each of the baseflow sites. Total Suspended solids were excluded from the baseflow analyses because limited conclusions can be drawn from this parameter during a baseflow sample. Many factors can affect the total suspended solids including small construction projects and car washing. These factors may only affect the stream for the limited time the sample is taken and can be misleading if extrapolated for a longer period of time. The results obtained were standardized to both daily pollutant load for drainage area and a daily load per acre and are shown in table 8-7.

Table 8-7: 2009 Daily Baseflow Pollutant Loads for Scott's Level Branch Sites

Site	Acres	TKN (mg/L)	TKN Daily Load (#s)	TKN Daily Load (#s per acre)	NO_2/NO_3 (mg/L)	NO_2/NO_3 Daily Load (#s)	NO_2/NO_3 Daily load (#s per acre)
SL-00 – Trib.	67	<0.1	N/A	N/A	0.88	6.19	0.0924
SL-01	2,186	0.29	2.12	0.0010	0.76	5.28	0.0024
SL-02	1,908	0.23	1.01	0.0005	0.83	3.73	0.0020
SL-03	1,434	0.31	0.63	0.0004	0.89	1.89	0.0013
SL-04	1,167	0.28	1.17	0.0010	0.85	3.76	0.0032
SL-05 – Trib.	202	0.31	0.11	0.0005	2.27	1.41	0.0070
SL-06	742	0.24	0.55	0.0007	0.75	1.90	0.0026
SL-07 – Trib.	62	0.30	0.03	0.0005	0.76	0.09	0.0015
SL-08	451	0.23	0.46	0.0010	0.85	1.50	0.0033
SL-09 - outfall	15	0.48	0.10	0.0067	3.23	0.72	0.0480
SL-10	265	0.23	0.31	0.0012	1.02	2.52	0.0095
Site	**Acres**	**TN (mg/L)**	**TN Daily Load (#s)**	**TN Daily Load (#s per acre)**	**TP (mg/L)**	**TP Daily Load (#s)**	**TP Daily Load (#s per acre)**
SL-00 – Trib.	67	<0.016	N/A	N/A	<0.025	N/A	N/A
SL-01	2,186	1.06	8.15	0.0037	<0.025	N/A	N/A
SL-02	1,908	1.12	4.84	0.0025	<0.025	N/A	N/A
SL-03	1,434	1.19	2.51	0.0018	<0.025	N/A	N/A
SL-04	1,167	1.13	4.94	0.0042	<0.025	N/A	N/A
SL-05 Trib.	202	2.49	1.18	0.0058	<0.025	N/A	N/A
SL-06	742	0.99	2.45	0.0033	5.98	19.58	0.0264
SL-07 Trib.	62	1.05	0.10	0.0016	5.04	0.68	0.0110
SL-08	451	1.34	2.68	0.0059	<0.025	N/A	N/A

SL-09 - Outfall	15	4.55	0.83	0.0553	0.08	0.01	0.0007
SL-10	265	1.17	1.73	0.0065	<0.025	N/A	N/A

A number of observations are possible based on the information in Table 8-7. First, site SL-09, an outfall with only 15 acres of drainage area is highest in daily load per acre for TKN, NO2/NO3, and TN. SL-06 is the highest for TP. These high concentrations are to be expected at an outfall. Even during dry weather, the outfall may receive runoff from residential activities such as car washing. The second observation is there is in general a decrease in nitrate/nitrite concentrations in a downstream direction (SL-10 → SL-1). The same pattern of decrease in a downstream direction is exhibited by total phosphorus and total nitrogen. This could be the result of nutrient uptake by biota in the stream as the water passes downstream.

8.3.2.3 Pollutant Load Calculations

Data from the USGS gage was recorded at 15-minute intervals from October 1, 2005 through December 31, 2009 resulting in 149,087 individual discharge readings. The regression equations determined above from the storm event samples, relating pollutant concentration to discharge, were used to determine the pollutant concentration for each 15-minute interval. From this data the load was calculated for each 15-minute interval using the following formula:

$P_L = (P_C * .000008345) * (CFS * 448.8 * 15)$, where

P_L = Pollutant Load,
P_C = Pollutant Concentration,
.000008345 = Conversion factor to convert mg/L to pounds per gallon,
CFS = Cubic feet per second,
448.8 = Conversion factor to convert cubic feet per second to gallons per minute
15 = number of minutes in the interval.

The results obtained by the above formula were standardized to both an annual pollutant load for the drainage area and an annual pollutant load per acre. In addition, the data were analyzed for seasonal loads, storm event pollutant loads, and the percent of the load delivered during baseflow conditions (Table 8-8).

Table 8-8: Pollutant Load Characteristics for USGS gaged site calendar year 2009

Parameter	Pounds/ Year	Pounds/year Standardized by average rainfall	Pound/Acre Standardized by average rainfall	% by Season	Storm Event lbs.	% Load as Storm Flow	Baseflow lbs.	% Load as Baseflow
TSS								
Fall	120,383	98,303	44.97	29.5%	113,044	93.9%	7,339	6.1%
Winter	64,600	52,751	24.13	15.8%	57,466	89.0%	7,134	11.0%
Spring	161,187	131,624	60.21	39.5%	156,465	97.1%	4,722	2.9%
Summer	62,391	50,948	23.31	15.3%	59,142	94.8%	3,250	5.2%
Total	**408,561**	**333,627**	**152.62**		**386,117**	**94.5%**	**22,445**	**5.5%**

Parameter	Pounds/ Year	Pounds/year Standardized by average rainfall	Pound/Acre Standardized by average rainfall	% by Season	Storm Event lbs.	% Load as Storm Flow	Baseflow lbs.	% Load as Baseflow
TKN								
Fall	2,259	1,845	0.84	31.0%	1,977	87.5%	282	12.5%
Winter	1,243	1,015	0.46	17.1%	958	77.0%	285	23.0%
Spring	2,720	2,221	1.02	37.3%	2,530	93.0%	190	7.0%
Summer	1,063	868	0.40	14.6%	911	85.7%	151	14.2%
Total	**7,285**	**5,949**	**2.72**		**6,376**	**87.5%**	**908**	**12.5%**
NO_2/NO_3								
Fall	1,216	993	0.45	31.6%	936	77.0%	280	23.0%
Winter	733	598	0.27	19.0%	435	59.4%	297	40.6%
Spring	1,338	1,093	0.50	34.7%	1,140	85.2%	198	14.8%
Summer	564	461	0.21	14.7%	376	66.6%	189	33.4%
Total	**3,851**	**3,144**	**1.44**		**2,887**	**75.0%**	**964**	**25.0%**
TN								
Fall	3,629	2,964	1.36	31.3%	3,088	85.1%	541	14.9%
Winter	2,029	1,657	0.76	17.5%	1,475	72.7%	554	27.3%
Spring	4,256	3,475	1.59	36.7%	3,887	91.3%	369	8.7%
Summer	1,678	1,370	0.63	14.5%	1,370	81.7%	308	18.3%
Total	**11,592**	**9,466**	**4.33**		**9,820**	**84.7%**	**1,772**	**15.3%**
TP								
Fall	409	334	0.15	30.6%	368	89.9%	41	10.0%
Winter	222	181	0.08	16.6%	181	81.6%	41	18.4%
Spring	508	415	0.19	38.0%	481	94.7%	27	5.3%
Summer	198	161	0.07	14.8%	177	89.4%	21	10.4%
Total	**1,337**	**1,092**	**0.50**		**1,207**	**90.3%**	**129**	**9.7%**
Total Copper								
Fall	25.4	20.8	0.0095	31.1%	22.0	86.6%	3.4	13.5%
Winter	14.1	11.5	0.0053	17.2%	10.6	75.1%	3.5	24.7%
Spring	30.3	24.7	0.0113	37.1%	28.0	92.3%	2.3	7.7%
Summer	11.9	9.7	0.0044	14.5%	10.0	83.9%	1.9	15.8%
Total	**81.7**	**66.7**	**0.0305**		**70.5**	**86.3%**	**11.1**	**13.6%**
Total Lead								
Fall								
Winter	8.2	6.7	0.0031	29.8%	7.6	93.1%	0.6	7.1%
Spring	4.4	3.6	0.0016	16.0%	3.8	87.5%	0.6	12.9%
Summer	10.8	8.8	0.0040	39.0%	10.4	96.1%	0.4	3.5%
Total	4.2	3.4	0.0016	15.1%	3.9	92.9%	0.3	6.4%
	27.6	**22.5**	**0.0103**		**25.8**	**93.4%**	**1.8**	**6.5%**
Total Zinc								
Fall								
Winter	56.9	46.4	0.0212	30.2%	52.1	91.5%	4.8	8.5%
Spring	30.7	25.1	0.0115	16.3%	25.9	84.5%	4.8	15.5%
Summer	72.5	59.2	0.0271	38.5%	69.4	95.7%	3.2	4.4%
Total	28.1	23.0	0.0105	15.0%	25.8	91.9%	2.3	8.2%
	188.2	**153.7**	**0.0703**		**173.2**	**92.0%**	**15.0**	**8.0%**

Parameter	Pounds/ Year	Pounds/year Standardized by average rainfall	Pound/Acre Standardized by average rainfall	% by Season	Storm Event lbs.	% Load as Storm Flow	Baseflow lbs.	% Load as Baseflow
Sodium								
Fall	84,647	69,122	31.62	31.6%	65,760	77.7%	18,887	22.3%
Winter	50,636	41,349	18.92	18.9%	30,627	60.5%	20,009	39.5%
Spring	93,587	76,422	34.96	34.9%	80,257	85.8%	13,330	14.2%
Summer	39,138	31,960	14.62	14.6%	26,590	67.9%	12,548	32.1%
Total	**268,009**	**218,853**	**100.12**		**203,234**	**75.8%**	**64,775**	**24.2%**
Chloride								
Fall	96,212	78,566	35.94	31.5%	72,449	75.3%	23,763	24.7%
Winter	59,100	48,261	22.08	19.4%	33,665	57.0%	25,436	43.0%
Spring	104,862	85,629	39.17	34.3%	87,921	83.8%	16,941	16.2%
Summer	45,170	36,885	16.87	14.8%	28,616	63.4%	16,554	36.6%
Total	**305,344**	**249,341**	**114.06**		**222,651**	**72.9%**	**82,693**	**27.1%**

There are distinct seasonal differences in the delivery of nutrient and total suspended solids pollutant loads, with summer being the season of reduced load delivery for all pollutants analyzed. Approximately 21.3% of the precipitation fell during the fall season, but only 24.2% of this precipitation was reflected in the stream flow (Table 8-5). The abundance of plants in the summertime means an increase in evapotranspiration, which accounted for most of the runoff from precipitation. This summer decrease in stream flow results in a decrease in the delivery of pollutants.

Baseflow accounts for a negligible amount of the pollutant load delivery for Total Suspended Solids (5.5%), Total Phosphorus (9.7%), Total Zinc (8.0%), Total Lead (6.5%), and Total Copper (13.6%). Total Nitrogen has 15.3% of its load delivered as baseflow. The Nitrite/Nitrate, Sodium, and Chloride have about one-quarter of their load delivered as baseflow. TKN (ammonia and organic nitrogen) has 12.5% of its load delivered during baseflow conditions. Organic nitrogen will be mobilized both within the stream channel and washed into the stream during storm events.

8.3.3 Geomorphological Monitoring Results

Streambank Soil Sampling: Nine sets (3 Powder Mill, 6 Scott's Level) of Stream bank and bed core samples were collected in the vicinity of the permanent cross sections for laboratory analysis of bulk density, particle size distribution, total nitrogen, and total phosphorus and other constituents. Eventually, it is planned to sample each of the 30 cross sections of both streams. The samples will be one-time sample collections, with 10% of the sites, randomly selected, for a second round of sample collection to provide an analysis of annual variability. The data from each cross section will allow either positive or negative loading estimates to be made for the cross sections. These estimates, if extended to represent their respective stream segments, may provide information helpful in understanding the sediment and chemical flux of the stream system. Based on the annual and long term change, and the results of the core samples, the estimated annual sediment, total nitrogen, and total phosphorus loads will be calculated for comparison with the chemical monitoring results derived from the in-stream monitoring site.

Scotts Level Branch Geomorphological Monitoring Results: The cross-sectional morphology of the 18 cross sections was examined to show changes that occurred in 2008-2009 and 2005-2009.

Figure 8-6 shows an overlay of CX #1 for 2008 and 2009. Table 8-9 presents the amount of aggradation (filling) or degradation (cutting) within the active channel, and Table 8-10 (listed from upstream to downstream) summarizes Table 8-9. Data in Table 8-9 were annualized to standardize aggradation and degradation estimates. The data files and plots are included on the CD accompanying this report. Cross Sections 2, 11, and 17 were most active in terms of net change. CX 2 aggraded by 8.4 cubic feet, while CX 11 and CX 17 degraded by 4.9 cubic feet each. All other reaches showed smaller adjustments.

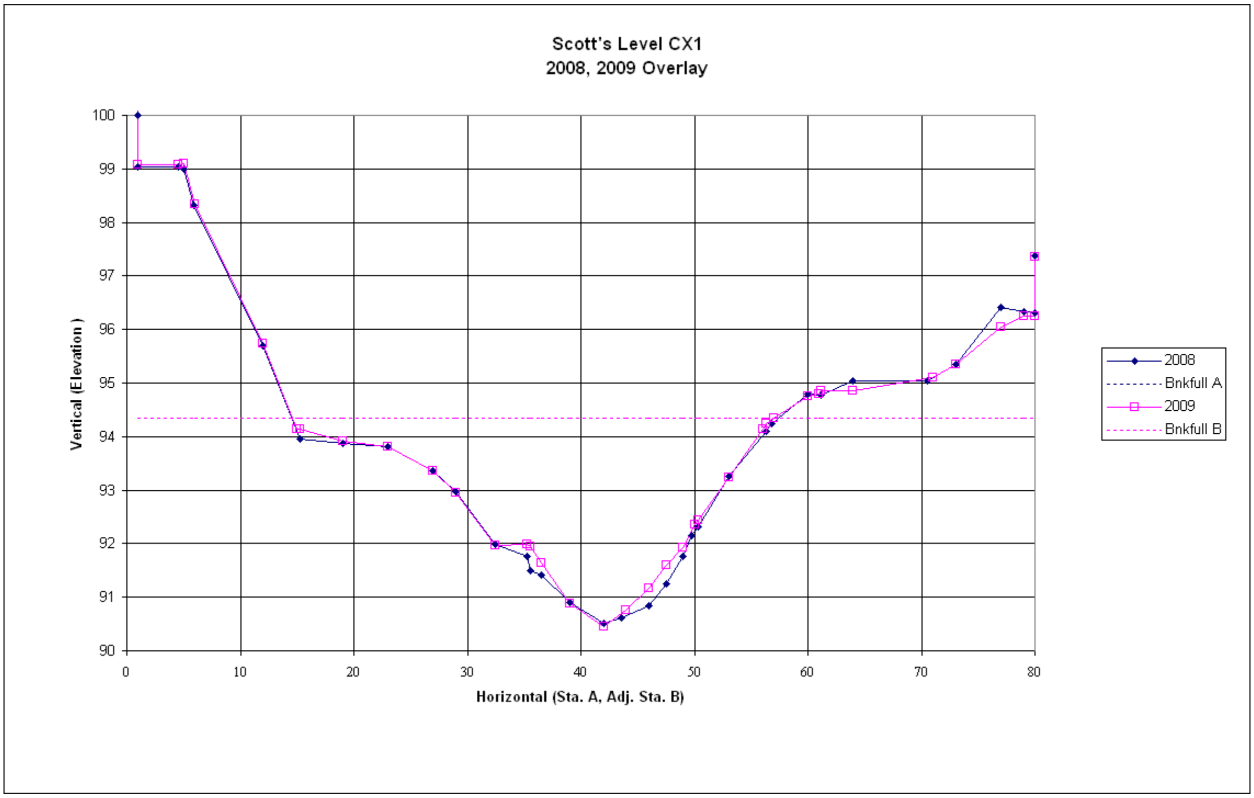


Figure 8-6: Scotts Level Branch Geomorphological Cross Section 1 Overlay showing differences in channel morphology between the 2008 and 2009 surveys.

Impervious land cover influences the majority of the Scotts Level Branch hydrology. Therefore the sediment fluxes within the stream channel are most likely part of the process of the stream reworking its surrounding legacy flood plain sediments and ultimately transporting them into the Gwynns Falls mainstem and beyond. The present data document the range of morphological instability along the length of Scotts Level Branch, and should serve as a baseline to determine whether stream channel and stormwater management improvements stabilize the stream channel.

Table 8-9: Scotts Level Branch Cross Sections - Annualized Cut and Fill Amounts

SL 20: Change (cu ft)	Period: 2008 – 2009	Period: 2005 – 2009	SL 10: Change (cu ft)	Period: 2008 – 2009	Period: 2005 – 2009
Total Cut	-0.4	-0.1	Total Cut	-2.4	-0.8
Total Fill	1.7	1.0	Total Fill	0.5	0.4
Total Change	2.1	1.1	Total Change	2.9	1.2
Net Change	1.2	0.9	Net Change	-1.9	-0.4

SL19: Change (cu ft)	Period: 2008 – 2009	Period: 2005 – 2009	SL 9: Change (cu ft)	Period: 2008 – 2009	Period: 2005 – 2009
Total Cut	-0.6	-0.1	Total Cut	-0.6	-2.7
Total Fill	3.0	1.5	Total Fill	2.8	0.2
Total Change	3.6	1.6	Total Change	3.4	3.0
Net Change	2.4	1.4	Net Change	2.1	-2.5
SL 18: Change (cu ft)	**Period: 2008 – 2009**	**Period: 2005 – 2009**	**SL 8: Change (cu ft)**	**Period: 2008 – 2009**	**Period: 2005 – 2009**
Total Cut	-3.3	-0.8	Total Cut	-0.9	-0.2
Total Fill	6.5	1.3	Total Fill	1.7	0.5
Total Change	9.8	2.2	Total Change	2.6	0.8
Net Change	3.2	0.5	Net Change	0.8	0.3
SL 17: Change (cu ft)	**Period: 2008 – 2009**	**Period: 2005 – 2009**	**SL 7: Change (cu ft)**	**Period: 2008 – 2009**	**Period: 2005 – 2009**
Total Cut	-5.2	-1.1	Total Cut	-1.1	-0.8
Total Fill	0.3	0.1	Total Fill	2.1	0.7
Total Change	5.5	1.3	Total Change	3.2	1.5
Net Change	-4.9	-1.0	Net Change	0.9	-0.1
SL 16: Change (cu ft)	**Period: 2008 – 2009**	**Period: 2005 – 2009**	**SL 6: Change (cu ft)**	**Period: 2008 – 2009**	**Period: 2005 – 2009**
Total Cut	-1.0	-0.4	Total Cut	-2.7	-0.4
Total Fill	1.5	0.6	Total Fill	0.4	0.5
Total Change	2.5	1.1	Total Change	3.1	0.9
Net Change	0.6	0.2	Net Change	-2.3	0.2
SL 15: Change (cu ft)	**Period: 2008 – 2009**	**Period: 2005 – 2009**	**SL 5*: Change (cu ft)**	**Period: 2008 – 2009**	**Period: 2005 – 2009**
Total Cut	-0.6	-0.5	Total Cut	NA	NA
Total Fill	1.2	0.3	Total Fill	NA	NA
Total Change	1.8	0.8	Total Change	NA	NA
Net Change	0.6	-0.3	Net Change	NA	NA
SL 14: Change (cu ft)	**Period: 2008 – 2009**	**Period: 2005 – 2009**	**SL 4*: Change (cu ft)**	**Period: 2008 – 2009**	**Period: 2005 – 2009**
Total Cut	-1.1	-2.0	Total Cut	NA	NA
Total Fill	1.3	1.2	Total Fill	NA	NA
Total Change	2.4	3.2	Total Change	NA	NA
Net Change	0.1	-0.8	Net Change	NA	NA
SL 13: Change (cu ft)	**Period: 2008 – 2009**	**Period: 2005 – 2009**	**SL 3: Change (cu ft)**	**Period: 2008 – 2009**	**Period: 2005 – 2009**
Total Cut	-0.9	-0.9	Total Cut	-1.0	-0.1
Total Fill	4.2	1.8	Total Fill	0.5	0.4
Total Change	5.1	2.7	Total Change	1.5	0.4
Net Change	3.3	0.9	Net Change	-0.5	0.3
SL 12: Change (cu ft)	**Period: 2008 – 2009**	**Period: 2005 – 2009**	**SL 2: Change (cu ft)**	**Period: 2008 – 2009**	**Period: 2005 – 2009**
Total Cut	-0.9	-2.0	Total Cut	-4.6	-0.8
Total Fill	4.6	2.2	Total Fill	3.8	0.5
Total Change	5.5	4.2	Total Change	-0.8	-0.3
Net Change	3.8	0.2	Net Change	8.4	1.4
SL 11: Change (cu ft)	**Period: 2008 – 2009**	**Period: 2005 – 2009**	**SL 1: Change (cu ft)**	**Period: 2008 – 2009**	**Period: 2005 – 2009**
Total Cut	-5.5	-0.6	Total Cut	-3.0	-1.0
Total Fill	0.6	0.5	Total Fill	5.6	4.3

Total Change	6.1	1.1	Total Change	8.6	5.3
Net Change	-4.9	-0.1	Net Change	2.6	3.3

* Permission from private property owners for sampling SL 5 and SL 4 has not yet been obtained, therefore there are no results.

Table 8-10: Scotts Level Branch Stream Channel Changes Over Time.

SL #	CX 2008-2009	CX 2005-2009
20	sa	sa
19	a	sa
18	a	sa
17 (Trib.)	d	sd
16	sa	sa
15	sa	sd
14	sa	sd
13	a	sa
12	a	sa
11	d	sd
10	sd	sd
9	a	d
8	sa	sa
7	sa	sd
6	d	sa
5	NA	NA
4	NA	NA
3	sd	sa
2	a	sa
1	a	a

Symbols: a: aggradation, d: degradation, sa:slight aggradation, sd:slight degradation

The aggradation/degradation and stream bank soil chemistry data, when combined with water chemistry data, allows examination of pollutant loads for various components of the Scotts Level Branch watershed. The expectation is that instream water quality estimates are equal to the sum of stream bank and watershed wash-off estimates. Table 8-11 shows loads for Total Nitrogen, Total Phosphorus, and Sediment from the instream and stream bank components of the Scotts Level Branch watershed for 2006-2009. The load estimates were standardized for rainfall, using the following precipitation totals from Baltimore-Washington International Airport (BWI): 2006, 43.24 inches; 2007, 34.97 inches; 2008, 44.97 inches; 2009, 55.57 inches; long-term average, 41.94 inches. Estimates of sediment loads were based on Total Suspended Solids for instream water quality and stream bank soil weights for geomorphology. The watershed wash-off estimate was made using the Scotts Level Branch outfall. The United States Geological Survey developed a flow-rating curve for the outfall, which allowed pollutant loads for watershed wash-off to be calculated for 2008. The pollutant load for Total Phosphorus was highest in stream bank soils, because soil particles bind phosphorus. Therefore streams typically have elevated phosphorus concentrations during stormflow. The load for Total Nitrogen was highest for instream water quality. Groundwater contributes most of the nitrogen (as baseflow) in a watershed. Sediment loads were greatest in stream bank soils in all years except 2009.

Table 8-11: Pollutant Load Estimates (Normalized by Average Yearly Rainfall)- Comparison between Water Quality Monitoring and Geomorphology for Scotts Level Branch, 2006-2009

Year	Component	Parameter		
		TN	TP	Sediment
2006	Geomorphology Pollutant Load (lbs/ac)	1.70	0.53	754.74
	Instream Water Quality Pollutant Load (lbs/ac)	4.06	0.44	125.61
2007	Geomorphology Pollutant Load (lbs/yr)	1.86	0.58	821.94
	Instream Water Quality Pollutant Load (lbs/ac)	4.63	0.40	130.67
2008	Geomorphology Pollutant Load (lbs/ac)	1.03	0.32	455.76
	Instream Water Quality Pollutant Load (lbs/ac)	3.77	0.37	224.22
2009	Geomorphology Pollutant Load (lbs/ac)	0.15	0.05	66.10
	Instream Water Quality Pollutant Load (lbs/ac)	4.33	0.50	152.62
4-year Mean	Geomorphology Pollutant Load (lbs/ac)	1.19	0.37	524.64
	Instream Water Quality Pollutant Load (lbs/ac)	4.20	0.43	158.28

Also included in Table 8-11 are parameter estimates for the entire watershed (geomorphology station SL-1), which includes the portion below the gage. The relative contribution of each component of the Scotts Level Branch watershed has changed annually over the study period. There are several explanations why the instream and terrestrial pollutant loads are out of balance. The estimates may not be accurate due to an inadequate amount of data. The estimates should become more refined as more data are collected each year. The disruption of natural processes caused by adverse human activities would account for some of the imbalance. Instream biological processing by microbes and macroinvertebrates would reduce the instream nutrient load. As the biological data show, the macroinvertebrate community across the entire watershed is impaired, robbing the stream of valuable ecological services. Nutrient uptake in the riparian zone might be the most significant remaining method by which nutrients are reduced, as most of the stream has a wide, forested buffer. High storm flows would contribute a large amount of sediment to the stream as a result of human activity. These sediment loads are far more than the stream can naturally move and redistribute. This analysis has begun to show patterns of nutrient and sediment loading to Scotts Level Branch. Continued water quality and stream bank soil sampling, along with estimates of loads from the outfall, should provide more refined estimates of the relative contribution of each of these components to the pollutant loads within the watershed, as well as estimates of export from the watershed. These data will allow DEPRM to more accurately determine the contribution of the various flow components to overall pollutant load estimates, and will form the basis for more accurate determination of benefits from future stream restoration.

Powder Mill Run Geomorphological Monitoring Results: Cross-sectional measurements for 2008 and 2009, and 2005 and 2009, were compared to determine changes in bedload movement. The data files and plots are included on the CD accompanying this report. Table 8-12 presents cubic feet of aggradation (filling) and degradation (cutting) within the active channel of each cross section. Table 8-13 summarizes Table 8-12. The Powder Mill Run channel remained active, especially at the lower (CX 1) and upper (CX 10) limits of the study area. A headcut began during late spring or summer 2009, just upstream of CX 1, which resulted in a large amount of channel material filling the cross section. Heavy rainfall (approximately 14 inches above average, as measured at BWI) and scouring stream flows were the likely cause of the headcut at CX 1, as well as the bedload movement at the other cross sections. The middle reaches of Powder Mill Run, which are relatively low gradient, continued to act as depositional areas. The imperviousness of the upstream channel likely concentrates high flows and causes downstream channel instability.

Table 8-12: Powder Mill Run Cross Sections - Cut and Fill Amounts

PM 10: Change (cu ft)	**Period: 2008 – 2009**	**Period: 2005 – 2009**	**PM 5: Change (cu ft)**	**Period: 2008 – 2009**	**Period: 2005 – 2009**
Total Cut	0.0	-0.2	Total Cut	-6.8	-2.7
Total Fill	10.1	2.8	Total Fill	5.8	1.9
Total Change	10.1	3.0	Total Change	12.6	4.6
Net Change	10.1	2.6	Net Change	-1.0	-0.8
PM 9: Change (cu ft)	**Period: 2008 – 2009**	**Period: 2005 – 2009**	**PM 4: Change (cu ft)**	**Period: 2008 – 2009**	**Period: 2005 – 2009**
Total Cut	-1.0	-0.2	Total Cut	-1.7	-0.4
Total Fill	3.8	2.3	Total Fill	4.7	2.3
Total Change	4.8	2.5	Total Change	6.4	2.7
Net Change	2.8	2.1	Net Change	3.0	1.9
PM 8: Change (cu ft)	**Period: 2008 – 2009**	**Period: 2005 – 2009**	**PM 3: Change (cu ft)**	**Period: 2008 – 2009**	**Period: 2005 – 2009**
Total Cut	-0.4	-0.6	Total Cut	-0.5	-0.2
Total Fill	3.5	0.4	Total Fill	4.0	1.7
Total Change	3.9	1.0	Total Change	4.5	1.9
Net Change	3.1	-0.2	Net Change	3.5	1.5
PM 7: Change (cu ft)	**Period: 2008 – 2009**	**Period: 2005 – 2009**	**PM 2: Change (cu ft)**	**Period: 2008 – 2009**	**Period: 2005 – 2009**
Total Cut	-3.8	-0.4	Total Cut	-1.2	-0.8
Total Fill	0.5	0.7	Total Fill	2.5	1.0
Total Change	4.3	1.1	Total Change	3.7	1.8
Net Change	-3.3	0.3	Net Change	1.3	0.2
PM 6: Change (cu ft)	**Period: 2008 – 2009**	**Period: 2005 – 2009**	**PM 1: Change (cu ft)**	**Period: 2008 – 2009**	**Period: 2005 – 2009**
Total Cut	-0.3	-0.5	Total Cut	-13.4	-3.8
Total Fill	4.4	1.7	Total Fill	33.5	5.7
Total Change	4.7	2.2	Total Change	46.9	9.5
Net Change	4.1	1.2	Net Change	20.1	1.9

Table 8-13: Powder Mill Run, 2008-2009 and 2005-2009 Stream Channel Changes

PM #	CX 2008-2009	CX 2005-2009
10	a	a
9	a	a
8	a	sd
7	d	sa
6	a	sa
5	sd	sd
4	a	sa
3	a	sa
2	sa	sa
1	a	sa

Symbols: a: aggradation, d: degradation, sa :slight aggradation, sd :slight degradation

8.3.4 Biological Monitoring Results

Benthic macroinvertebrate and fish sampling were conducted as per MBSS protocols. Benthic macroinvertebrates were sampled between March 4th and March 5th, and fish were sampled between August 27th and September 21st. Scotts Level Branch was sampled at SL-1, SL-6, SL-9, SL-14, and SL-18. Powder Mill Run was sampled at PM-1, PM-4, and PM-10. The Benthic Index of Biotic Integrity (BIBI) and Fish Index of Biotic Integrity (FIBI) were calculated using metrics developed by MBSS for Piedmont streams. The BIBI and FIBI scoring criteria are: 1.00-1.99 (Very Poor), 2.00-2.99 (Poor), 3.00-3.99 (Fair), and 4.00-5.00 (Good). Stream physical habitat was assessed when macroinvertebrates and fish were collected using the MBSS Physical Habitat Index. The protocol measured components of stream physical habitat, including fish habitat quality, macroinvertebrate habitat quality, stream depth and velocity diversity, riffle quality, pool quality, the percentage of sediment surrounding stream bottom substrates, and the percentage of shading in the stream reach. Each parameter was estimated on a scale of 0-20, except for sediment and shading, which were percentage estimates. Physical habitat data were converted to physical habitat index (PHI) scores and rated using criteria from Southerland et al (2005). Minimally degraded stations had PHI scores of 81-100, partially degraded stations had PHI scores of 66-80, degraded stations had PHI scores of 51-65, and severely degraded stations had PHI scores of 0-50.

The IBI scores are shown in Figure 8-7. All BIBIs were in the Very Poor condition category, except for PM-1. So few organisms were collected from PM-1 (10), that a BIBI could not be calculated. It is likely that the scouring flows which caused the headcut described in Section 8.3.3 (Geomorphological Monitoring Results) swept most invertebrates from the reach. The FIBI scores for all sites in Scotts Level were Poor or Very Poor. The FIBI scores in Powder Mill were Poor at PM-1 and Very Poor at PM-4 and PM-9. Station PM-10 was not electrofished because of a large amount of human waste near the stream edge. PM-9 was sampled instead, because it is behind a fence in a less accessible location. FIBI scores were always higher than BIBI scores. Fish in both Scotts Level Branch and Powder Mill Run are better able than benthic macroinvertebrates to survive the acute and chronic water quality problems within both streams. The mobility of fish likely allows them to better exploit good habitat and avoid such episodic events as high storm flows. The PHI scores are shown in Figure 8-8. Scotts Level Branch physical habitat condition was partially degraded at SL-1, and degraded at all other stations.

Powder Mill Run physical habitat was severely degraded at PM-1, partially degraded at PM-4, and degraded at PM-9.

The benthic and fish communities of Scotts Level Branch and Powder Mill Run show the effects of environmental stress. Both are low in diversity and are primarily composed of pollution tolerant organisms. Stream habitat is degraded and provides poor living space for both benthos and fish. Results of biological monitoring have been consistent since monitoring began in 2005, which suggests that the baseline biological condition has been identified. These baseline data will be useful in monitoring and identifying the effects of stream restoration.

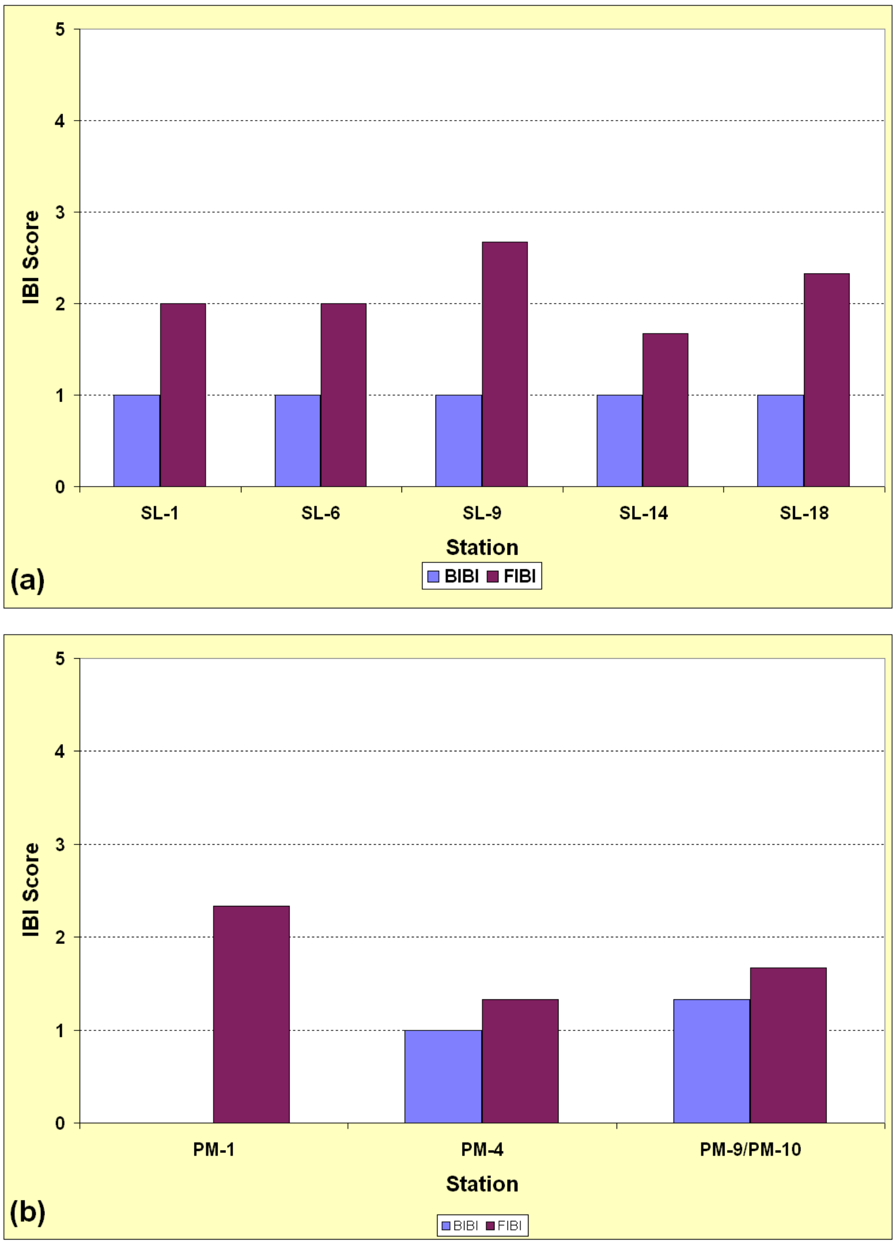


Figure 8-7: (a) Scotts Level Branch and (b) Powder Mill Run IBI Scores. Note: A BIBI could not be calculated for PM-1 because only 10 organisms were collected from the 75-m reach. Fish were collected from PM-9, which is downstream of station PM-10, due to a human waste contamination issue at PM-10.

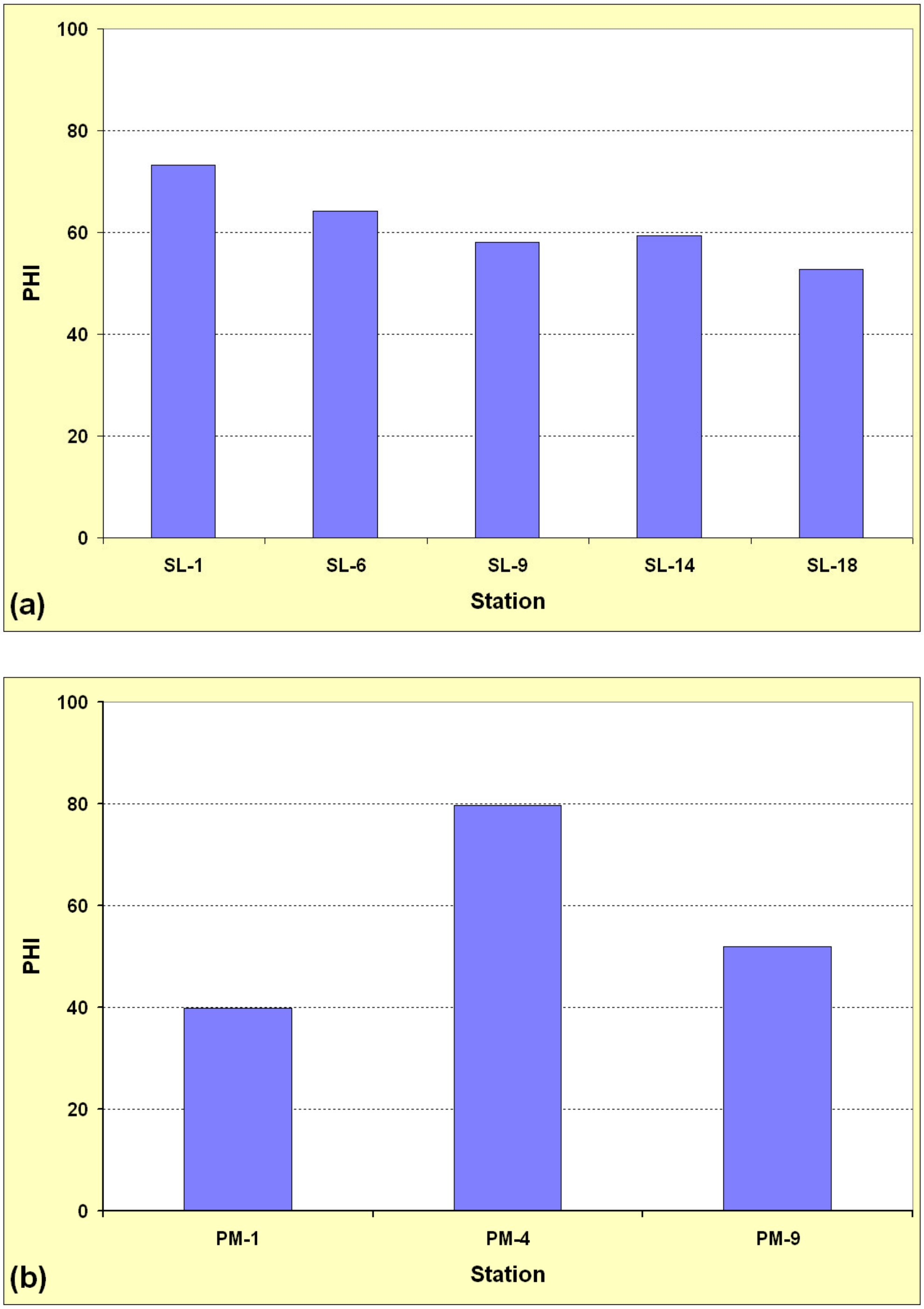


Figure 8-8: (a) Scotts Level Branch and (b) Powder Mill Run PHI Scores

8.4 Windlass Run Monitoring – Stormwater Management Assessment

Baltimore County's National Pollutant Discharge Elimination System (NPDES) permit requires the monitoring of a subwatershed for geomorphological impacts resulting from development under the revised Stormwater Management Design Manual (year 2000). In order to comply with this component of the permit, Baltimore County conducted a comprehensive review of the available land for development. An analysis using geographic information systems (GIS) was used for selection of the monitoring subwatershed. The characteristics for determination of the selected subwatershed were:

- 1) an area of open undeveloped land, and
- 2) an area with a zoning category that would lead to development.

Nearly all new development and redevelopment will be affected by the guidelines in the new stormwater design manual, but the denser developments are expected to show a more dramatic change to the stream system. Therefore the study area must have a zoning category of sufficient density to affect the stability of the stream system. The results of a countywide screening, followed by field verification led to the selection of Windlass Run as the monitoring subwatershed.

The Windlass Run subwatershed is 1,926 acres, and has the potential for a large amount of future development. The level of imperviousness in the subwatershed at the beginning of the study was about 3 % and is expected to increase to well over 20%. Much of the undeveloped land is zoned for manufacturing. The development in this subwatershed began after the extension of MD route 43 was completed. This roadway is the primary access to these new properties and is needed for the intense level of development expected in this subwatershed. If this high-density development is not controlled, it is expected to have a severe impact on the water quality and stability of Windlass Run. The protection provided by the new stormwater management regulations should be easily visible through monitoring of the stream conditions.

Windlass Run is a Coastal Plain stream system typified by a stable, low gradient, sinuous, unconfined, silt and sand channel within well-developed floodplains. Average Rosgen bankfull width and corresponding bankfull depths are 10 and 2 feet, respectively. The Windlass Run system is very stable, and there are no areas of moderate or severe streambank erosion. One year of stream gage data was recorded by U.S.G.S. in 1992 – 1993. Well-vegetated stream buffers surround the stream. The upper portion exhibits multiple channels, which are stable and meander through non-tidal wetlands. These conditions are reflective of those described in the Bird River watershed plan that was completed in 1995.

Monitoring in the Windlass Run watershed includes stream geomorphology and biology. The Baltimore County NPDES Municipal Stormwater Discharge Permit only requires the stream stability geomorphological monitoring.

8.4.1 Stream Geomorphologic Monitoring

Six (6) monitoring sites in the Windlass Run subwatershed are shown in Figure 8-9 below. The site selection process took into consideration the location of future development and the extension of MD Route 43. Three sites are located along the mainstem: two above (WR3, WR5) and one below (WR2) the crossing of the proposed MD Route 43 extension. One site (WR4) is on a tributary within the area of proposed industrial and high-density development, and down stream of Route 43. Another cross section (WR6) is located on a tributary within the area of proposed development. The last cross section (WR1) is a reference site on a tributary near the bottom of the subwatershed. This tributary is within an area zoned for agricultural uses and should not be affected by the other development activities in the watershed. Sites WR1 and WR6 are not down slope or downstream of any of the Route 43 construction.

The geomorphic monitoring consists of a monumented channel cross-section measurement, a channel slope/ profile measurement, and a Wolman pebble count. Cross sections were selected on the reach between meander bends and where the conditions best represented confined flow. Profiles were also surveyed at all of the cross section reaches and include the cross sections. The procedures outlined by D. Rosgen (1996) were generally used for channel classification and stability assessment. The six cross sections and profiles have been surveyed annually since 2002. Note, however, that no profile was done at Cross Section #6 in 2002 and 2003 due to heavy vegetation. Pebble counts, sinuosity, and a Rosgen Level 3 assessment were also completed at each site. The monitoring will continue yearly.

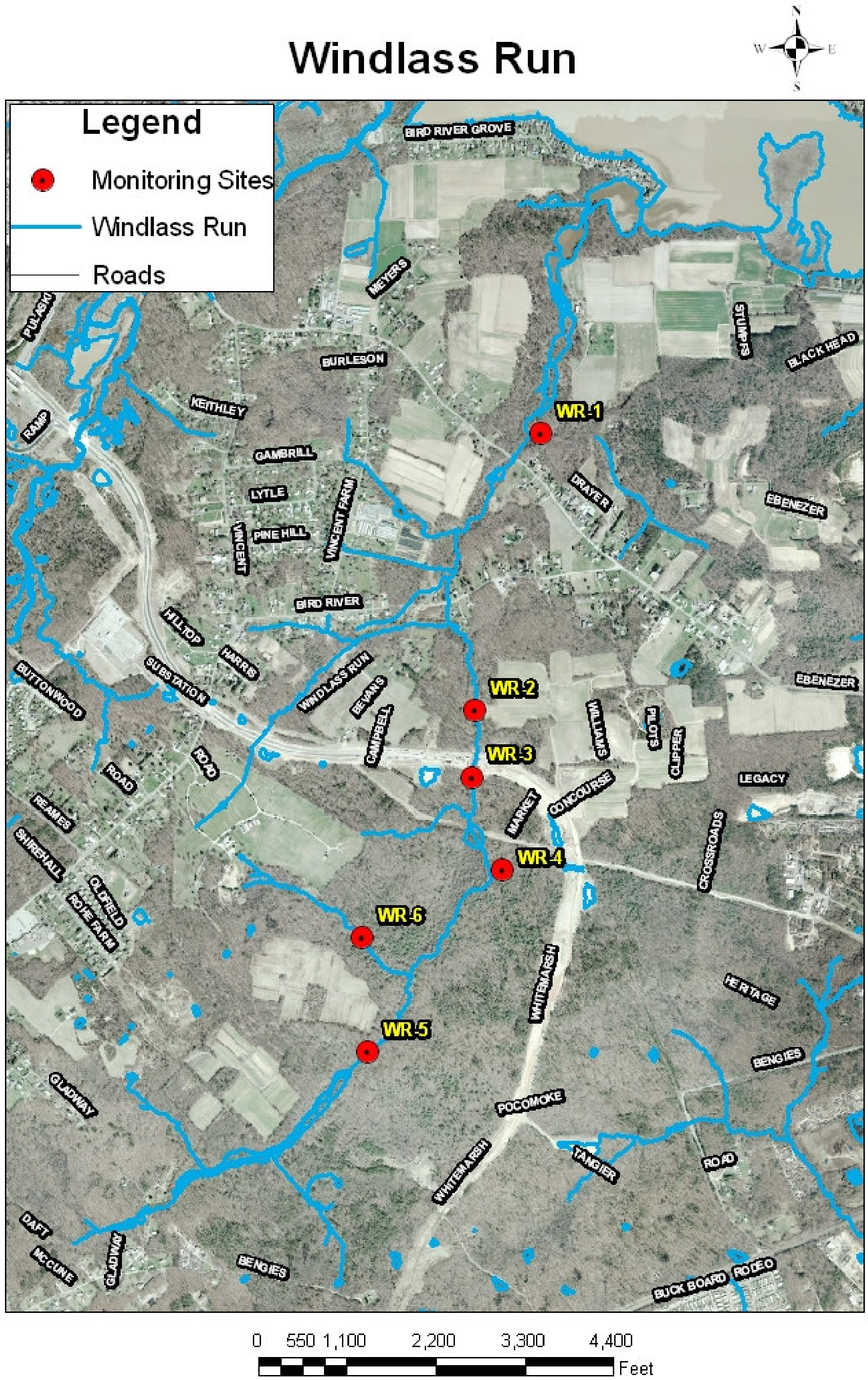


Figure 8-9: Windlass Run Aerial Photograph Showing Monitoring Station Locations.

Figures 8-10 through 8-13 show the progression of development in Windlass Run, from 1995-2007, in years for which orthophotographs were available. Development occurring in the interval between years is summarized below. Changes in geomorphology and biology related to the land disturbance caused by development are discussed in the results for each monitoring component.

1995 – 2002:

- A small housing development was built 2,850 feet northwest of WR-5.
- Two driveways were cleared 1,520 feet west of WR-2.

2002 – 2005:

- The roadbed for the Route 43 extension was cleared.

2005 – 2007:

- The Route 43 extension was paved.
- A roadway was cleared 2,470 feet southwest of WR-5.
- Land clearing and grading for commercial/industrial complexes occurred 1,330 feet east of WR-6, 95 feet east of WR-2, WR-3, and WR-4, and 380 feet west of WR-1.

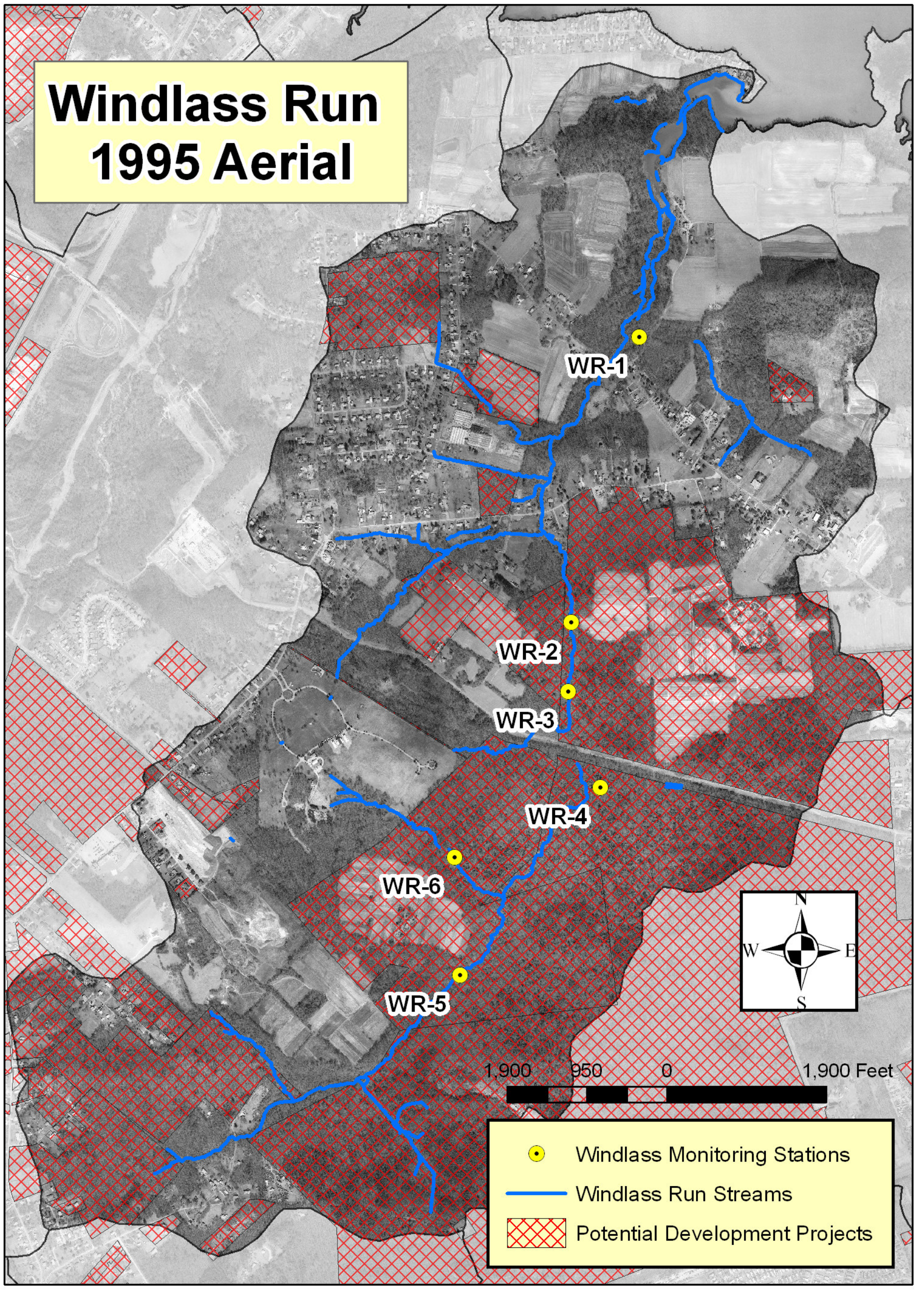


Figure 8-10: Orthophotograph of Windlass Run watershed, 1995.

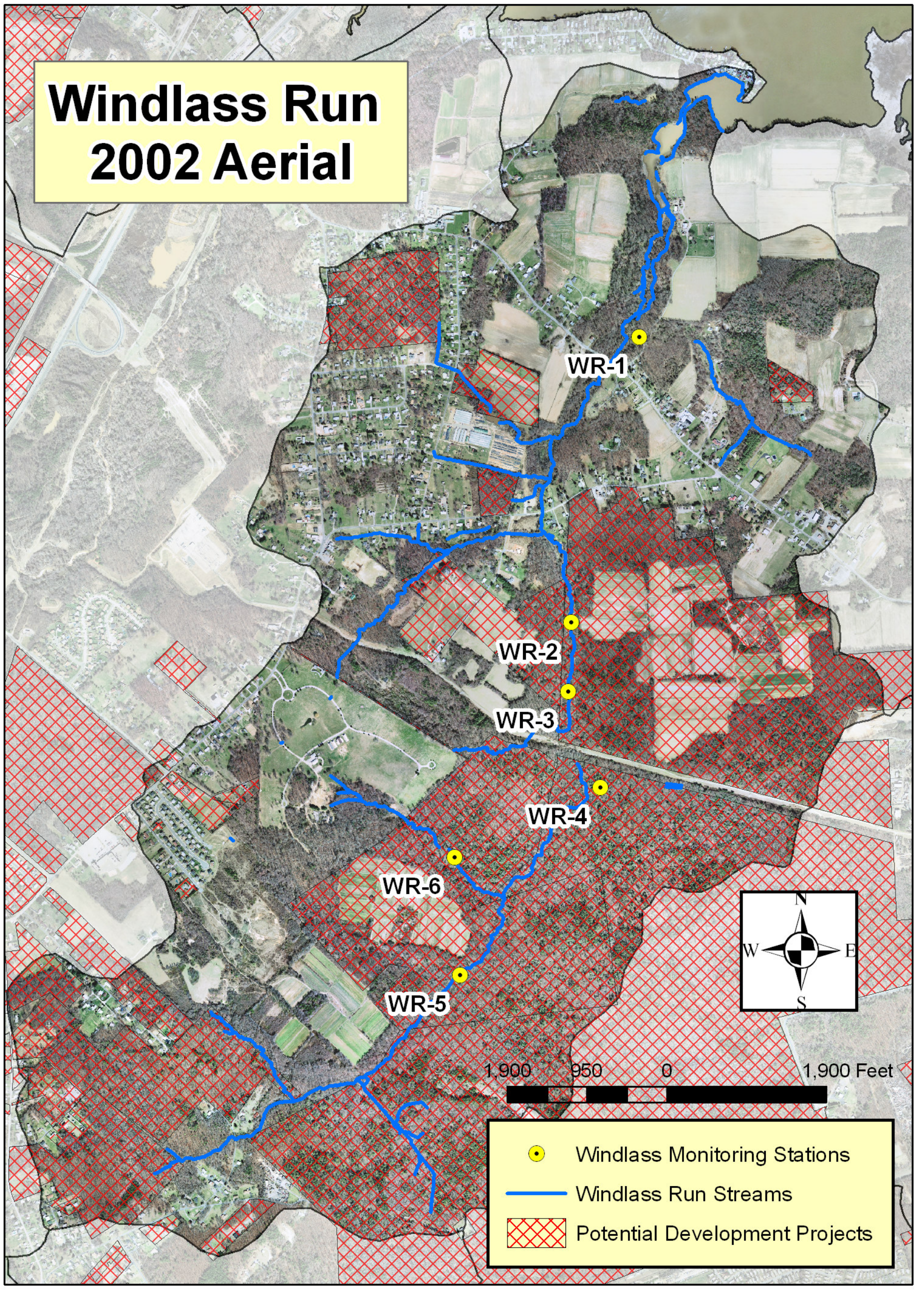


Figure 8-11: Windlass Run watershed orthophotograph, 2002.

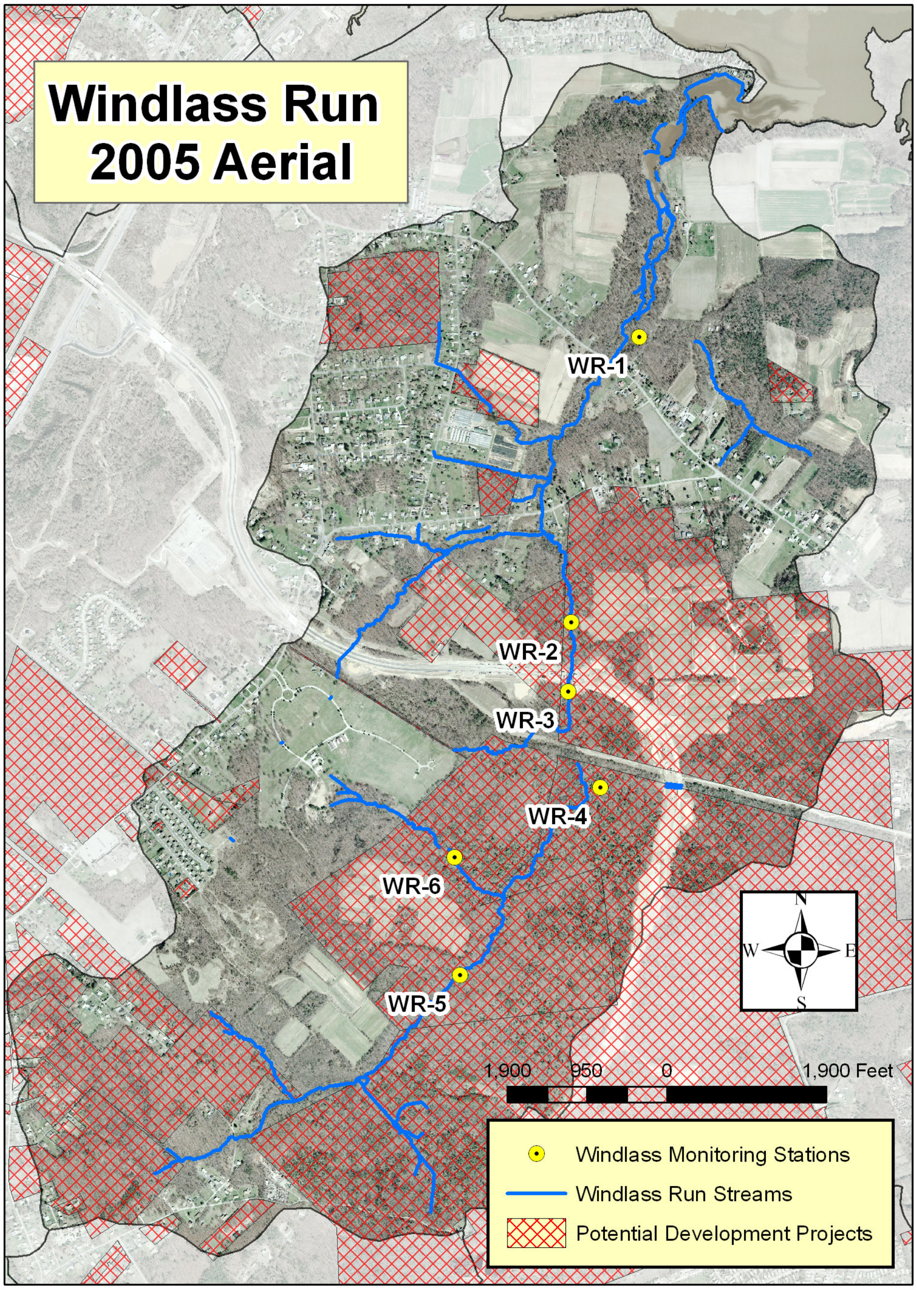


Figure 8-12: Windlass Run orthophotograph, 2005.

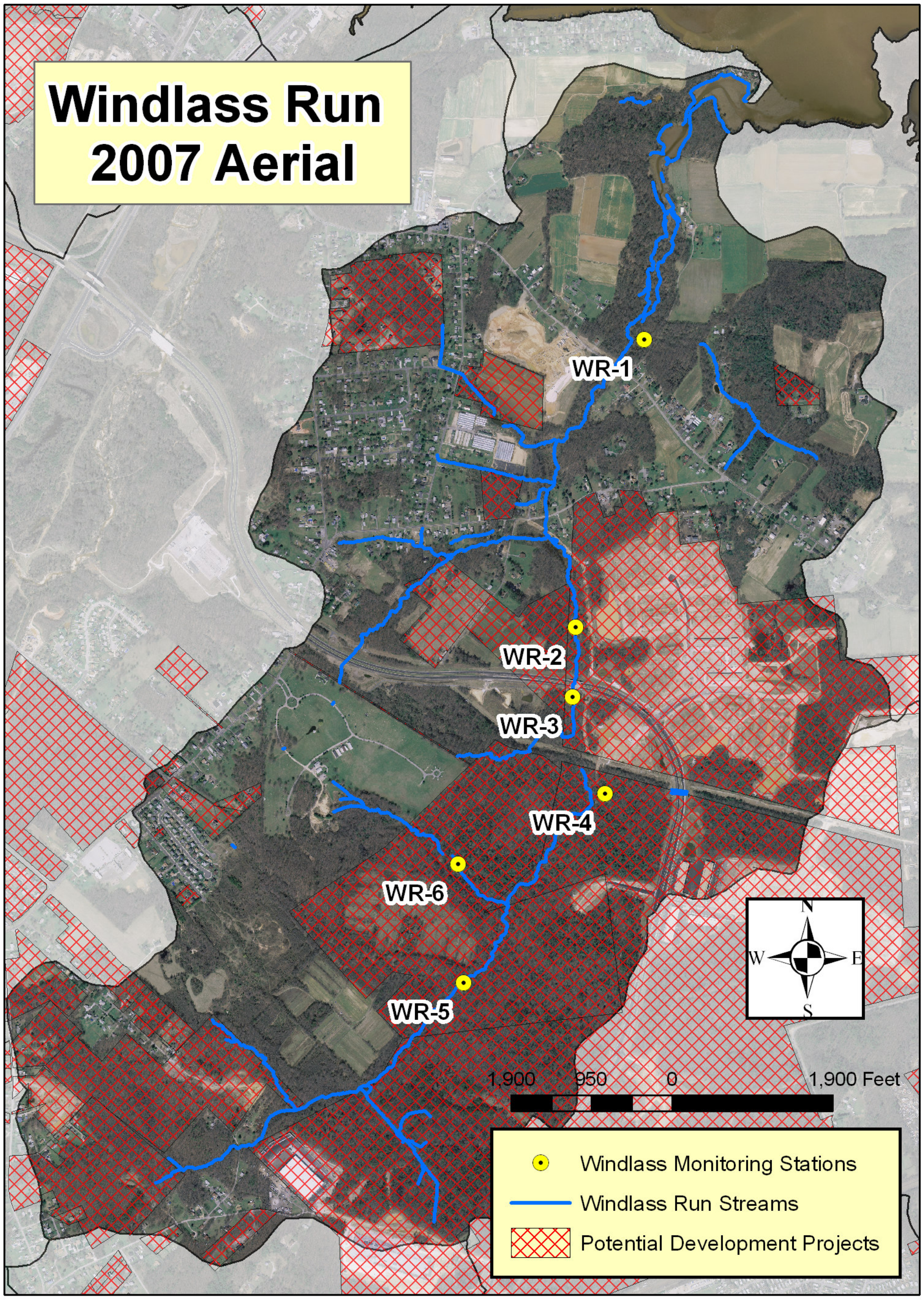


Figure 8-13: Windlass Run orthophotograph, 2007.

Windlass Run Monitoring Results:

The cross sections and profiles were overlain to reveal any morphological changes between 2009-2010 and 2002-2010. Pebble count data were summarized using D_{50} or dominant particle size (if the particle size distribution did not allow for determination of D_{50}). The change in the reaches over the two study intervals are discussed below and summarized in Figures 8-14 and 8-15, and Tables 8-14 and 8-15.

Reach 1 (Reference reach on a tributary)

- The profile aggraded slightly during 2009-2010, and it aggraded between 2002-2010.
- The substrate coarsened in 2007, but fined afterwards.
- The bridge over the access road, upstream of the profile and cross-section, has deteriorated and is releasing coarse gravel into the reach.

Reach 2 (On the mainstem below the Route 43 crossing)

- The thalweg has been active in the profile since 2002 with both aggradation and degradation over time and over the thalweg length. It aggraded overall in 2002-2010, but degraded between 2009-2010.
- The substrate coarsened slightly in 2007, but has not changed in any other year.

Reach 3 (Just above Route 43 crossing)

- The thalweg deepened overall but filled between 2009-2010.
- The substrate coarsened slightly in 2007 and 2009.

Reach 4 (On a tributary below Route 43)

- Slight coarsening of the substrate in 2003 and 2008-2009.
- Abundant, fresh sand deposition observed throughout the profile. New breaks in surface elevation between 33' and 70' of the profile caused by a debris dam at 64' of the profile.

Reach 5 (On mainstem above Route 43)

- The profile aggraded over its entirety during 2008-2009. Overall, aggradation occurred during 2002 - 2010.
- No change in particle size over the course of the study.

Reach 6 (On a tributary unaffected by Route 43)

- The profile degraded between 2002-2010, but aggraded between 2009-2010. Wide variation in particle size over the course of the study.

- Stream now makes a sharp left turn at 98’ of the profile. The original channel ends at 124’ at a large leaf dam. Stream was originally diverted to the left at 124’. Downstream of 98’ the stream becomes extremely braided and alternates between short sections of flowing water and wetland.

- It is likely that the active ATV trail, which crosses upstream of the profile, is responsible for the changes in sediment deposition. There has been no appreciable upstream change in land use over the study period.

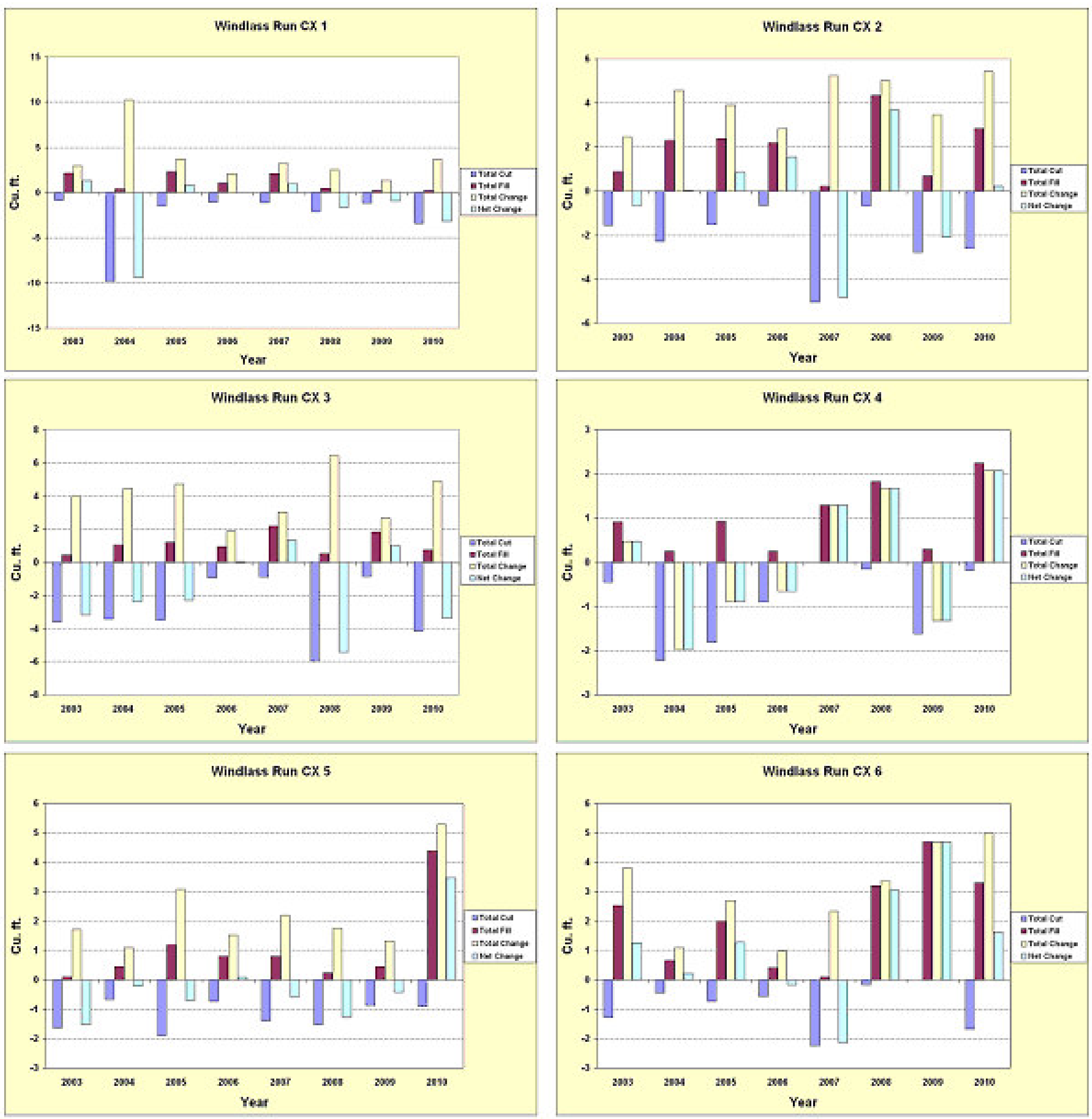


Figure 8-14: Summary of cross-sectional changes in Windlass Run during entire study period

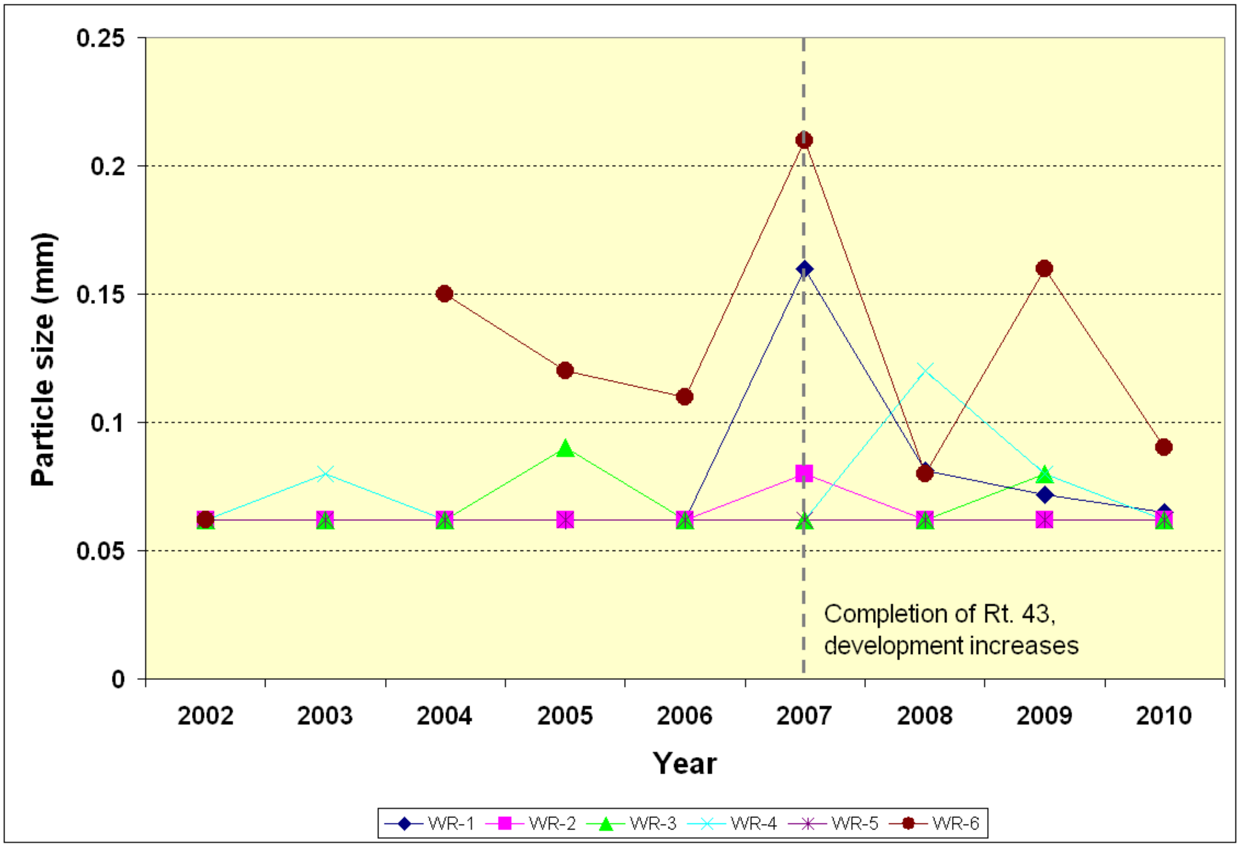


Figure 8-15: Summary of pebble counts in Windlass Run during entire study period. Particle size was determined as D_{50}. If the particle size distribution did not allow for D_{50} determination, the dominant particle size was used.

Table 8-14: Windlass Run Cross Sections - Cut and Fill Amounts

WR 1: Change (cu ft)	Period: 2009 – 2010	Period 2002 – 2010
Total Cut (negative value)	-3.4	-1.3
Total Fill	0.2	0.3
Total Change	3.6	1.6
Net Change	-3.2	-1.0
WR 2: Change (cu ft)	**Period: 2009 – 2010**	**Period 2002 – 2010**
Total Cut (negative value)	-2.6	-0.3
Total Fill	2.8	2.0
Total Change	5.4	2.3
Net Change	0.2	1.7
WR 3: Change (cu ft)	**Period: 2009 – 2010**	**Period 2002 – 2010**
Total Cut (negative value)	-4.1	-1.1
Total Fill	0.7	0.1
Total Change	4.8	1.1
Net Change	-3.4	-1.0
WR 4: Change (cu ft)	**Period: 2009 – 2010**	**Period 2002 – 2010**
Total Cut (negative value)	-0.2	0.0
Total Fill	2.2	0.3
Total Change	2.4	0.3
Net Change	2.0	0.3

WR 5: Change (cu ft)	Period: 2009 – 2010	Period 2002 – 2010
Total Cut (negative value)	-0.9	-0.6
Total Fill	4.4	0.6
Total Change	5.3	1.2
Net Change	3.5	0
WR 6: Change (cu ft)	**Period: 2009 – 2010**	**Period 2002 – 2010**
Total Cut (negative value)	-1.7	0.0
Total Fill	3.3	0.6
Total Change	5.0	0.6
Net Change	1.6	0.6

Table 8-15: Windlass Run Stream Channel Changes Over Time

WR #	Down slope Of Rt. 43	*CX 02-10*	*CX 09-10*	*TW 02-10*	*TW 09-10*
2	yes	*sa*	*sa*	*a*	*sd*
3	yes	*sd*	*d*	*d*	*a*
4	yes	*sa*	*a*	*a*	*d*
5	no	*0*	*a*	*a*	*a*
1	no	*sd*	*d*	*a*	*sa*
6	no	*sa*	*sa*	*d*	*sa*

Symbols: a: aggradation, d: degradation, c: coarsening, f: fining, p: planiform change, s:slight, m:moderate

The Windlass Run stream channels are low gradient and well connected with their flood plains at bankfull flows. They also have good riparian vegetation coverage along their banks. The stream system is almost entirely within a well-forested setting providing good habitat, erosional resistance, and canopy coverage. Windlass Run is presently in good condition. The tributary at CX 6 is suffering ATV-related sedimentation. Some visual evidence of increased hydrology was observed at all stations, however it could be due to rainfall patterns during the past year. Windlass Run emerged from a record rainfall year including tropical storm Isabel in 2003 with apparently little change in morphology or habitat quality. The major part of construction of the Highway 43 extension occurred in the watershed during 2004, however no significant change that could be attributed to this impact was noted. Cross sections #2, #3, and #4 are the locations that are downstream or down slope of this construction. Construction of several business parks and other industries began in 2007. The several years of completed pre-development monitoring may now be used as the baseline condition to detect any important changes due to development in the watershed.

8.4.2 Biological Monitoring

Benthic macroinvertebrates are being used as indicator organisms to monitor the effects of disturbance in the Windlass Run watershed. The condition of the benthic macroinvertebrate community before and after development will help determine the effectiveness of the new stormwater regulations at maintaining the suitability of Windlass Run for aquatic life.

Benthic macroinvertebrate sampling was conducted as per MBSS protocols. Benthic macroinvertebrates were sampled annually, during the spring index period (March 1st - April 30$^{th)}$, at WR-1, WR-2, WR-3, WR-4, and WR-5, as shown in Figure 8-10. WR-1 was not sampled in 2004 and 2006 because a beaver dam downstream of the station, on the Windlass Run mainstem, was causing backwater effects within the station reach. Data for WR-1 from 2005 are missing because the sorted sample had dried before it could be identified. A Benthic Index of Biotic Integrity (BIBI) was calculated using metrics developed by MBSS for Coastal Plain streams. The BIBI scoring criteria are: 1.00-1.99 (Very Poor), 2.00-2.99 (Poor), 3.00-3.99 (Fair), and 4.00-5.00 (Good). The BIBI scores are shown in Figure 8-16 and discussed in relation to the development timeline presented above.

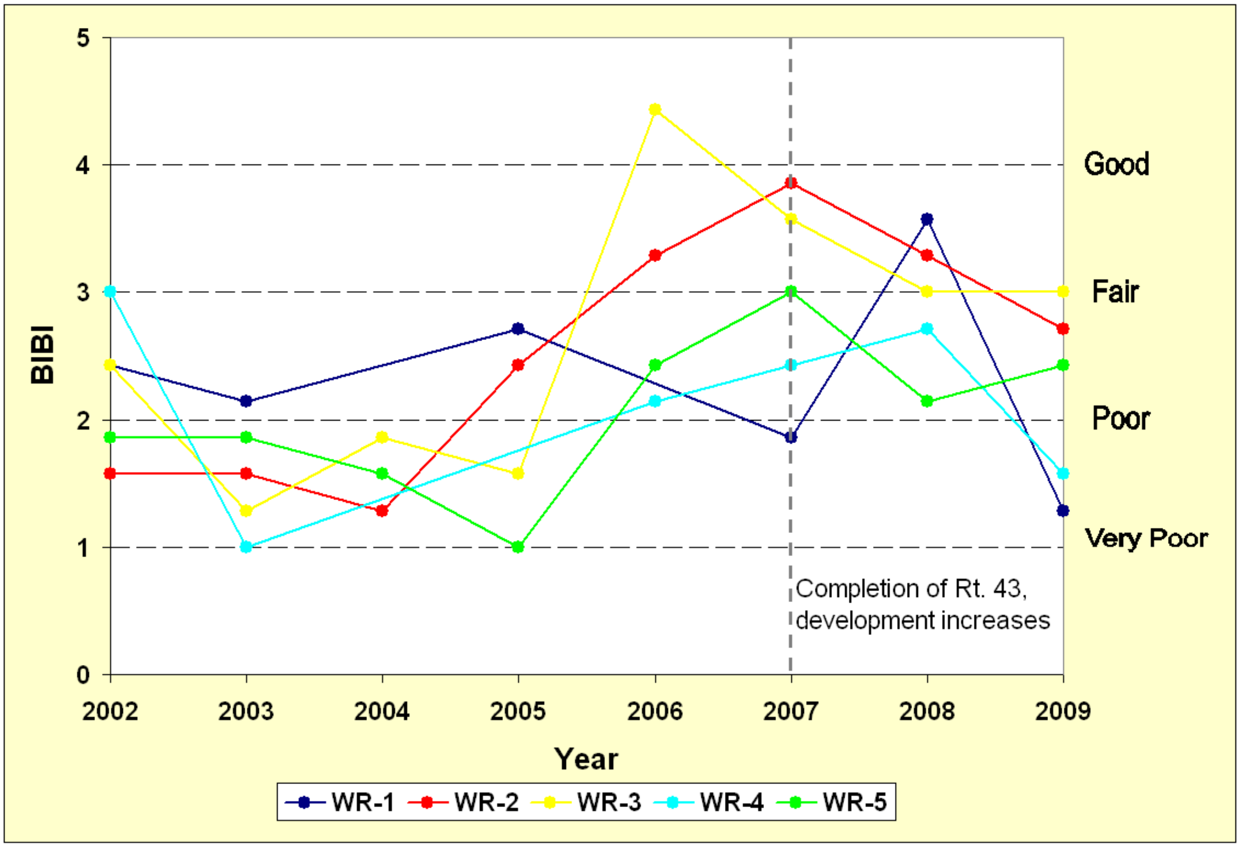


Figure 8-16: Windlass Run BIBI Scores

1995 – 2002:

- Biological condition in 2002 was typical of streams experiencing long periods of agricultural land use.

2002 – 2005:

- Biological condition remained consistent at all stations. Although there were some year-to-year changes in biological condition category, stations were rated Very Poor or Poor.

2005 – 2007:

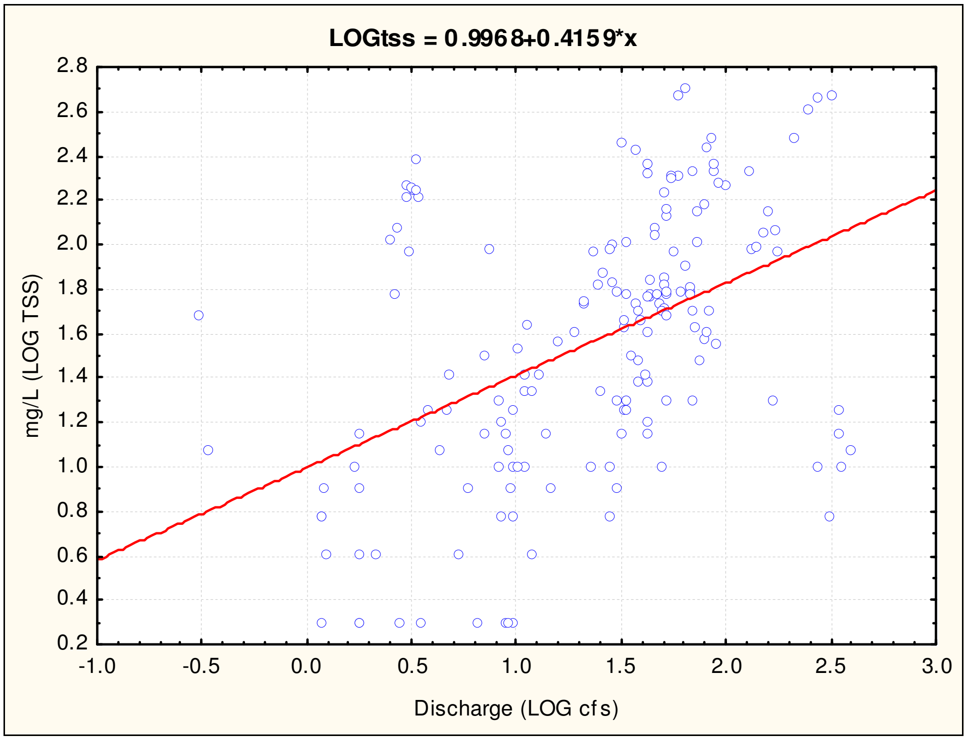
- Biological condition generally improved during this interval, which was a period of increased construction activity.

2007 – 2009:

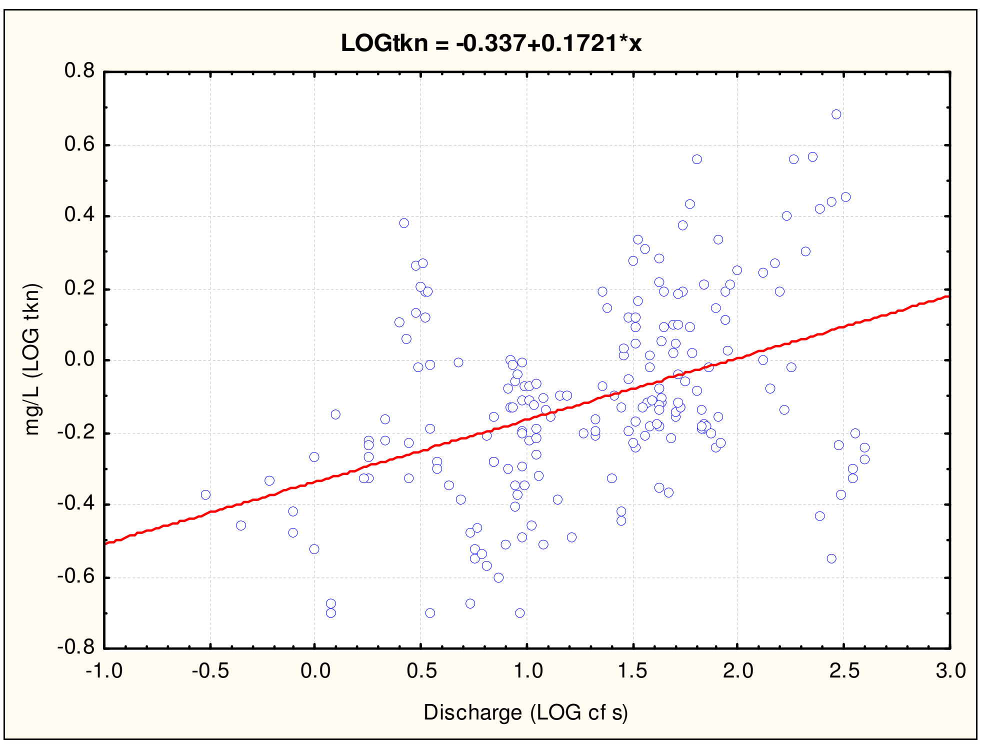
- Biological condition decreased slightly during this period at all stations. The station with the greatest decrease in BIBI score also had no development in its upstream land area.

The recent subtle changes in geomorphology suggest that development is influencing Windlass Run, especially in Reaches 2, 3, and 4. The most notable difference is in substrate composition, which has coarsened in the affected reaches. The biological data are less clear, as biological condition has improved since the beginning of development. The effects of a long history of agricultural land use will need to be identified before the effects of recent development are fully understood. The relative stability of the stream channels facilitated identification of the beginning of development-related change in Reaches 2, 3, and 4. Further monitoring will help determine the effectiveness of storm-water management techniques applied in Windlass Run.

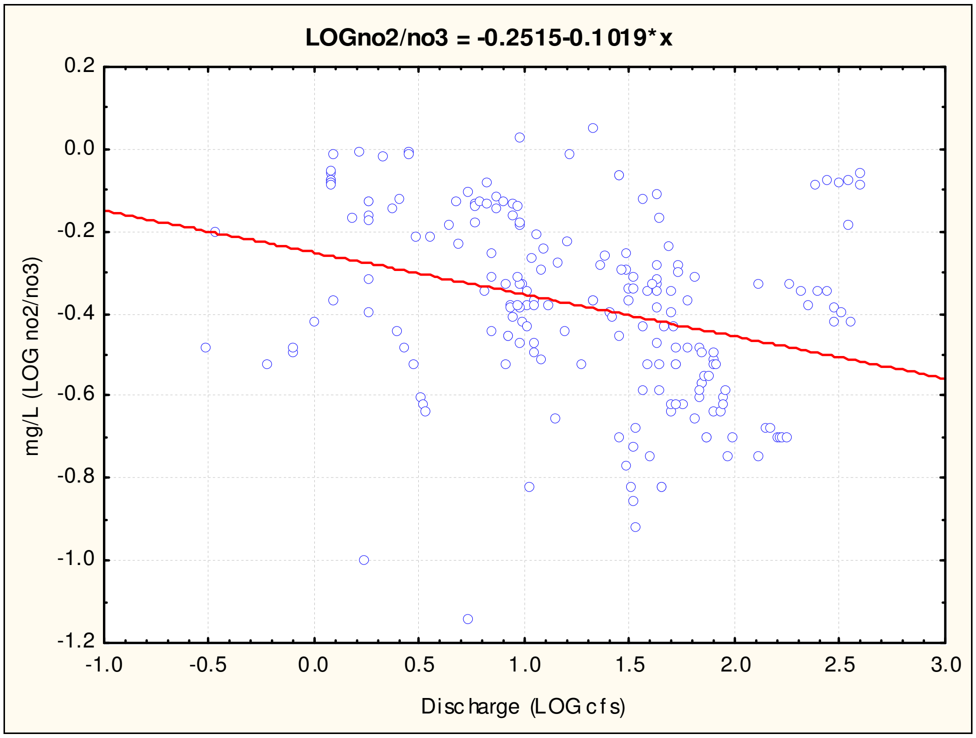
Appendix 8-1: Regression Analysis Graphs



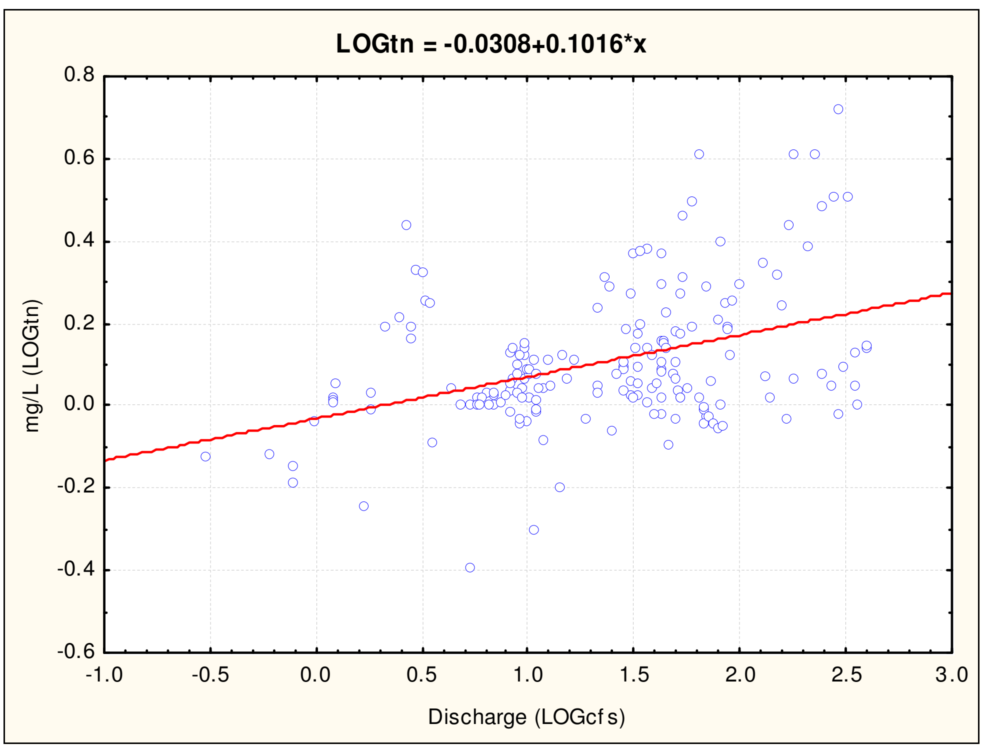
Total Suspended Solids (TSS) Data and Regressions for 2005-2009.



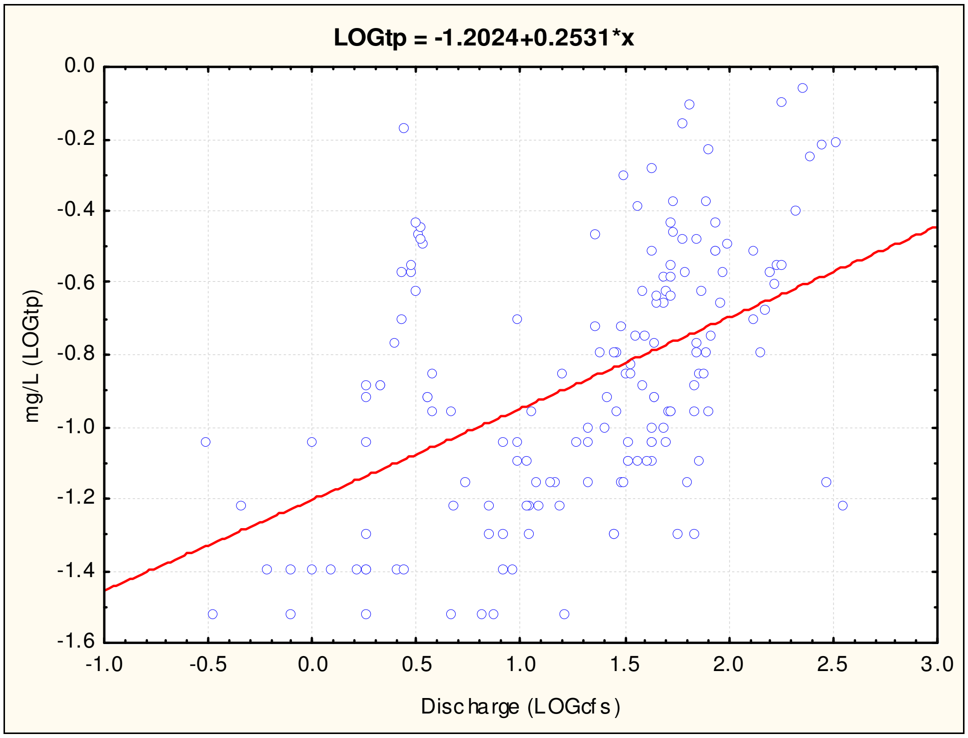
Total Kjeldahl Nitrogen (TKN) Data and Regressions for 2005-2009.



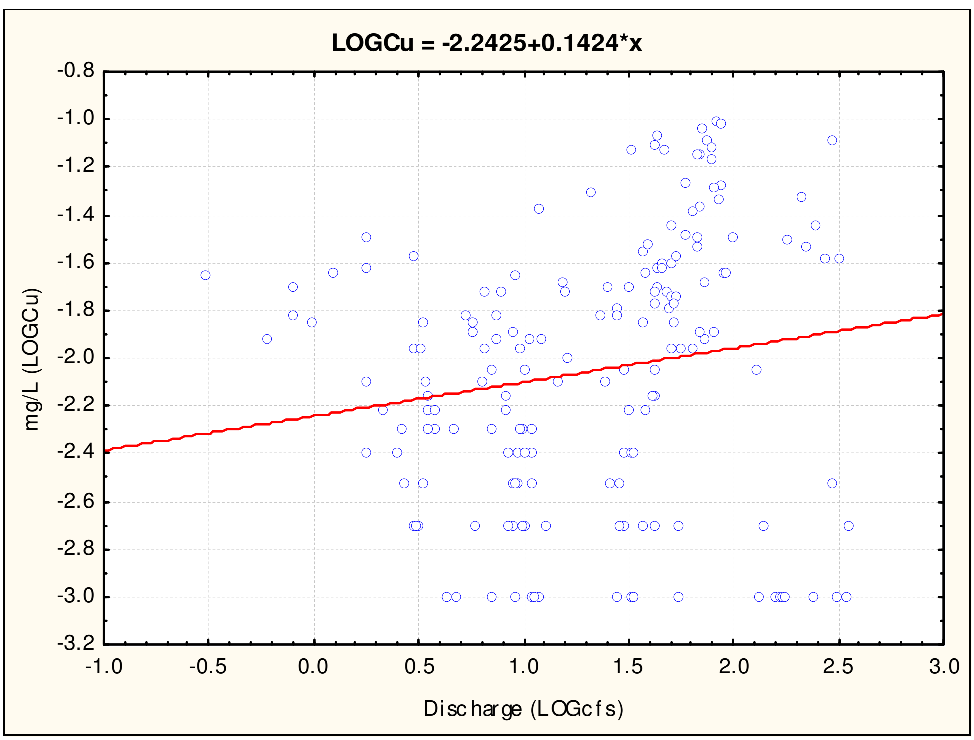
Nitrate/Nitrite (NO_2/NO_3) Data and Regressions for 2005-2009.



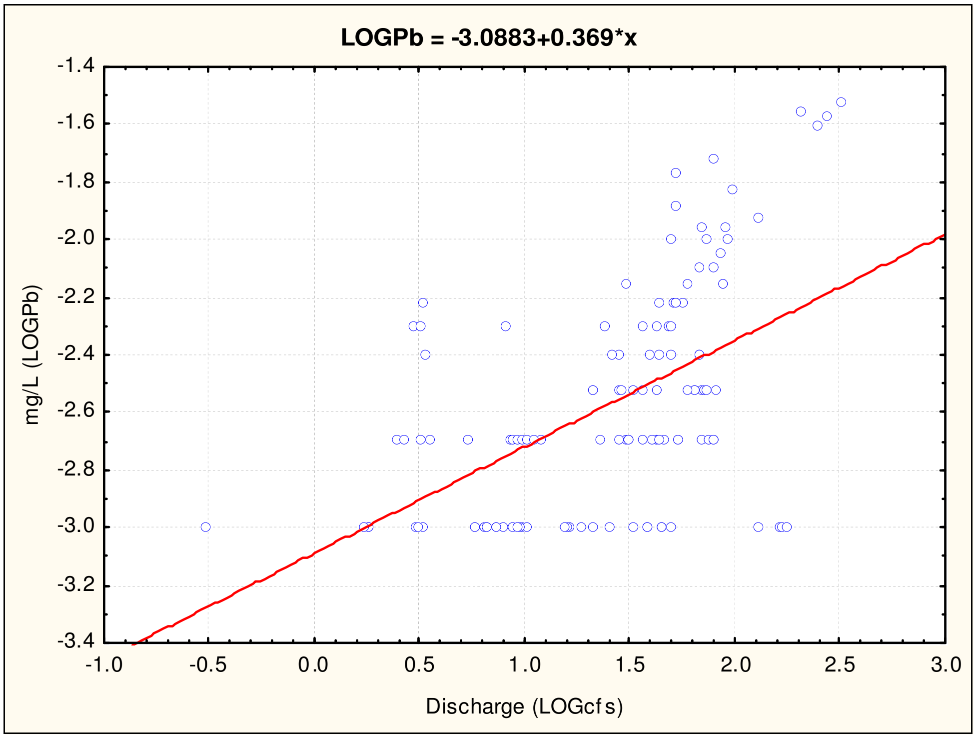
Total Nitrogen (TN) Data and Regressions for 2005-2009.



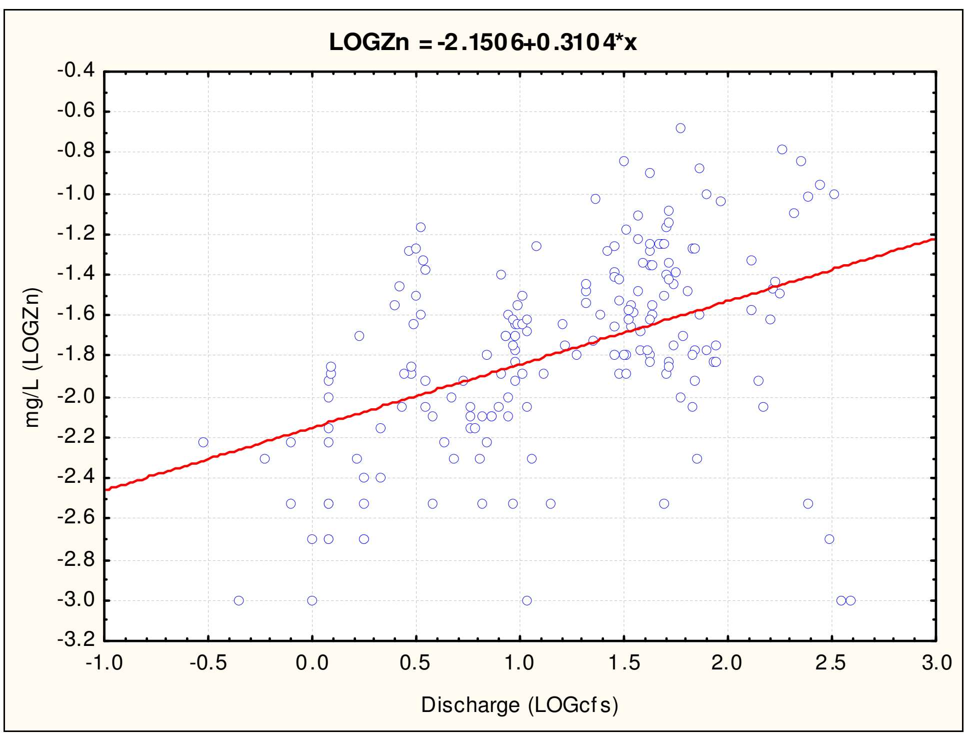
Total Phosphorus (TP) Data and Regressions for 2005-2009.



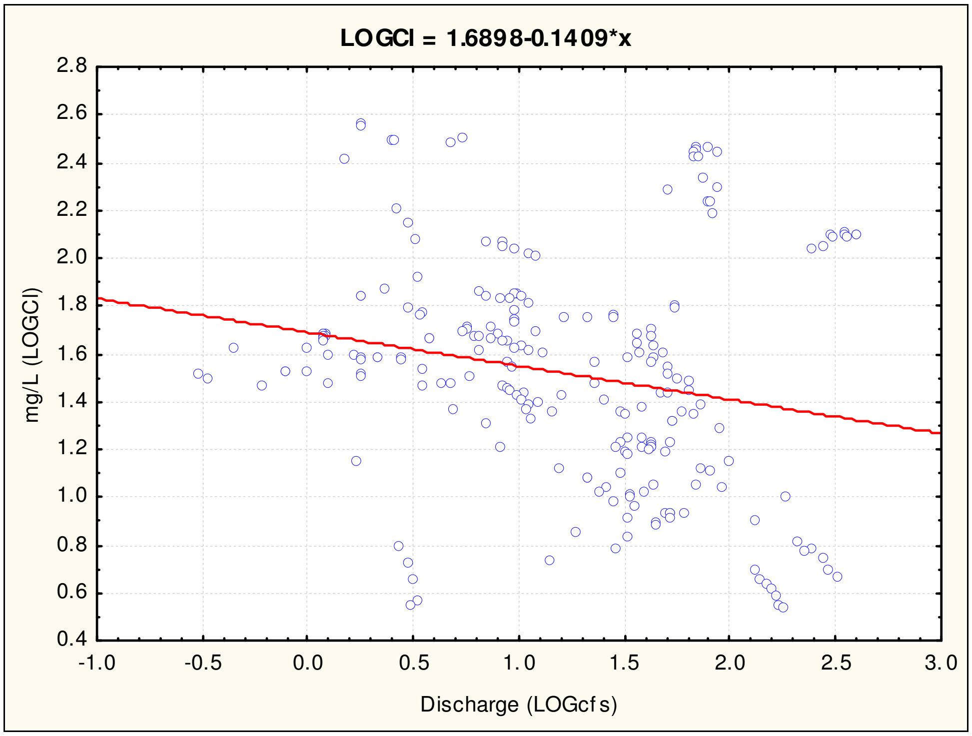
Total Copper (Cu) Data and Regressions for 2005-2009.



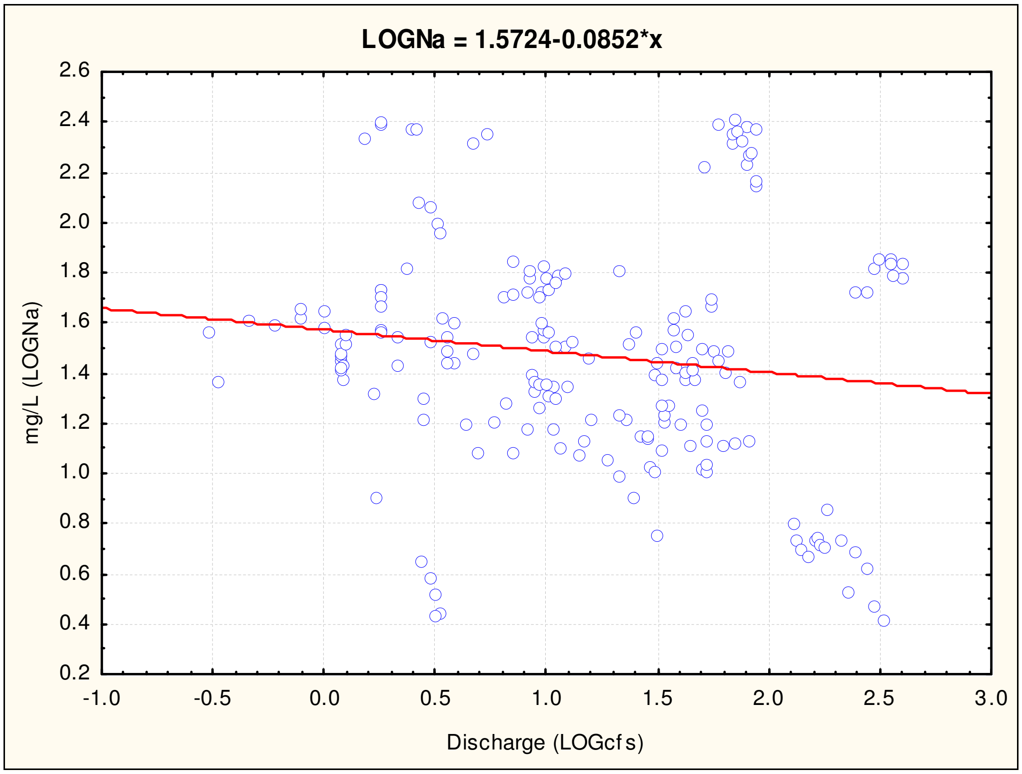
Total Lead (Pb) Data and Regressions for 2005-2009.



Total Zinc (Zn) Data and Regressions for 2005-2009.

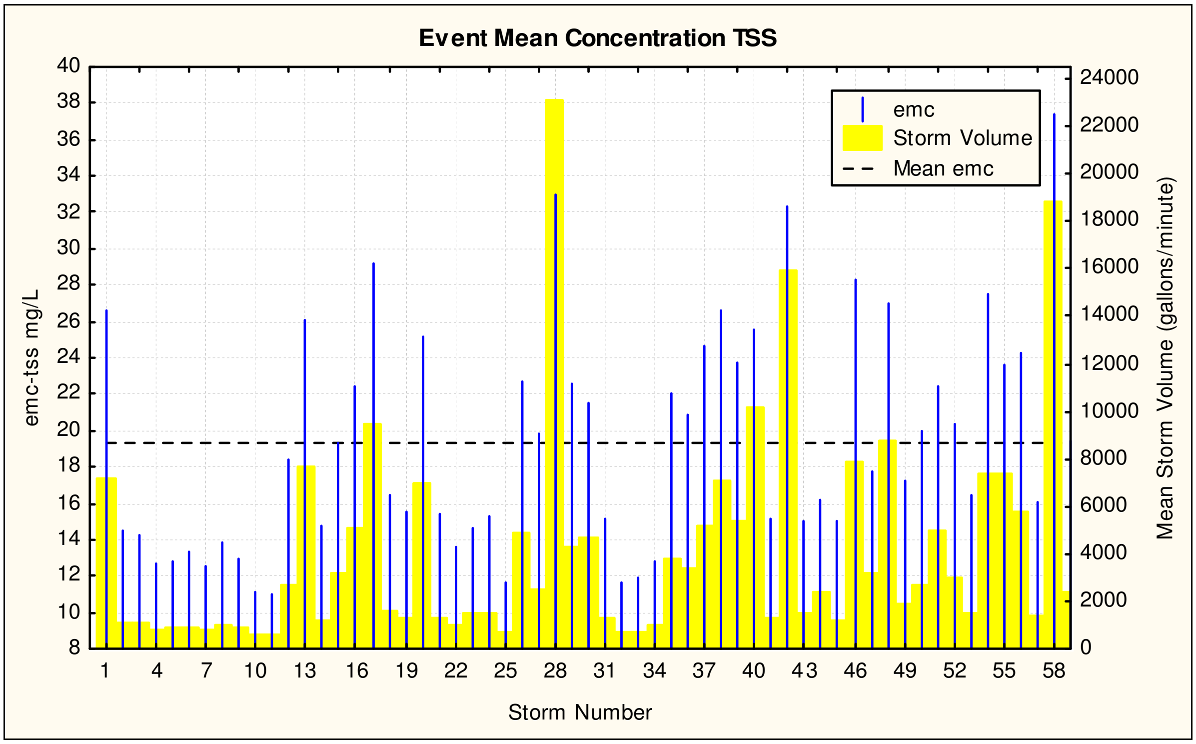


Chloride (Cl) Data and Regressions for 2005-2009.

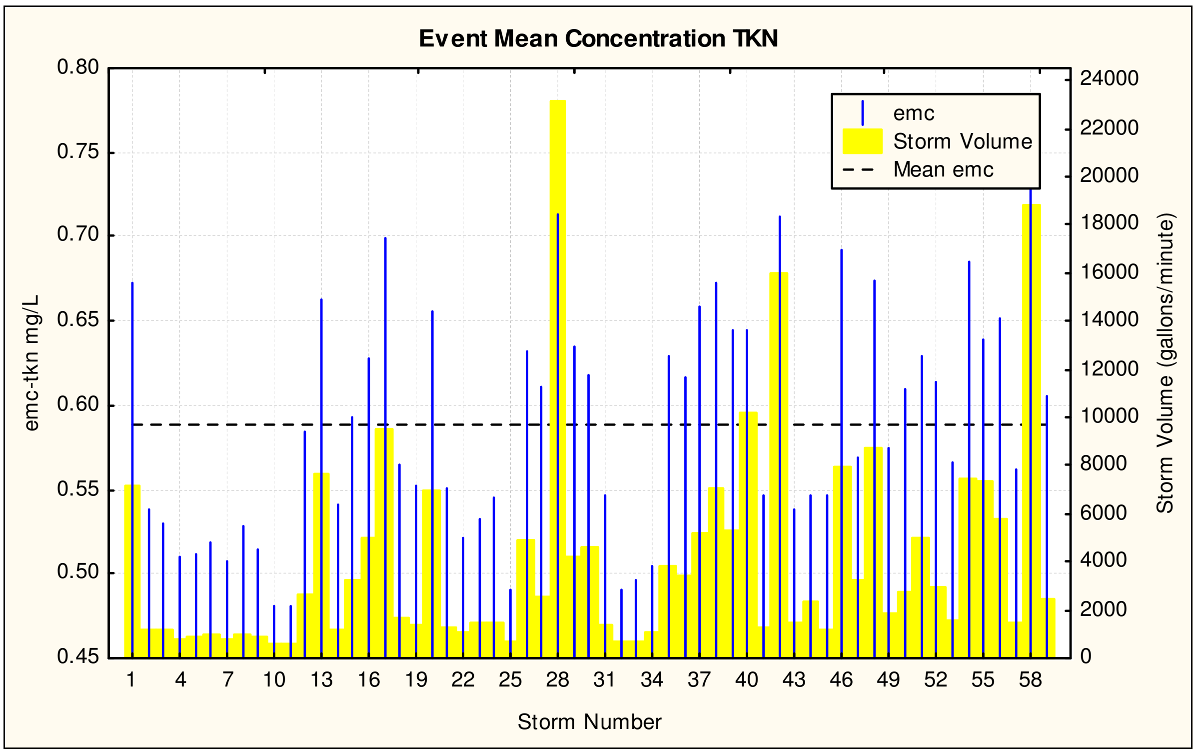


Sodium (Na) Data and Regressions for 2005-2009.

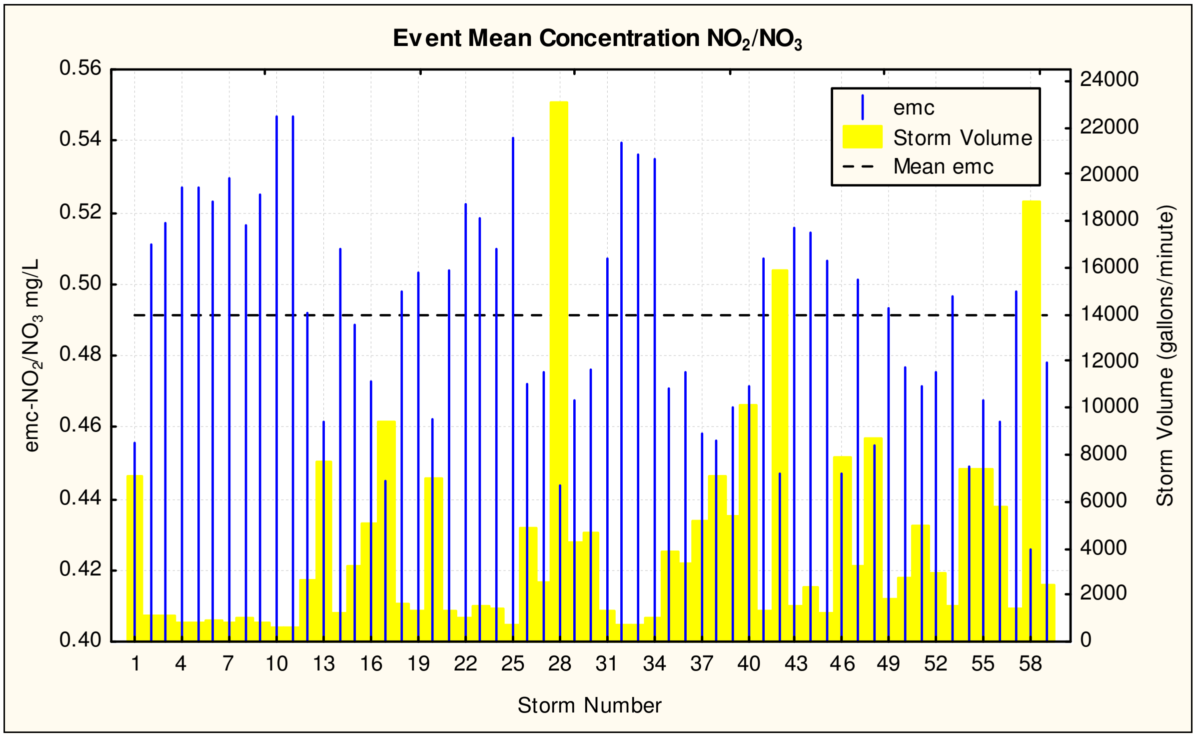
Appendix 8-2: Event Mean Concentration Graphs



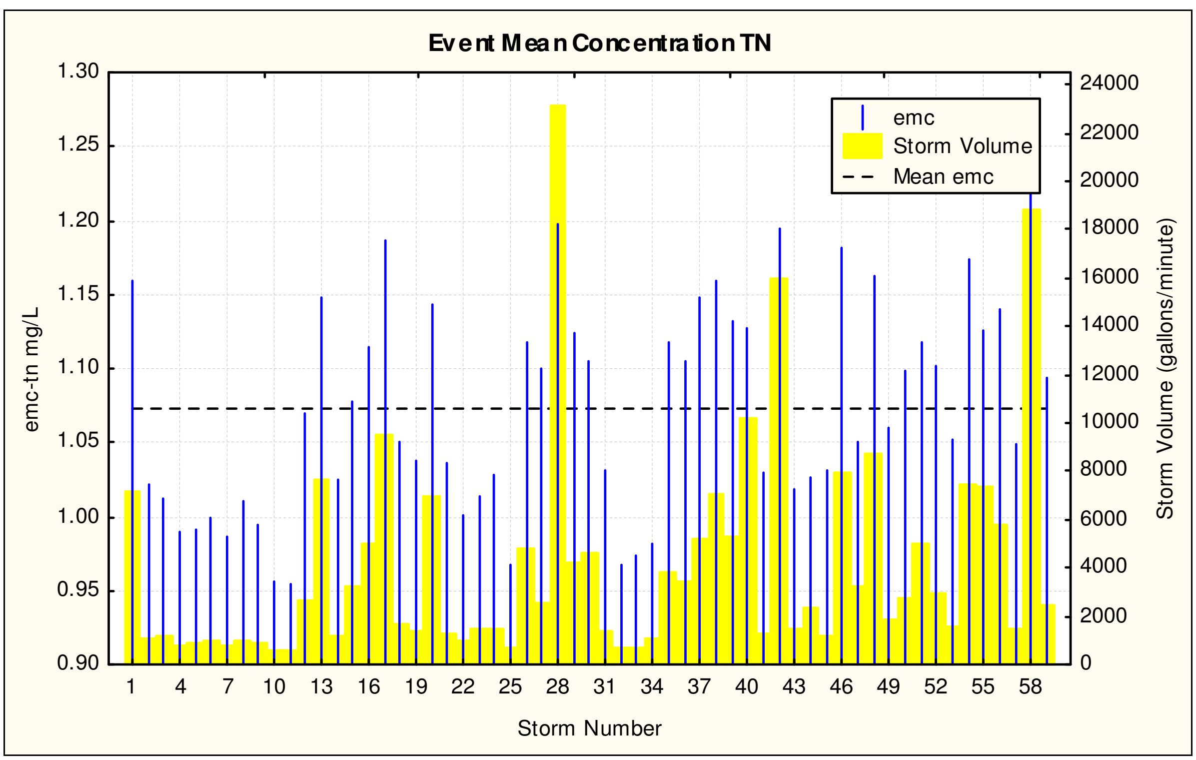
Event Mean Concentration for Total Suspended Solids (TSS) 2009



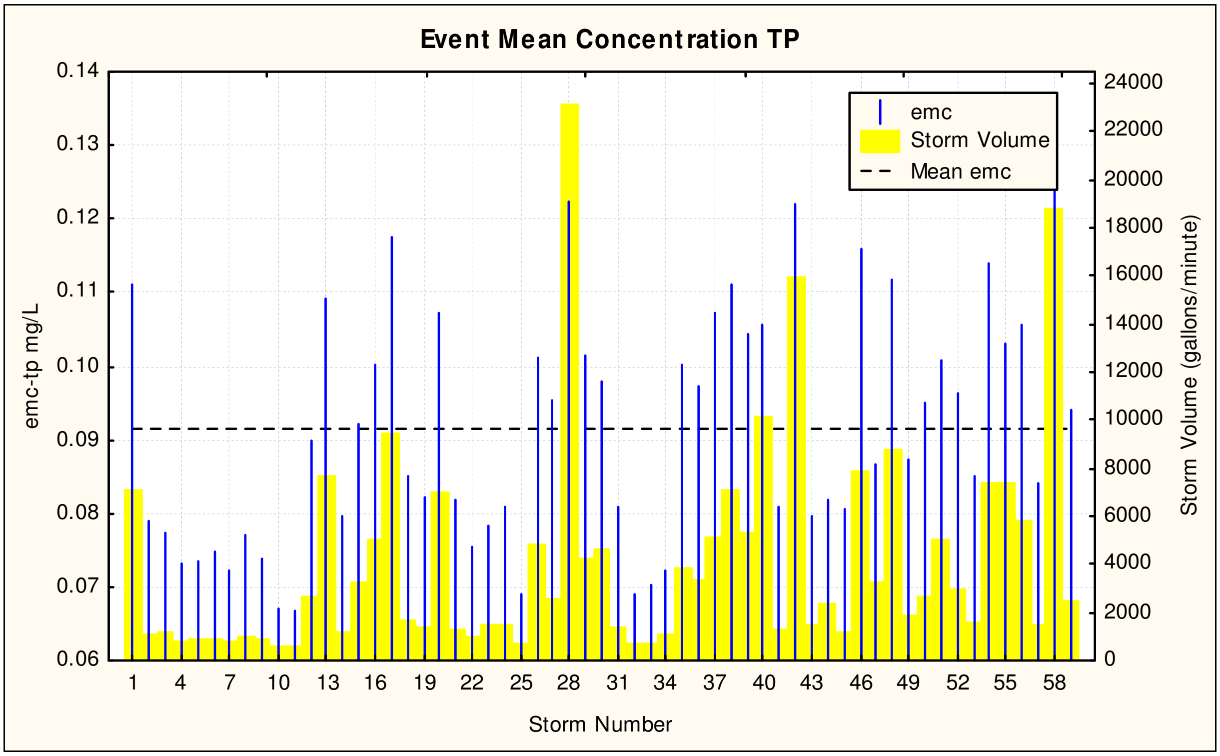
Event Mean Concentration for Total Kjeldahl Nitrogen (TKN) 2009



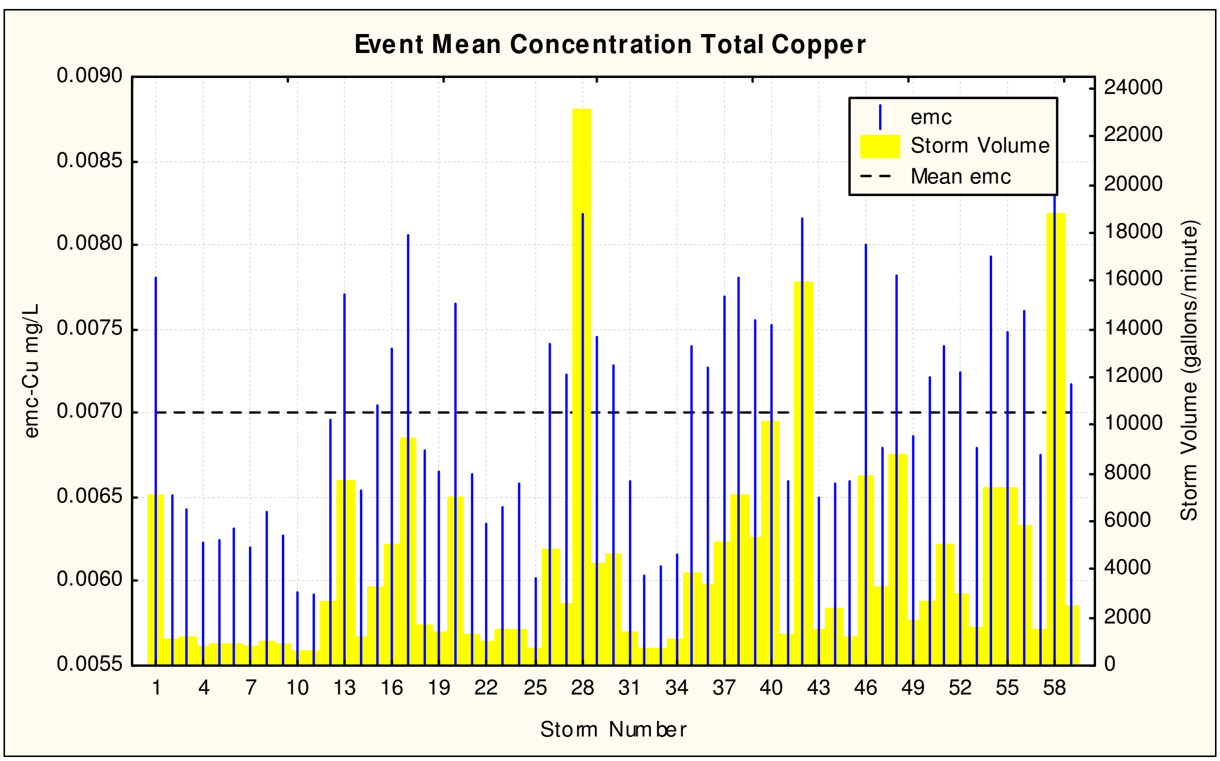
Event Mean Concentration for Nitrate/Nitrite (NO_2/NO_3) 2009



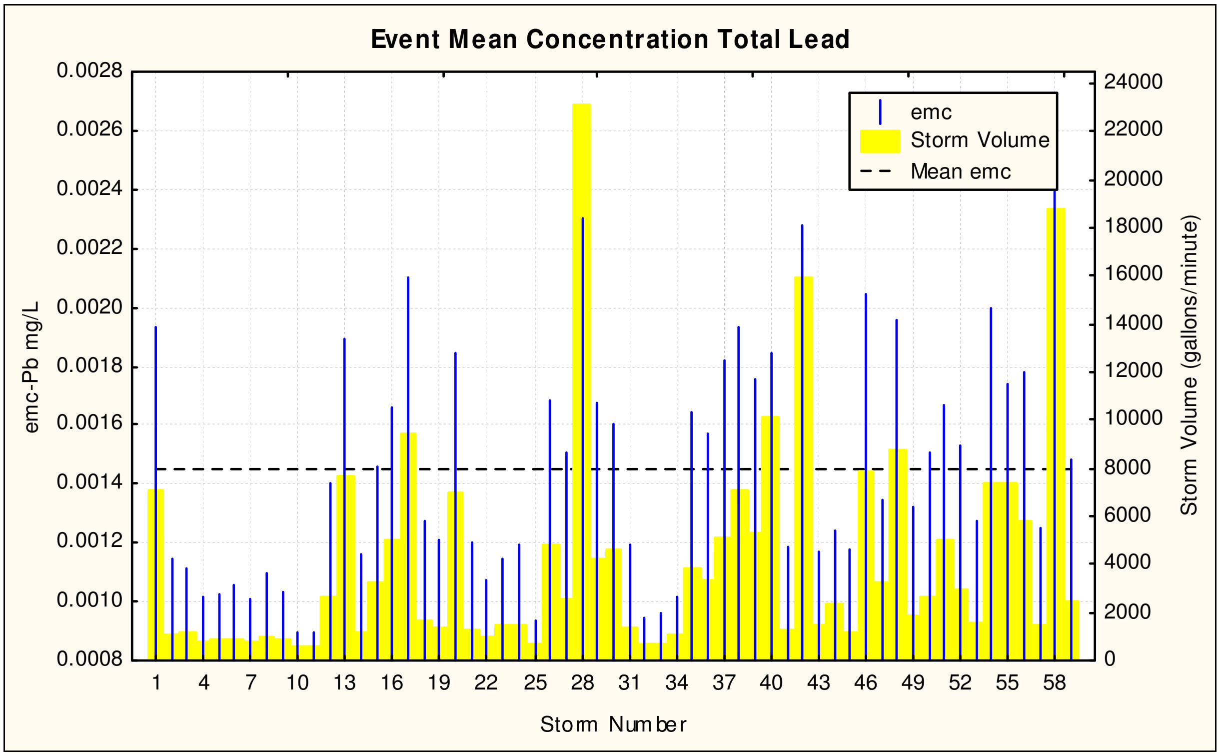
Event Mean Concentration for Total Nitrogen (TN) 2009



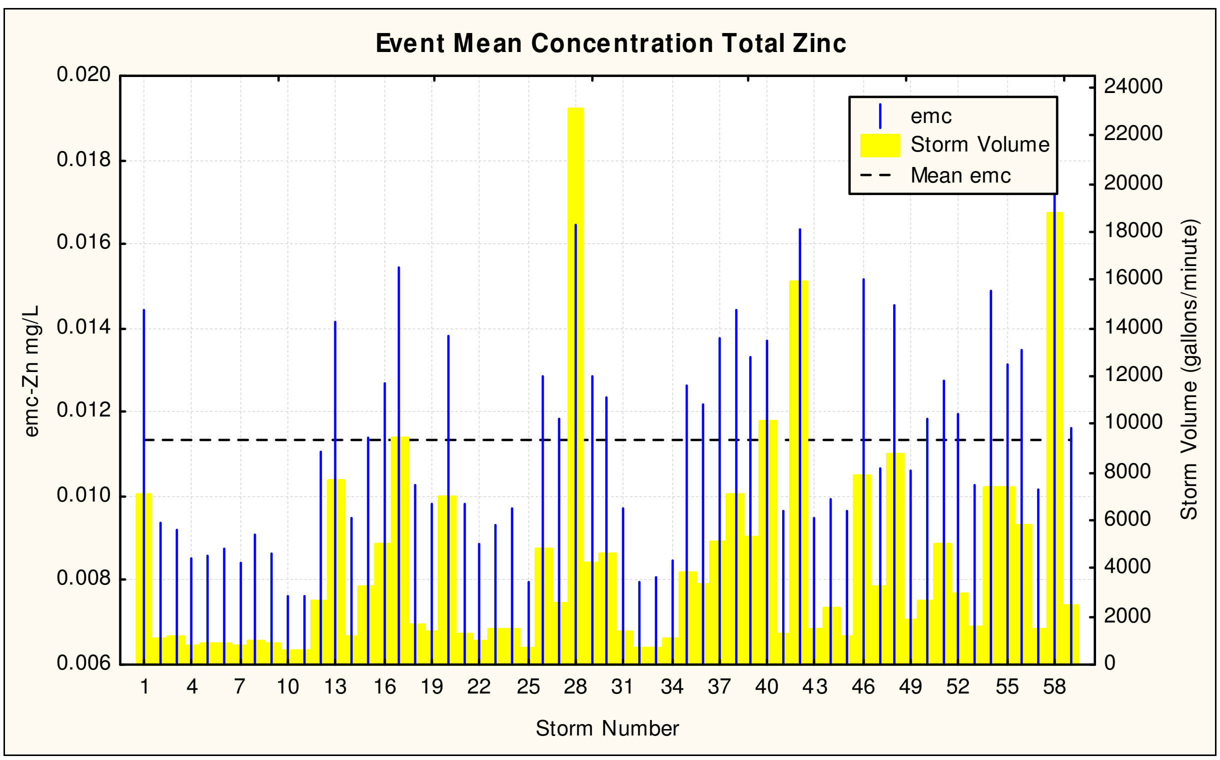
Event Mean Concentration for Total Phosphorus (TP) 2009



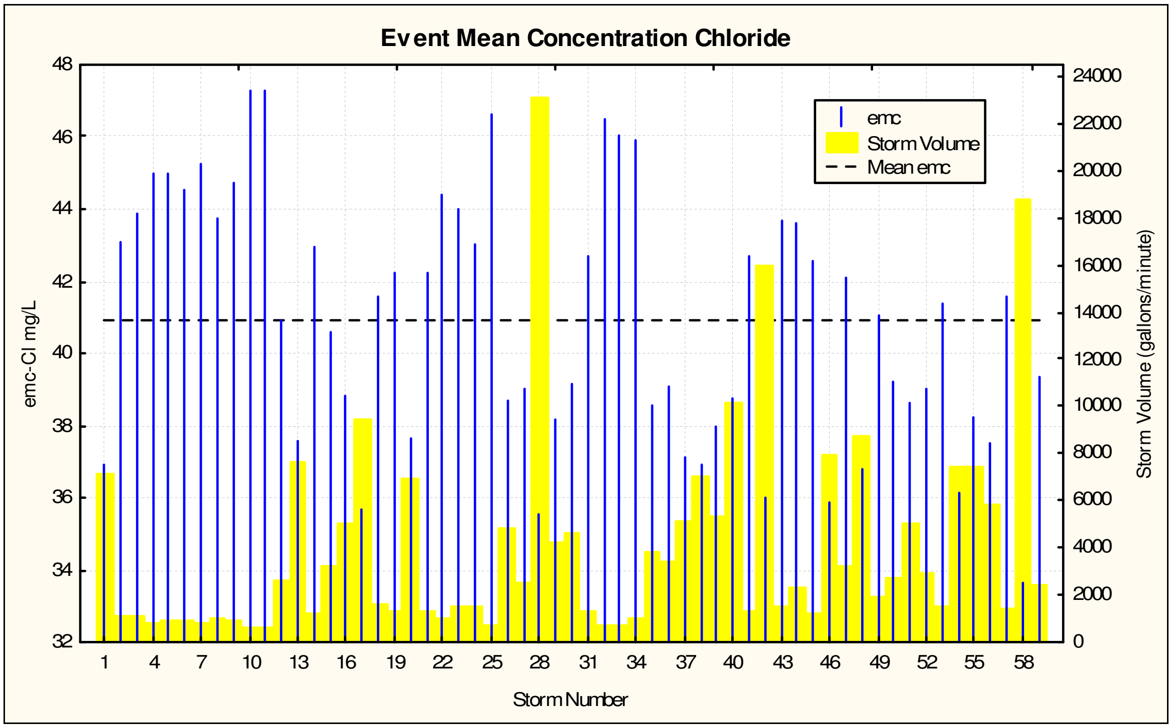
Event Mean Concentration for Total Copper 2009



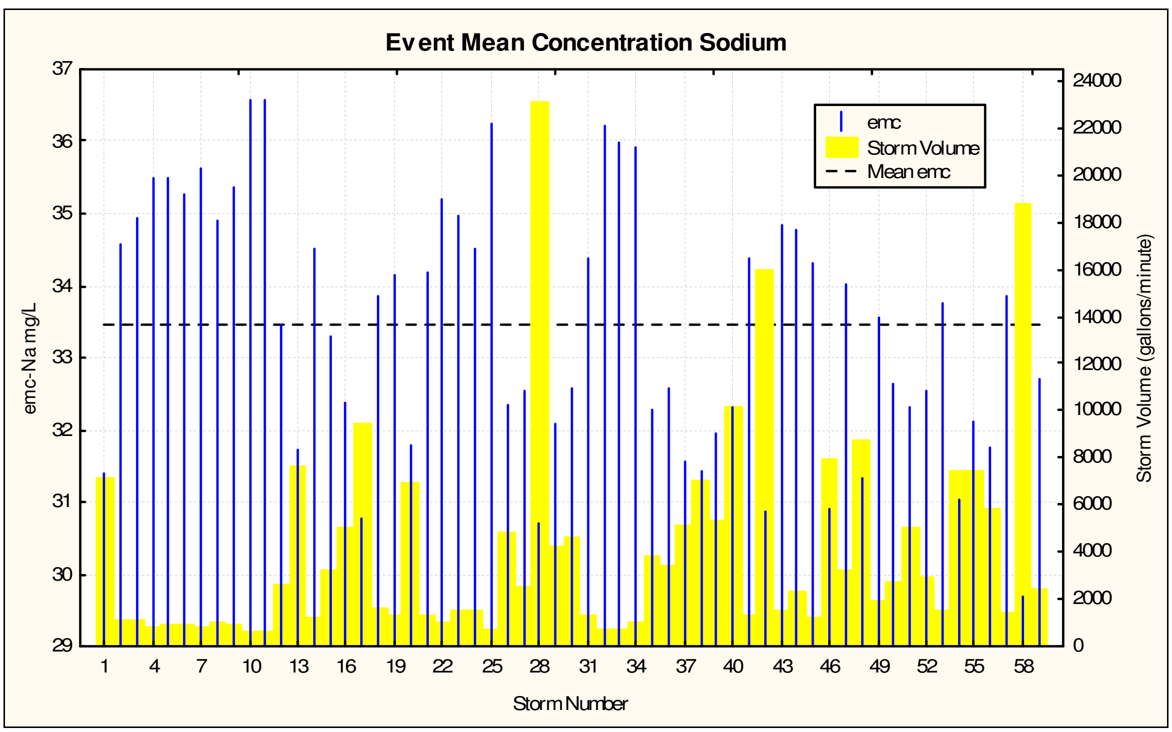
Event Mean Concentration for Total Lead 2009



Event Mean Concentration for Total Zinc 2009



Event Mean Concentration for Chloride 2009



Event Mean Concentration for Sodium 2009