
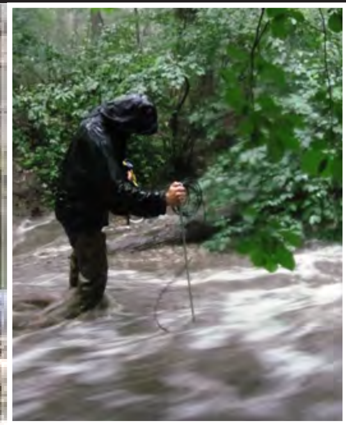
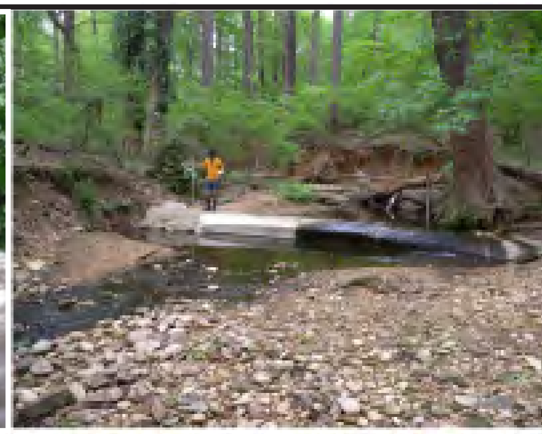

-FOUNDRY BRANCH-
Development of a Dissolved Oxygen (DO) Model Framework
MWCOG Final Report

Prepared For:
District of Columbia
Department of the Environment

Prepared By:
Metropolitan Washington
Council of Governments

September 2011

ARRA
American Recovery and Reinvestment Act
This green project is funded by U.S. EPA

GOVERNMENT OF THE DISTRICT OF COLUMBIA

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DISTRICT DEPARTMENT OF THE ENVIRONMENT

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I. Executive Summary

The purpose of this project was to: 1) conduct a comprehensive baseline assessment of existing physical, chemical and biological conditions and 2) develop a modeling framework for the development of a TMDL to address low Dissolved Oxygen (DO) impairments in Foundry Branch. The Metropolitan Washington Council of Governments (COG) was contracted by the District of Columbia Department of the Environment (DDOE) to perform the following five tasks: 1) identify potential nutrient loading sources, 2) compile GIS-related mapping data, 3) assess stream physical, chemical and biological conditions, 4) collect flow and in-stream water quality data adequate to support DO model development and 5) develop the modeling framework for DO conditions for Foundry Branch. The 21 month-long Foundry Branch study, described herein, consisted of seven parts: 1) employment of the Modified Rapid Stream Assessment Technique (RSAT) Level Ill to evaluate the Foundry Branch system (to include permanent channel cross-section stations, a longitudinal profile survey, and streambed pebble count; 2) baseflow and stormflow discharge characterization; 3) 'summer' water temperature monitoring; 4) baseflow and stormflow water chemistry grab sampling; 5) aquatic community and macroinvertebrate sampling; 6) development of the Foundry Branch DO modeling framework; and 7)recommendations based on study results. It should be noted that report findings herein focus on the upper Foundry Branch main stem. The reader is referred to the appendices for additional Foundry Branch information.

Results from the study generally support earlier findings (Banta, 1993 and DDOE, 2008) that both DO levels and the Foundry Branch biological community are severely impaired. In addition, decades of uncontrolled stormwater runoff in combination with major channel modifications have: 1) created a characteristically 'flashy', urban stream flow regime; 2) altered channel morphology and increased levels of stream channel erosion; 3) seriously compromised the integrity of the approximately 80-90 year old sewer line system, resulting (under certain flow conditions) in the exfiltration of sewage and/or infiltration of stream flow into the pipe system; 4) dramatically increased main stem stormflow levels of sediment, nutrients and other pollutants; 5) reduced streambed stability and physical aquatic habitat; 6) resulted in the enclosure of over 15 miles of the original Foundry Branch stream channel network; and 7) completely eliminated the resident fish community.

Additional major findings and recommendations of the study are described in the following sections.

A. Physical/Hydrological Condition Characterization

• Stream Cross-Section and Gradient

The mean cross-sectional area for the upper Foundry Branch main stem is approximately 91.7 ft^2. In addition, mean stream channel widths, bank heights and wetted perimeters were 20.4 feet, 3.4 feet and 6.9 feet, respectively. The upper half of this urban stream channel (i.e., approximately the first 1,800 feet) is highly entrenched with mean bank heights in the five foot range. As one proceeds downstream towards Massachusetts Avenue, stream gradient and bank heights both drop, the channel becomes much wider and the wetted perimeter generally comprises less than 30 percent of the bottom channel width. From cross-sections 7 - 10, the stream experiences significant backwater flooding during larger rainfall/runoff events from the partially clogged Massachusetts Avenue storm drain debris/trash grate. In character with second order Piedmont/Fall Zone streams, the mean gradient for the upper 'A' main stem is a modest 2.5 percent.

• Relative Stream Bank Stability

Out of a total RSAT-surveyed stream length of 2,424 feet (0.46 mi.), 574.5 linear feet (23.7 percent) exhibited moderate to severe stream bank erosion conditions It should be noted that these conditions were observed in all Foundry Branch stream channel patterns (i.e., straight, meanders and bends, etc).

• Substrate Size/Pebble Count

Pebble count results revealed that the median (i.e., D-50) Foundry Branch particle size is very coarse gravel (i.e., 36 mm). In addition, the D-84 sized particle for all seven surveyed reaches was very coarse gravel to small cobble (i.e., 32.00-127.99 mm). The preceding findings confirm that the Foundry Branch streambed material is generally gravel with some small cobble upstream of and including cross-section No. 4, and predominantly gravel below.

- Stream Thermal Regime Characterization

Results from the June to September 2010 (104 days) continuous stream temperature monitoring portion of the study indicated that stream temperatures were well below the DDOE Class 'C' standard (i.e., 32.2°C /90°F). In addition, water temperatures were at or below 20°C (i.e., MDE Use III natural trout waters criterion) 21 percent of the time, and were at or below 24°C (i.e., MDE 24 °C Use IV recreational trout criterion) 86 percent of the time. Based on the preceding results, the temperature regime for the entire Foundry Branch main stem can be generally categorized, per Galli (1990) as being that of a coolwater stream system.

B. Baseflow and Stormflow/Stage Discharges

- Baseflow

Between April 1st and November 18, 2010, COG staff made a total of 15 baseflow discharge measurements at the station No. 3 monitoring site. Mean main stem baseflow during the study period was a fairly anemic 0.064 cfs (i.e., or approximately 0.19 cfs/mi^2). However, below station No. 3, intermittent surface flow was observed from approximately May through September 2010. COG staff also observed that some infiltration of baseflow into portions of the sanitary sewer line system was occurring.

- Stormflow/Stage Discharge

A total of 13 separate stormfall events were monitored for the generation of the stage-discharge rating curve (i.e., 43 discharge measurements, total, taken during the ascending portion of the hydrograph). Importantly, at stream discharges in the approximately 100-200 cfs range, backwater conditions created by the partially clogged Massachusetts Avenue storm drain debris/trash grate rack precluded further measurements.

C. Baseflow Water Quality

- Instantaneous Baseflow DO

Between March 2010 and June 2010, no violations of the DDOE 5.0 mg/L dissolved oxygen (DO) concentration standard were observed for the 16 instantaneous baseflow measurements taken upstream of sewer line crossing no. 4 during daylight hours. However, DO concentrations (< 1.0 mg/L) were recorded in the pool immediately downstream of this sewer crossing during the low baseflow period (i.e., May - July, 2010) and prior to the DC Water sewer line repairs.

- Baseflow pH

pH ranged from 6.20 to 7.20. Generally, naturally occurring fresh water streams have a pH range of 6.5 to 8.0.

- Baseflow Nitrate

Instantaneous baseflow nitrate (NO_3) readings revealed: 1) concentrations ranged from a low of 1.60 to a high of 3.8 mg/L, with a median value of 2.45 mg/L. All of the observed values (N=12) were, per USGS (1993) interpretation, in the moderate to high range.

- Baseflow Fluoride

Foundry Branch instantaneous baseflow fluoride (F^-) concentrations ranged from a low of 0.28 mg/L to an extremely high 1.33 mg/L, with a median value of 0.68 mg/L; thereby, strongly suggesting an inflow of either municipal drinking water and/or sewage. It should be noted that naturally occurring fluoride concentrations for local, non-urban streams generally ranges from 0.1 to 0.2 mg/L, and that the District of Columbia reports concentrations of 0.33-1.30 mg/L for its treated water (DC Water, 2010).

- Baseflow Conductivity

Instantaneous baseflow conductivity levels ranged from 400 mS/cm to 1,000 mS/cm, with a median value of 608 mS/cm. Limited water quality surveys of relatively undisturbed Piedmont and Coastal Plain streams in Maryland and other mid-Atlantic states strongly suggest that Foundry Branch baseflow conductivity levels should be in the 60-160 mS/cm range (Thomas, 1966; Janicki et al., 1995; Galli et al., 1997, MCDEP, 1998; Stribling et al., 1999).

- WSSC Laboratory - Analyzed Baseflow Water Quality Grab Samples

E. Coli bacteria levels (i.e., range: 62-2,420 MPN/ml; mean 704 MPN/ml) exceeded the DDOE Class 'A' 410 MPN/100 ml standard roughly 40 percent of the time; whereas, on all five sampling dates, Enterococci bacteria levels (i.e., range: 80-921 MPN/ml; mean 294 MPN/ml) always exceeded the more rigorous EPA/MDE Use I Waters 33 MPN/100 ml standard. In addition, results from the November 10, 2010 bacterial source tracking (BST) sample suggest that non-human sources (i.e., birds, dogs, deer and other wildlife) are the main contributors. Throughout the survey period, both baseflow BOD_5 and TSS levels were low (i.e., below the WSSC 2.0 mg/L BOD_5 detection limit, the maximum TSS level was < 4.10 mg/L).

D. Stormflow Water Quality

- Stormflow Bacteria, $BOD_{5,}$ NO_3, TSS and TP Levels

Among the several stormflow-related observations made by COG staff during the study were that: 1) runoff from even relatively small rainfall events (i.e., <0.20 inches rainfall/24 hrs) produced turbid, dark-brown to dark-gray color conditions, 2) the stream returned to baseflow condition within approximately four to six hours following the cessation of rainfall, and 3) water clarity for smaller rainfall events (i.e., storms generating less than one-inch total rainfall and that did not create a backwater effect downstream of station No. 3, returned to near baseflow condition within the span of approximately two to three hours.

E. coli levels ranged from 488 to 20,100 MPN/100 ml (mean=10,072 MPN/100 ml), far exceeding the DDOE Class 'A' 410 MPN/100 ml standard. Similarly, Enterococci bacteria levels (range: 1,020 - 21,900 MPN/100 ml; mean = 10,546 MPN/100 ml) also greatly exceeded the EPA/MDE Use I Waters 33 MPN/100 ml standard. In addition, the one BST sample collected from station 3 on April 12, 2011 confirmed that humans are among the top three contributors, accounting for 17 percent of that storms bacterial load.

While relatively low, BOD_5 stormflow levels were up to seven times higher (i.e., range: 4.7-15.4 mg/L; mean=8.3 mg/L) than for those observed under baseflow conditions (i.e., < 2 mg/L). Compared to baseflow conditions, median stormflow NO_3 levels were much lower (i.e., 0.57 mg/L versus 3.03 mg/L), reflecting a rainfall/runoff dilution effect.

Stormflow TSS levels (i.e., range: 20-255 mg/L; mean= 96.2 mg/L) generally reflected both rainfall amount and intensity. For example, the medium size 8/12/10 event (0.82 inches, total) had a maximum intensity of 0.53 inches per hour, occurred seven days after the previous rainfall date, and produced the highest TSS level (i.e., 255 mg/L). In contrast, the much smaller 9/27/10 event (0.03 inches, total) occurred nine days after the previous rainfall date, had a maximum intensity of 0.01 inches per hour, and generated a relatively low TSS level of 29.0 mg/L.

Stormflow TP levels (i.e., range: 0.24 - 0.52 mg/L; mean = 0.33 mg/L), were well above the 0.10 mg/L TP concentration level recommended by EPA (1986) for the reduction and/or avoidance of nuisance plant growth in streams.

E. Continuous DO Monitoring

Baseflow DO levels for the March 31 - July 31, 2010 period (i.e., pre-sewer line repair completion) were below DDOE's 5.0 mg/L standard 55 percent of the time. During this period, DO levels ranged from 0.0 - 12.47 mg/L, with a mean concentration of 3.39 mg/L. DO levels for the August 1- November 21, 2010 period (i.e., post sewer line repair) improved slightly, and ranged from a high of 10.29 mg/L to a low of near zero, with a mean concentration of 6.14 mg/L.

Throughout the study, the lowest observed DO levels (i.e., 2.0 mg/L, or less) occurred intermittently at both probe No. 1 and 2 during baseflow conditions. These extremely low levels were generally recorded in the late afternoon to the 2 a.m. time period, with highest DO readings observed in the early morning hours; exactly the opposite of the normally expected diurnal pattern. The maximum 2010 baseflow DO level was 12.47 mg/L (i.e., approximately 110 percent saturation) most likely reflecting high photosynthetic activity in the stream during early leaf-off conditions.

Under stormflow (wet weather) conditions, Foundry Branch DO levels actually increased. These higher stream discharges generally resulted in a temporary DO increase on the order of 3-4 mg/L (i.e., the Delta DO).

F. Aquatic Community

Reflective of the highly depauperate conditions present, a total of eight (8) macroinvertebrate taxa were collected in upper Foundry Branch. For the summer 2010 RSAT voucher collection, four (4) taxa were identified, and for the 20-jab surveys, six (6) taxa were identified. The highest number of taxa collected (6, poor range) was associated with the spring 2010 20-jab sample. Spring MBSS IBI scores for upper Foundry Branch were verbally rated as being very poor (i.e., IBI scores < 2.0). In addition, the associated verbal ratings for the individual metrics were all in the very poor categories. It should be noted that there are still two tributaries (i.e., 'W' street Tributary and Phillips Run) located in the lower Foundry Branch that feature individuals from the stonefly (Amphinemura spp.) and caddisfly (Diplectrona spp.) groups. Their presence generally indicates both a cool/cold summer stream temperature regime and a stable streambed.

G. Modeling

The LimnoTech modeling report has been included as Appendix A. In general, the WASP5-based model did a much better job of simulating stormflow DO conditions than those for baseflow. Results show a wet weather event that is, like the 2010 events, not especially sensitive to the upstream DO formulation. It is noteworthy that the diurnal pattern (Figure 1) does not appear to represent expected photosynthesis effects with respect to timing; that is, the highest DO levels in the data occur in the early morning with the lowest DO levels in the late afternoon, roughly the opposite of the expected pattern. Figure 2 shows the effect of the inclusion of a hypothetical dry weather sanitary source. It should be noted that while this sanitary source did reduce DO levels, modeling results were somewhat inconclusive as they did not drive it as low as observed in the data. The preceding findings further suggest that there may be an intermittent sewage discharge problem present.

Figure 1. Upper Foundry Branch - DO Comparison at Sewer Crossing #4 (Wet Weather, June 2011 event) (LimnoTech, 2011)

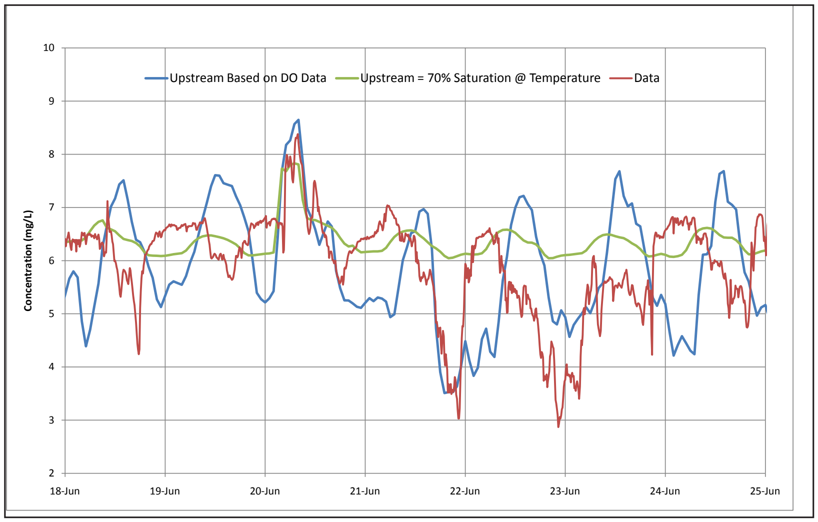
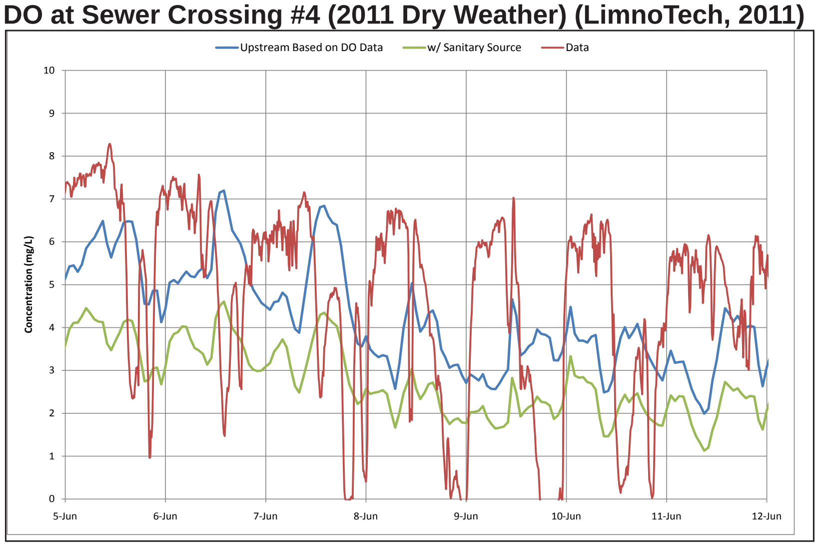


Figure 2. Upper Foundry Branch - Effect of Sanitary Source on DO at Sewer Crossing #4 (2011 Dry Weather) (LimnoTech, 2011)



H. Recommendations

In an effort to comprehensively address both existing problems and restoration opportunities for Foundry Branch, COG staff developed the following suite of recommendations. Importantly, it is understood that the comprehensive restoration of Foundry Branch is dependent upon DDOE, DC Water, NPS, the District of Columbia Department of Public Works and Transportation (DC-DPWT), the U.S. Army Corps of Engineers and other organizations working together to pursue a variety of sewer system upgrades, stormwater management, storm drainage, and stream restoration options, which will significantly reduce erosive stormflows, improve water quality and enhance aquatic and terrestrial habitat conditions throughout the subwatershed. Other and more specific recommendations are as follows:

1. The aging, main trunk and lateral sanitary sewer lines, which may date as far back as the mid-to-late 1930's and that parallel much of Foundry Branch, have had a long history of breaks and leaks. In fact, decades of uncontrolled stormwater runoff have, at several channel locations, severely compromised the structural integrity of the sewer system. Given the overall age and condition of this sewer system, it is strongly recommended that DC Water continue to inspect it with state-of the art closed circuit television (CCTV) and with sonar technology. This will enable DC Water to perform accurate and comprehensive assessments of trunk and lateral sewer line integrity.

2. Following inspection of the sewer system, DC Water should strongly consider the following near-term actions:

    - The six inch PVC lateral line (located in the upper Foundry Branch, immediately downstream of the 60" RCP outfall) is anticipated to again break under higher stormflow conditions. Therefore, it is strongly recommended that this pipe be replaced and relocated out of this high velocity area as soon as possible;

    - Replace and relocate the sewer manhole stack located in the stream channel (upper Foundry Branch at transect No. 9);

    - Replace, or at a minimum rehabilitate, all sewer lines crossing the stream channel, specifically the older vitreous clay pipes, via the employment of an Insituform® or equivalent lining. Subsequently, in-stream grade control structures (such as rock vanes) should be installed to prevent additional streambed downcutting and channel widening; and

    - Replace and/or rehabilitate the entire trunk sewer line system and associated manholes. In addition, if at all possible this work should be done in concert with the restoration of Foundry Branch's stream morphology.

3. DDOE and/or DC Water should perform an illicit discharge detection survey looking for illegal pipe hookups in the storm drain network that may chronically contribute the following: raw sewage, nutrients, toxic pollutants, etc. This survey should be conducted, at a minimum, for upper Foundry Branch outfall Nos. 1, 2, 3, and 5. The employment of various EPA recommended illicit discharge detection and elimination (IDDE) methods (with follow up CCTV of storm drain network systems that have been positively IDDE verified) should be considered.

4. Given the major technical, institutional and financial challenges associated with the implementation of subwatershed-wide stormwater management controls (which significantly reduce runoff volumes entering Foundry Branch), a Rosgen-based main stem stream channel restoration project for the entire length of open channel (i.e., approximately 1.6 miles) is recommended. This would include the repair and/or the installation of more effective velocity dissipation features at the preceding four storm drain outfall locations (i.e., Nos. 1, 2, 3, and 5).

5. To the greatest practical extent, the employment of various stormwater management water quality control techniques (such as, but not limited to, environmental site design/low impact development (ESD/LID), DDOE approved water quality inserts and inlets, sand filters, porous pavement, green roofs, etc) are needed throughout the Foundry Branch watershed. This is especially true for major roadways and commercial areas, which typically generate higher runoff volumes and pollutant loads.

6. Perform flow discharge, DO and water quality monitoring of upper Foundry Branch storm drain outfalls, specifically targeting dry weather, 12 hour period (i.e., 6 p.m. to 6 a.m.), baseflow conditions at storm drain outfall Nos. 1 and 3; so as to provide additional insight on contributing factors to the upper Foundry Branch low dissolved oxygen problem.

7. Perform post-restoration physical, chemical (to include chemical and bacterial laboratory analysis of water grab samples collected under baseflow and stormflow conditions) and biological monitoring of Foundry Branch, so as to evaluate stream recovery from proposed DC Water sewer line man hole replacement and rehabilitation and other watershed environmental restoration projects. It is strongly recommended that bacterial source tracking (BST) be performed so as to better determine the origin(s) of the bacteria contamination (i.e., bird, deer, human, etc.

8. In collaboration with DC Water and the National Park Service, the debris/trash grate located in the upper Foundry Branch at the terminus of the open stream channel section should be cleaned and maintained, free of debris and trash (on a regular basis), so as to both eliminate backwater conditions and reduce the likelihood of associated episodic low dissolved oxygen levels in the lower portion of the stream.

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II. Introduction

A. Project Background

The purpose of this project was two-fold: 1) to conduct a comprehensive baseline assessment of existing physical, chemical and biological conditions, and 2) to help develop the modeling framework for the future development of a total maximum daily load (TMDL) to address long-standing low dissolved oxygen (DO) impairment problems in Foundry Branch. As such, the Metropolitan Washington Council of Governments (COG) was contracted by the District of Columbia Department of Environment (DDOE) to perform the following five tasks: 1) identify potential nutrient loading sources, 2) compile GIS-related mapping data, 3) assess stream physical, chemical and biological conditions, 4) generate baseline stream flow and in-stream water quality data adequate for DO model development and 5) develop a modeling framework for characterizing DO conditions in Foundry Branch.

The baseline assessment of existing physical, chemical and biological conditions and the development of the DO model focus almost exclusively on the open channel, upper 'A' Foundry Branch subwatershed area. It should be noted that COG staff did perform a limited assessment of the remaining lower Foundry Branch watershed area; concentrating generally on physical and biological conditions for the open main stem and tributary stream channel areas. For specific DO modeling results, Foundry Branch main stem and select tributary-specific physical, chemical and biological conditions, the reader is referred to Appendices A-F.

Importantly, funding for this project came from the American Recovery and Reinvestment Act (ARRA) of 2009. One of the many goals of ARRA is to fund projects that help achieve water quality standards compliance. This project represents an important and key starting point for assisting the District of Columbia ultimately achieve compliance with D.C. Official Code §§ 8-103.01 *et seq*., D.C. Official Code § 8-151.07(10) and the federal Clean Water Act, sections 33 U.S.C. §§ 205(j)(2) and sections 303(e), 603(c) and § 604(b) under ARRA.

B. Foundry Branch Watershed

Foundry Branch, which drains an approximately 1,126 acre (1.76 mi^2) urbanized watershed within the northwestern quadrant of the District of Columbia, is a moderate size third-order tributary to the Potomac River. According to its water use classification system, the District of Columbia has designated Foundry Branch (i.e., Potomac River tributaries) as follows: 1) Primary contact recreation = A; 2) Secondary contact recreation and aesthetic enjoyment = B; 3) Protection and propagation of fish, shellfish and wildlife = C; and 4) Protection of human health related to consumption of fish and shellfish = D. Currently, the stream meets just three (i.e., B, C and D) out of the four use classes (DCR, 2010). DDOE has also listed Foundry Branch, specifically the upper section, as an impaired waterbody (DDOE, 2008) for the following: 1) low DO, 2) high bacterial counts and 3) high metal levels.

Figure 1. Upper Foundry Branch - 60" RCP outfall and perched concrete pad

The headwaters of Foundry Branch, which begin just north of Tenley Circle, are enclosed within a storm drain pipe network. Approximately 800 feet south of Van Ness Street the stream becomes open (Figure 1). The first of the two open stream channel sections emerges from a 60" reinforced concrete pipe (RCP). This first section is approximately 0.51 miles long and terminates, approximately 400 feet north of Massachusetts Avenue, at a large trash grate. This grate marks the streams reentry back into the enclosed storm drain pipe system. The second, lower, open stream section is located below New

Mexico Avenue. This section is approximately 1.12 miles long. Just north of Reservoir Road, it too reenters the main Foundry Branch parallel pipe storm drain system (which outfalls directly into the Potomac River).

The stream flows through the National Park Service's Glover Archbold stream valley park. The stream valley park area is well-forested and bounded by commercial, institutional, garden and high rise apartments, row-house and single-family home land uses. The average imperviousness for the entire watershed is approximately 35 percent.

Geologically, the stream is located within the Fall Zone, the transitional area where the upland Piedmont and the Coastal Plain physiographic regions meet. It should be noted that portions of the open stream channel exhibit more Piedmont-like characteristics, including moderately higher stream gradient, bedrock/boulder outcrops and a mix of rubble, cobble, and gravel streambed materials.

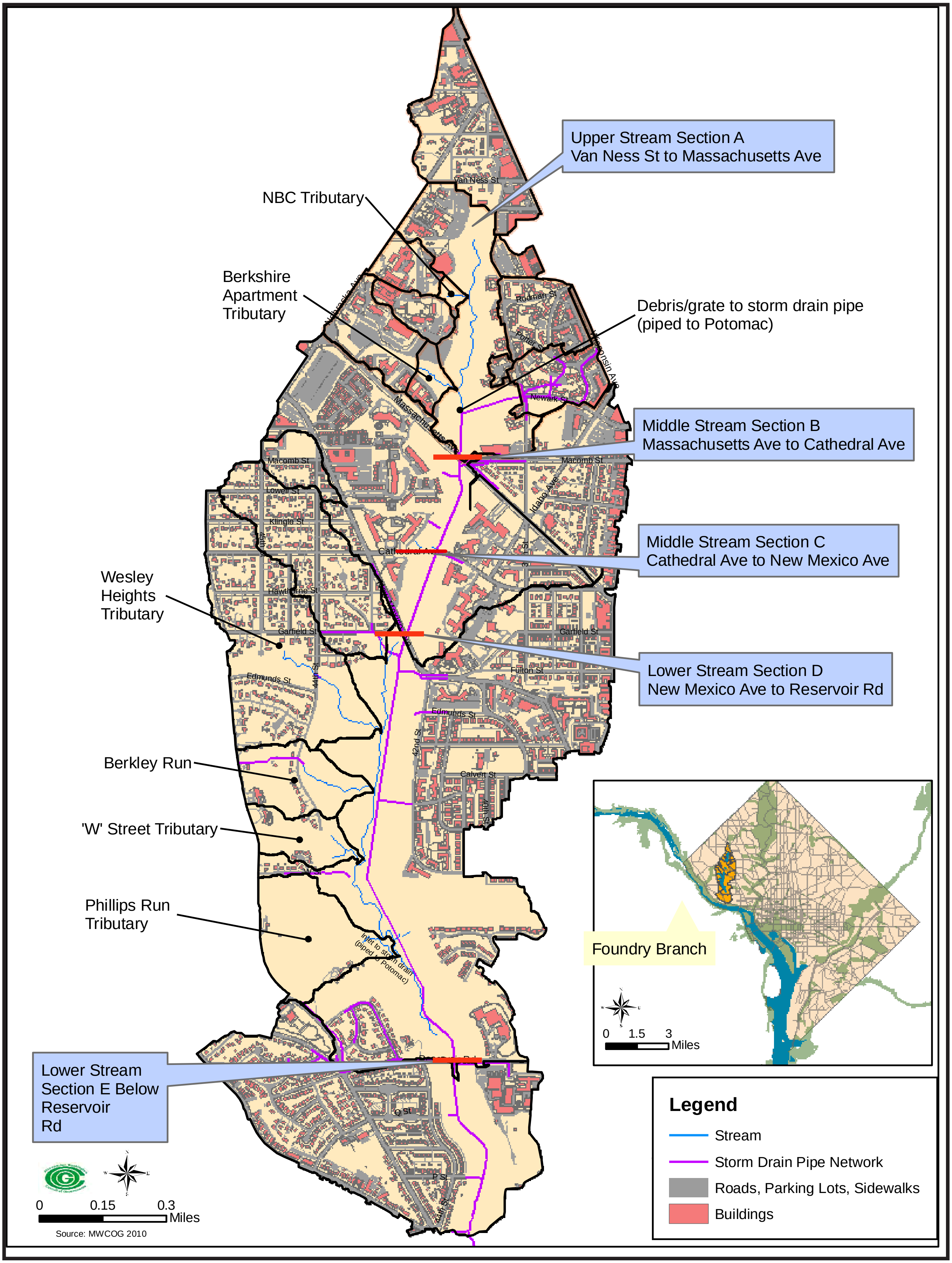
For the purpose of this study, the Foundry Branch watershed was subdivided (based on major road crossings) into five smaller discrete subwatershed units. These include: upper 'A', middle 'B' and 'C', and lower 'D' and 'E' unit sections. There are total of six major tributaries with perennial flow. Of the six, two are located in the upper 'A' unit and four are located in the lower 'D' unit'(Table 1 and Figure 2).

Because of the extensive and complex enclosed storm drain system present, Foundry Branch stream flow is hydraulically unique. In the upper and middle sections, both baseflow and stormflow are discharged directly to the Potomac River via a large, 108 inch diameter, parallel pipe storm drain system; and therefore does not contribute flow to the lower 'D' open channel reach. Below Reservoir Road, flow from the lower 'D' reach

Table 1. Foundry Branch Subwatershed Unit Description

Subwatershed Unit Section Name	Major Road Crossings	Open Stream Channel			Approximate Drainage Area	
			Perennial Flow (Yes/No)	Length (miles)	Acres	Mi^2
Upper A (Upper Foundry Branch)	Van Ness Road to Massachusetts Avenue	Open	Yes	0.46	209.7	0.33
1. 'NBC' Tributary	None	Open	Yes	0.09	22.4	0.03
2. Berkshire Apartment Tributary	None	Open	Yes	0.12	27.8	0.04
Middle B	Massachusetts Avenue to Cathedral Avenue	Piped	No	--	58.4	0.09
Middle C	Cathedral Avenue to New Mexico Avenue	Piped	No	--	155.0	0.24
Lower D (Lower Foundry Branch)	New Mexico Avenue to Reservoir Road	Open	Yes	1.15	543.5	0.85
3. Wesley Heights Tributary	None	Open	Yes	0.36	83.6	0.13
4. Berkley Run	None	Open	Yes	0.21	25.2	0.04
5. 'W' Street Tributary	None	Open	Yes	0.15	16.0	0.04
6. Phillips Run	None	Open	Yes	0.12	37.5	0.06
Lower E	Reservoir Road to Potomac River	Piped	No	--	159.0	0.25
Main Stem Subtotal				**1.61**	**--**	**--**
Total				**2.66**	**1,126**	**1.76**

Figure 2. Foundry Branch Watershed



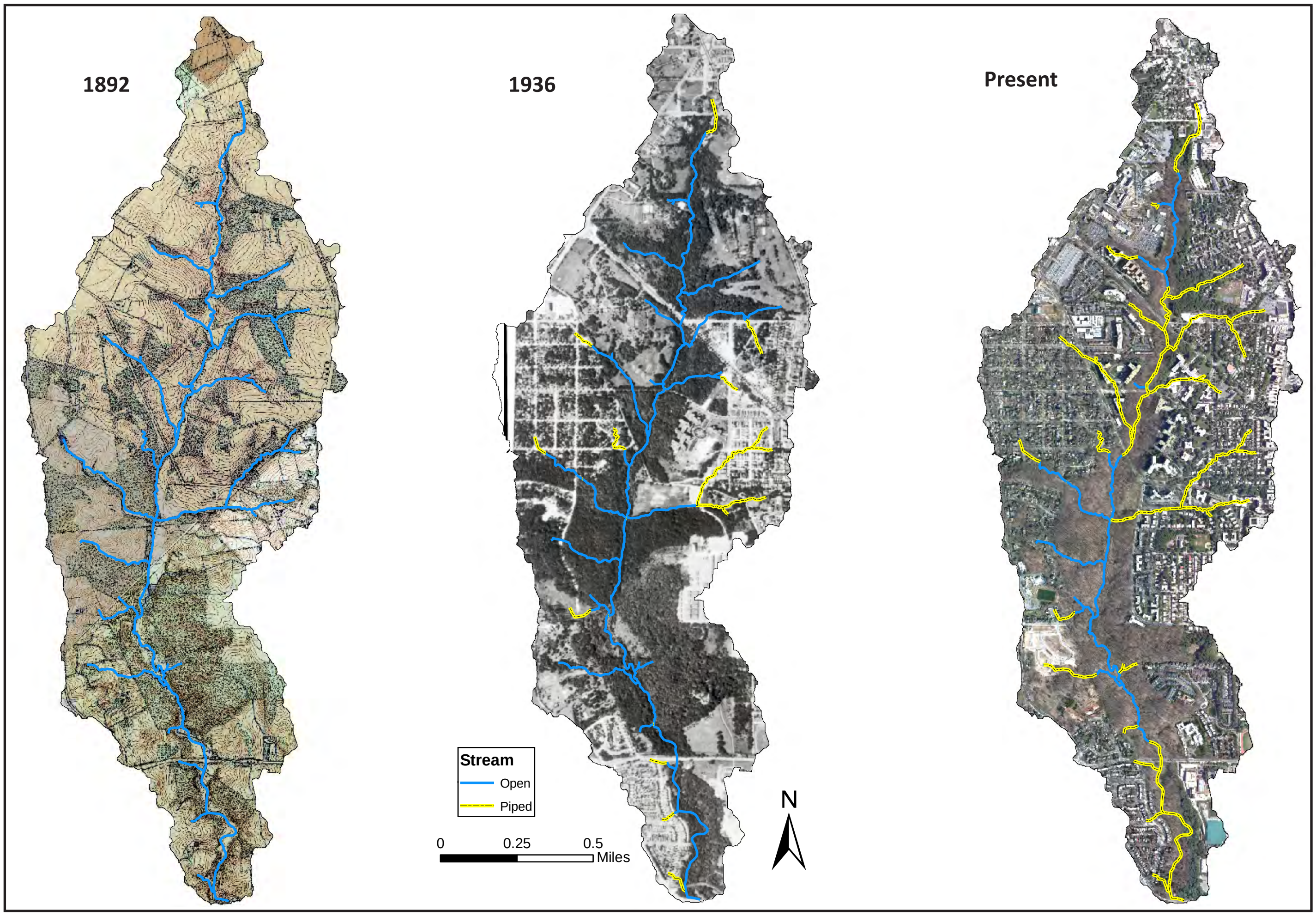
enters the same parallel storm drain pipe system. It is important to note that: 1) there are no open main stem stream channel areas in the middle 'B', 'C' and lower 'E' units, and 2) that the parallel pipe storm drain system, which runs down along the eastern side of the stream valley, effectively captures the majority of street runoff from the east side of the watershed (i.e., from approximately Massachusetts Avenue down to Reservoir Road). It is also important to note that, for all intents and purposes, stormwater runoff in the Foundry Branch watershed is completely uncontrolled.

Also for reporting purposes, henceforth , the upper 'A' Foundry Branch shall be referred to as upper Foundry Branch and lower 'D' Foundry Branch shall be referred to as lower Foundry Branch.

C. Problem Assessment

As seen in Figure 3, in the late 1800's land use in the Foundry Branch watershed was still, surprisingly, predominantly agricultural. By the mid-1930's, the watershed was rapidly transitioning from agricultural/large open space land uses to the present, highly developed urban landscape one. Among the many environmental

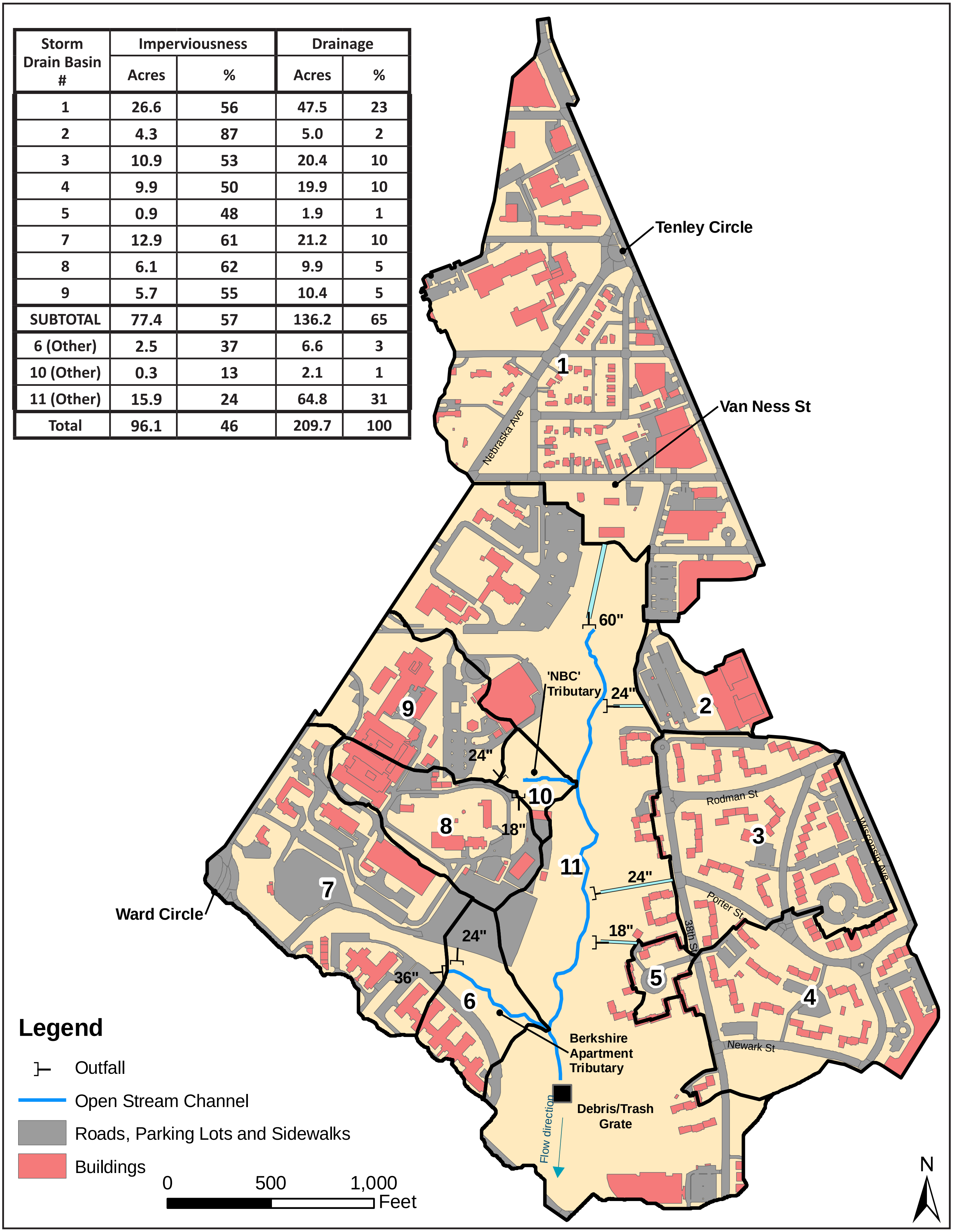
Figure 3. Foundry Branch Watershed - Year 1892, 1936 and Present



changes over the past 80 years is the loss, due to stream enclosure/piping (i.e., as part of the approximately 15 mile long storm drain network), of roughly 80 percent of the former open stream channel network. As in most urbanized watersheds, stormwater runoff is typically conveyed directly to the stream via a network of storm drain pipes. Foundry Branch has over 15 of these storm drain pipe outfalls. Not surprisingly, decades of uncontrolled stormwater runoff have adversely impacted Foundry Branch and its biota.

Figure 4. Upper Foundry Branch - Summary - Imperviousness and Storm Drain Network

Storm Drain Basin #	Imperviousness		Drainage	
	Acres	%	Acres	%
1	26.6	56	47.5	23
2	4.3	87	5.0	2
3	10.9	53	20.4	10
4	9.9	50	19.9	10
5	0.9	48	1.9	1
7	12.9	61	21.2	10
8	6.1	62	9.9	5
9	5.7	55	10.4	5
SUBTOTAL	77.4	57	136.2	65
6 (Other)	2.5	37	6.6	3
10 (Other)	0.3	13	2.1	1
11 (Other)	15.9	24	64.8	31
Total	96.1	46	209.7	100



1. Upper Foundry Branch

Location wise, the highly developed upper Foundry Branch portion of the watershed is bound on the north by Tenley Circle, and to the south by Massachusetts Avenue. It drains 209.7 acres of commercial, residential and institutional land uses and is 46 percent impervious (Figure 4). In comparison, the overall Foundry Branch imperviousness level is 35 percent. As previously stated, the open upper Foundry Branch section begins immediately below the 60" RCP outfall and the stream flows through the Glover Archbold stream valley park, terminating approximately 400 feet north of Massachusetts Avenue. This headwaters area lies entirely within the Fall Zone area, and the main stem portion has a moderately steep gradient, averaging 2.5 percent. Within this unit, there are also two perennial tributaries present (i.e., 'NBC' and Berkshire Apartment tributaries). Both of these tributaries originate from the storm drain system, entering the main stem from the west side.

As seen in Figure 4, four storm drain pipe systems outfall directly to the upper Foundry Branch stream channel from the north and east. The largest, the Van Ness Street storm drain system (basin No.1), drains approximately 47.5 acres of commercial and single family residential home land uses. The 60 " RCP pipe outfall, which discharges runoff directly to the stream, features a four foot high perched concrete pad. Further downstream, there are three additional storm drain systems (i.e., basin No.s 2, 3 and 5 draining primarily institutional and garden apartment land uses) that outfall directly to the stream. Storm drain basin No. 4 is entirely piped and flows directly to the main Foundry Branch parallel pipe storm drain system. The 'NBC Tributary drains storm drain basin No.s 8 and 9; whereas, the Berkshire Apartment tributary drains storm drain basin No. 7.

Coursing its way through upper Foundry Branch and the Glover Archbold stream valley park is an approximately 80-90 year old, failing main trunk sewer line. There are four main stem sewer line crossings (i.e., two trunk and two lateral lines). During the study, on two separate occasions, raw sewage was observed (and reported) entering upper Foundry Branch. Further site investigations of these four exposed sewer line crossings (by COG, DDOE and DC Water) strongly suggest that both exfiltration and infiltration problems are occurring. In addition, the large volumes of uncontrolled stormwater runoff (in combination with moderate to highly erodible stream bank and streambed materials and a moderately steep stream gradient) have: 1) accelerated both stream channel widening and downcutting (Figure 5), 2) exposed portions of the 80-90 year old sanitary sewer line system (Figure 6), and 3) increased pollutant and sediment loads and deliveries, with attendant aquatic habitat and biological community loss in Foundry Branch (as first documented by Banta, 1993).

Figure 5. Upper Foundry Branch - Storm Drain #5 - 18" diameter RCP outfall with broken head wall in the center of the stream channel

Figure 6. Upper Foundry Branch - Storm Drain #3 - 24" diameter RCP outfall and exposed lateral sewer line crossing (Baseflow flows underneath the sewer line)

III. Study/Design /Methods

A. Study Area/Reconnaissance

1. Foundry Branch Study Area

During the January-March, 2010 period, COG staff performed a preliminary reconnaissance field survey of the entire Foundry Branch main stem and its six tributaries. The total, open perennial main stem and tributary stream channel network length was 1.61 and 1.05 miles, respectively. Thirty-six (35) permanent stream transects (spaced on average 200 to 400 feet apart) were established for the Rapid Stream Assessment Technique (RSAT) evaluation portion of the study. A total of 21 transects were located along the main stem, and 14 transects (total) were located within the six perennial tributaries. It is important to note that the upper Foundry Branch unit included ten RSAT transects (Figure 7). Each RSAT stream transect site was geo-referenced, with sub-one meter accuracy, via a Trimble Geo-XT global positioning satellite (GPS) receiver. The GPS-derived latitude/longitude coordinates for each transect are included as Appendix B.

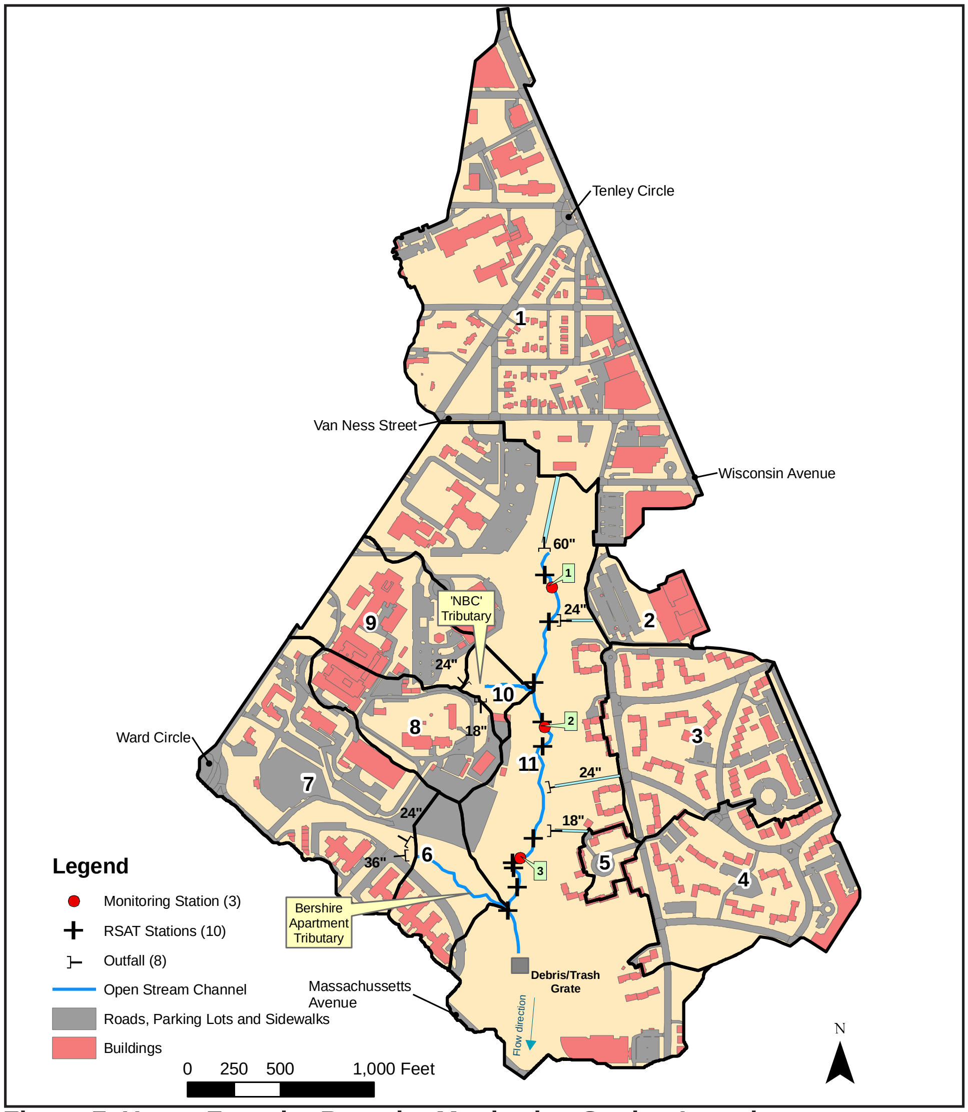


Figure 7. Upper Foundry Branch - Monitoring Station Locations

As part of the reconnaissance survey, COG staff documented the presence of both storm drain outfalls (and their associated drainage areas) and sewer line crossing locations within the stream channel, as well as their general condition. On multiple occasions during the study, COG staff reported sewer line breaks and leaks to both DDOE and DC Water for follow up emergency repair (Figure 8).

Figure 8. Upper Foundry Branch - Broken sanitary sewer PVC pipe immediately below the 60" RCP outfall (Repaired in March 2010)

Baseline water quality/chemistry characterization was performed via: 1) bi-monthly instantaneous grab sampling (employing both a Horiba U-22 XD water quality multi-probe meter, and a Hach DR820 colorimeter and collection of discrete water samples for subsequent analysis by WSSC's Water Quality Laboratory) and 2) continuous monitoring of water temperature, DO and pH (via deployment of a YSI sonde probe and HOBO continuous recording thermometers) at three strategic stream station locations (Figure 8).

B. Physical/Hydrological Characterization

1. Modified RSAT Level III Survey

The Rapid Stream Assessment Technique (RSAT) was developed by COG in 1992 (Galli, 1996a)to provide a simple, rapid reconnaissance-level assessment of stream quality conditions. Since its inception, RSAT has undergone a series of revisions and upgrades. The modified RSAT Level III method used in this study features greater use of hand-held water quality meters for enhanced baseflow water quality characterization, professional surveyor's grade equipment for both establishing and precisely measuring permanent cross-sections and developing stream longitudinal profile, pebble counts, and the capability to assess both Piedmont and Coastal Plain streams. A brief overview of the types of field measurements and observations associated to the modified RSAT Level III follows.

a) Permanent cross-sections

As previously indicated, for the channel morphology characterization portion of the study, COG staff established 21 permanent channel cross-section stations (i.e., 10 in the upper Foundry Branch and 11 in the lower Foundry Branch). To mark each preceding station location, a 0.5 inch wooden staff was driven into the top of each bank (left side looking downstream), latitude and longitude coordinates were acquired using the Trimble Geo-XT satellite receiver and photographs were taken to provide cross-reference information for future follow-up channel measurements. Cross-sectional elevational differences were then recorded, at one-foot (upper Foundry Branch) and 2-foot (lower Foundry Branch) intervals, via an 11 foot-long fiberglass surveyor's rod with a leveler attached and the LEICA Total Station model number TCR110 (Figure 9). Channel measurements were made to the nearest 100^{th} of an inch. Permanent channel cross-sections are included for the upper and lower Foundry Branch stations in Appendix B and E, respectively.

Figure 9. Upper Foundry Branch - COG staff recording cross-section data using the Leica TCR110 total station

b) Longitudinal Survey

A detailed longitudinal profile survey was performed to characterize the mean stream gradient for the 0.51 mile upper Foundry Branch main stem, as well as location and height of major channel gradient features, such as sewer line crossings. As such, COG staff took a total of 55 measurements employing the Leica TCR110 total station. Starting within the stream channel, at the furthest downstream location and working in an upstream direction, distance and elevation readings were recorded along the thalweg (i.e., the major flowing part of the stream) at distance intervals that ranged from approximately 11 - 111 feet. Lowest and highest elevational measurements were taken at streambed features that included: riffles, pools, bedrock outcrops, at grade sewer line crossings and a perched storm drain outfall concrete pad. Elevational measurements were then post-processed to a Glover Archbold Park stream valley benchmark elevation location that was provided by the National Park Service.

c) Pebble Count

A modified Wolman (1954) pebble count was performed at seven representative stream locations within upper Foundry Branch. At each station, 100 particles total were counted along a tape measured, 100 foot-long longitudinal transect. At three-foot intervals along the tapeline, three to four particles were randomly selected across the entire 'wetted perimeter' width of the channel. The intermediate axis of each particle was then measured to the nearest millimeter (mm) and recorded. For each preceding site, representative riffle, run and pool habitat types were sampled on a proportional basis. Pebble count data were summed for each location to obtain D-15, D-34, D-50 and D-84 particle size distributions.

C. Baseflow and Stormflow Stage/Discharge Development

1. Baseflow Discharge

Baseflow discharges were measured at station 3 on top of the weir-like, at-grade concrete sewer line casing (Figure 10). A total of 15 measurements were made using a Marsh-McBirney Incorporated, model 2000 Flowmate flow probe. Measurements were taken from different dates (i.e., generally two to three times a month between April and November 2010). The time stamp was recorded for each discharge measurement to correspond to the time that a stage height was recorded by the water level data logger. It should be noted that a stage gauge staff was installed on June 17th, 2010 in the pool immediately upstream of station 3.

Figure 10. Upper Foundry Branch - COG staff performing baseflow measurement at station No. 3

2. Rainfall Measurement

For the project study period, climatological and hourly rainfall data was obtained for the Reagan National Airport weather station. Rainfall event data (i.e., total rainfall, 15 minute intensity, event data and time) was also obtained at a local Foundry Branch rain gauge located approximately 1.5 miles from upper Foundry Branch via the use of a RainWise® RGEL Tipping Bucket Recording Rain Gauge. This location provided more accurate/ watershed-specific rainfall data for several summer, localized thunderstorm events.

3. Stormflow Discharge

Stormflow discharges were measured for 13 separate storm events that produced between 0.06 and 2.95 inches of rainfall. For these 13 stormflow events, a total of 43 individual measurements were taken on top of the concrete sewer line casing at station 3 (Figure 11). It should be noted that due to the unpredictability of first-flush stormflow events, staff safety was deemed a higher priority than near peak stormflow discharge measurements. Therefore, discharge measurements (i.e., average stream velocity, the wetted perimeter width and riffle depths) were limited during extreme high flows. Date, time stamp and staff gauge height were recorded for each discharge measurement to correspond with the information recorded by the water level data logger. Discharge was calculated using the following simple formula: Discharge (ft^3/sec) = riffle cross-sectional area (ft^2) X mean stream velocity (ft/sec). The stage and discharge data were downloaded and a best-fit curve was determined using Microsoft Excel 2007.

Figure 11. Upper Foundry Branch - COG staff measuring stormflow discharge

4. Stage-Discharge Curve Development

In order to develop a stage-discharge curve, which characterizes and predicts flows according to water depths and staff gauge height, COG staff deployed the Global Water automated water level logger and manually operated the Marsh-McBirney Incorporated model 2000 Flowmate at station 3. The stage level logger, which features a data logger encased in a waterproof cylinder connected to a 15 foot cable that terminates at a pressure transducer sensor, was installed in a pool immediately below the sewer line at station 3 and deployed on June 12th. Due to the sewer line leak, it was redeployed immediately upstream of the sewer line (i.e., for the June 21st through December 14th, 2010 period) to record various pools stages (inches) at 10-minute intervals. The redeployment entailed carefully attaching the data logger cylinder housing to a galvanized steel, U-channel eight foot post that was driven approximately four feet into the streambed along the left bank (looking downstream). The terminal sensor, also affixed to the U-channel post, was submerged to a depth approximately 12.4 inches from the bottom of the pool. It should be noted that the terminal sensor tip was pointed down to reduce silt deposition and clogging of the sensor. Once the average discharge data was calculated, it was related to the stage data via the time stamp. A best-fit curve was employed, using Microsoft Excel 2007, to develop the stage and discharge curve for upper Foundry Branch.

5. Summer Thermal Regime Characterization

Characterization of the "summer" thermal regime occurred from May through October 2010. A multiple parameter YSI sonde (10-minute recording interval) was deployed at station 3 and four HOBO® temperature probes (12-minute recording interval) were used at four lower Foundry Branch tributaries. However, for the tributaries, due to a HOBO ® probe malfunction and an unrecoverable probe (i.e., dislodged and lost during high stormflow), temperatures were recorded for only two of the four (i.e., Wesley Heights Tributary and Phillips Run).

D. Stream Water Quality

1. Baseflow and Stormflow

a) Instantaneous Grab Sampling

As previously stated, a Horiba U-22XD, multi-probe water quality meter was used on a bi-monthly basis to measure instantaneous DO, pH, TDS, conductivity, turbidity, and water temperature. In addition, nitrate concentrations (which also provide indirect evidence of potential inputs such as sewage, chemical fertilizers and/or decaying organic matter), orthophosphate (a limiting macro-nutrient for algae) and fluoride were measured via the employment of a Hach DR820 colorimeter. It should be noted that nitrate, orthophosphate, and fluoride results were subsequently used to help provide additional insights as to the cause(s) for upper Foundry Branch low DO conditions.

In addition to the RSAT-related water quality grab sampling, five baseflow and five stormflow water chemistry grab samples were collected between July 2010 and March 2011, and sent to the Washington Suburban Sanitary Commission's (WSSC) Consolidated Laboratory Services Group (an EPA certified laboratory) for analysis of the following eight water quality parameters: 1) *Escherichia coli* (*E. coli*), 2) *Enterococcus spp.*, 3) biochemical oxygen demand (BOD_5), 4) nitrite (NO_2), 5) nitrate (NO_3), 6) total suspended solids (TSS), 7) total Kjeldahl nitrogen (TKN) and 8) total phosphorous (TP). It should be noted that the detection of elevated levels of *Escherichia coli* (*E. coli*), *Enterococcus spp.*, BOD_5, NO_2, NO_3, TKN and/or TP generally suggest anthropogenic pollutant sources such as sanitary sewers, fertilizers, etc, that may be contributing to low DO concentrations. Both baseflow and stormflow water-grab samples were collected at station 3, which is the stage-discharge site.

In an effort to further identify likely sources for bacterial contamination, COG staff collected one additional baseflow and two separate date stormflow samples for bacterial source tracking (BST) analysis. All samples were sent to the Virginia Polytechnic Institute (for DNA fingerprinting) to determine what percentage of the *Enterococcus spp.* counts were human, avian, canine, deer, horse, or other.

a) *Continuous (YSI Sondes)*

The "industry standard" continuous surface water quality/dissolved oxygen (DO) YSI 600 series sonde monitoring probes were used to characterize upper Foundry Branch conditions. These probes feature an "optical sensor design and anti-fouling wiper control for improved reliability during extended deployments" (YSI, 2011). A single sonde probe was deployed for the period of March – November 2010 at station 3 (Figure 12). It

Figure 12. Upper Foundry Branch - YSI 600 series sonde with optical DO probe and laptop data retrieval setup

was initially deployed in a pool immediately below the furthest downstream, sewer line #4 crossing (station 3). However, due to a series of unforeseen events (i.e., sewer line leak at crossing #4 and extreme low flow conditions), and anticipating that the sewer line area would be disturbed for emergency repair work, the sonde was relocated (on June 21, 2010) to an immediate upstream pool. At this new location, the sonde (inserted into a perforated PVC housing, was again attached to an eight foot long, galvanized steel, U-channel post that was driven four feet into the streambed along the left bank (looking downstream). The sonde was submerged, to a depth of approximately 12 inches from the bottom of the pool (Figure 13); where it remained safely in place until it was removed (for cold season protection reasons) on November 21, 2010.

Figure 13. Upper Foundry Branch - Station 3 - YSI sonde and water level data logger housings attached to a U-channel post

So as to permit paired DO data comparisons, both the original YSI 600 sonde and a new, second YSI 6820 sonde were deployed (from March 8 - April 21) at station 3. Satisfied with the results, the YSI 6820 sonde was moved upstream to station 1 (i.e., to a pool location 100 feet downstream of the 60” RCP). As a result, for the April 21, 2011 - June 29, 2011 period, the YSI sondes provided continuous DO data for both stations 1 and 3.

The sonde DO data was downloaded approximately every two weeks. At that time, the sondes were calibrated using an air-saturated water calibration technique and then redeployed. Additional data recorded by the sondes included: percent oxygen saturation, conductivity, water temperature, pH, TDS and depth.

E. Aquatic Community/Macroinvertebrate Sampling

On April 29-30, 2010, spring Maryland Biological Stream Survey (MBSS)-based benthic macroinvertebrate surveys were performed at four Foundry Branch locations: 1) upper Foundry Branch, 2) Wesley Heights Tributary, 3) W Street Tributary and 4) Phillips Run. Six core MBSS metrics for streams in the Piedmont physiographic region (MDDNR, 2006) were calculated (i.e., total taxa, total number of EPT taxa, total number Ephemeroptera, percent urban intolerant, percent Chironomidae, and percent clingers).

The current quantitative MBSS macroinvertebrate collection method employs 20 jabs from a 225 foot long multiple stream habitat reach. Macroinvertebrates are collected from representative habitat areas such as riffles, runs and pools using a 600-micron mesh D-frame net. A target of 200 organisms is removed from the sample within an hour of picking in the field, or the sample is picked for the combined length of one hour. Organisms were placed in 70 percent ethyl alcohol and taken back to the laboratory for identification purposes In addition, macroinvertebrates were collected at each transect from the bottom side of 10 cobble-sized stones and included in the voucher collection during the summer RSAT survey. A D-frame net with a 600-micron mesh was used to collect the RSAT macroinvertebrates samples. Taxonomic identification was subsequently performed by qualified COG staff in the lab using the following taxonomic references: Harper and Hynes, 1971; Merritt and Cummins, 2008; Pennak, 2001; Stewart and Stark, 2002; Wiggins, 1996; etc. For aquatic insects, identification was, with few exceptions, to the genus level. Processed samples will be kept at COG.

F. Modeling

As part of the upper Foundry Branch study, COG retained the services of LimnoTech to help develop a workable DO model (based on WASP5) and to provide additional insights on the potential cause(s) of the low DO levels. Included as part of their work was a series of DO modeling runs for characterizing both wet and dry weather conditions. It should be noted that the model (or portions thereof) may possibly be used in the future by DDOE to help it assess TMDL issues for other small District of Columbia watersheds. The LimnoTech scope of work is summarized below.

1. Selecting a suitable model to simulate the water quality of the stream;

2. Providing linkage of non-point source loadings (including sanitary sewer), stream discharge and receiving water quality;

3. Generating a model schematic grid and conducting model calibration and verification;

4. Performing a minimum of four model run scenarios: a) baseflow diurnal cycle, b) stormflow-less than one inch rainfall over 24 hours, c) one inch or greater rainfall over 24 hours and d) "best case scenario," zero exfiltration/discharge from the sanitary sewer system; and

5. Preparing a technical memorandum which: documented model inputs and the model calibration approach, interpreted modeling results for the four preceding scenarios, and provided recommendations for potential follow up monitoring and/or modeling work.

Note: for additional specific LimnoTech modeling-related details and results, the reader is referred to Appendix A.

IV. Results

A. Physical/Hydrological Condition Characterization

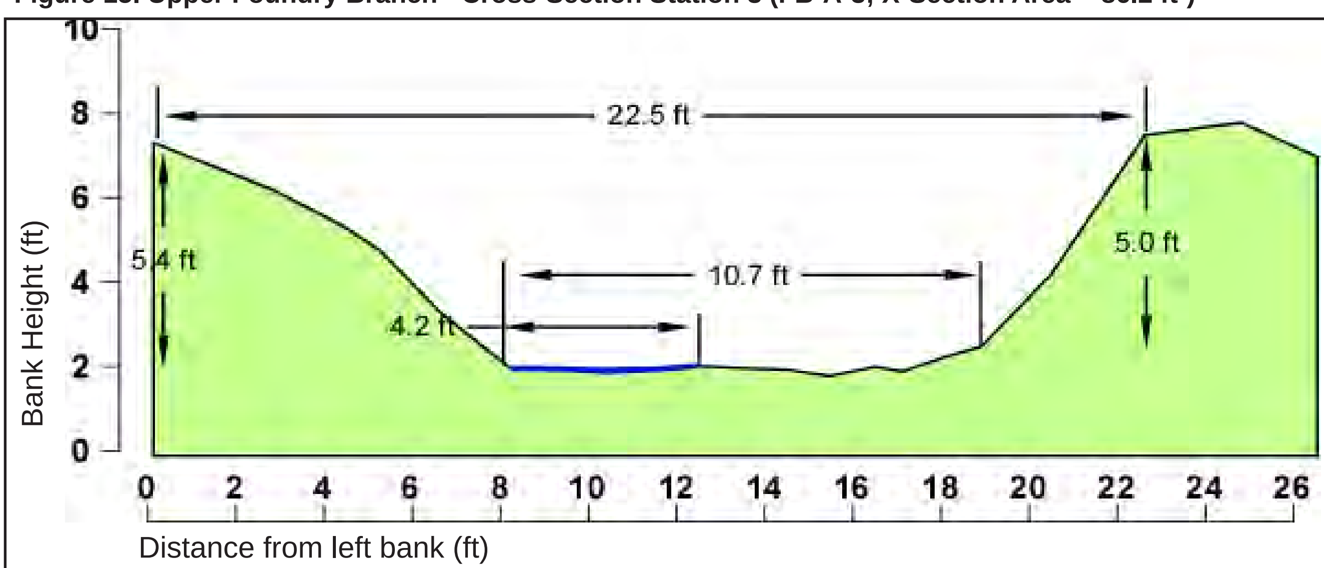
1. Stream Cross-Section and Gradient

Stream channel cross-section (N=10) characterization results revealed that the mean cross-sectional area for the upper Foundry Branch main stem is approximately 91.7 ft^2. In addition, mean stream channel widths, bank heights and wetted perimeters were 20.4 feet, 3.4 feet and 6.9 feet, respectively. Figures 14 through 16 depict representative main stem cross-sections. As seen in Figure 14, the upper half of this urban stream channel (i.e., approximately the first 1,800 feet) is highly entrenched with mean bank heights in the five foot range. This upper portion of Foundry Branch also features a partial bedrock controlled streambed with four exposed sewer line areas, reflecting both decades of uncontrolled stormwater runoff and Fall Zone-related geology. The wetted perimeter in this section generally comprised 50 percent (or less) of the bottom channel width. It should be noted that, small Piedmont streams of this size draining totally forested watersheds typically have mean bank heights in the 1-2 foot range and wetted perimeters that cover 80 percent or more of the bottom channel width.

Figure 14. Upper Foundry Branch - Stream channel between cross-section stations 2 and 3

As one proceeds downstream towards Massachusetts Avenue (Figures 15 - 18), stream gradient and bank heights both drop, the channel becomes much wider and the wetted perimeter generally comprises less than 30 percent of the bottom channel width. These conditions are especially pronounced from the fourth, large sewer line crossing (i.e., cross-section No. 7) to downstream approximately 150 feet to cross-section No. 9. In this channel section area (from cross-sections No. 7 - 10), the stream experiences significant backwater flooding during larger rainfall/runoff events from the partially

Figure 15. Upper Foundry Branch - Cross-Section Station 3 (FB-A-3; X-Section Area = 86.2 ft^2)



clogged Massachusetts Avenue storm drain debris/trash grate. It should be noted that at cross-section No. 10, the stream channel narrows significantly with high in-channel sand deposition observed for the remaining 250 foot channel section. In character with second order Piedmont/Fall Zone streams, the mean gradient for the upper 'A' main stem is a modest 2.5 percent (Figure 18).

Figure 16. Upper Foundry Branch - Cross-Section Station 7 (FB-A-7; X-Section Area = 101.1 ft²)

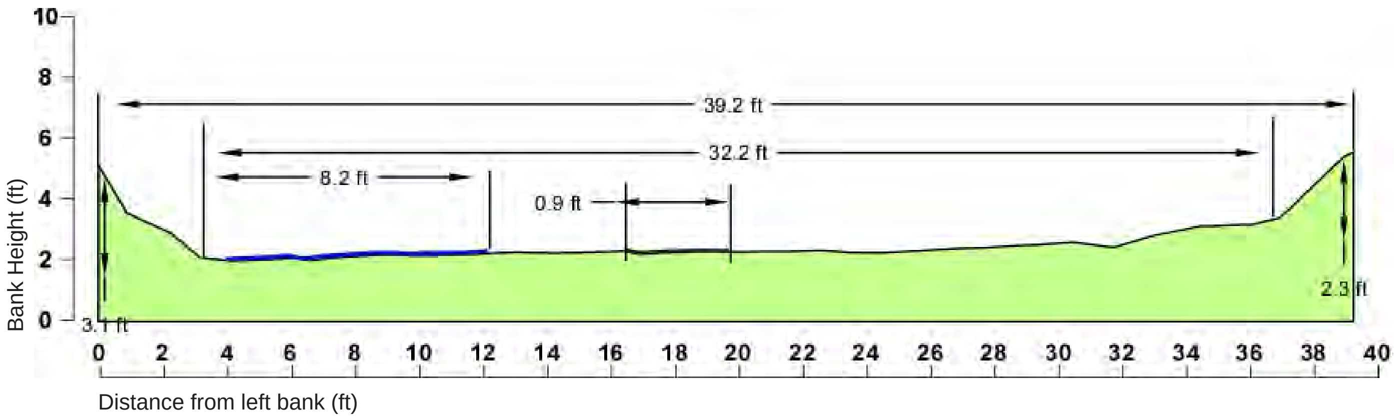


Figure 17. Upper Foundry Branch - Cross-Section Station 8 (FB-A-8; X-Section Area = 76.3 ft²)

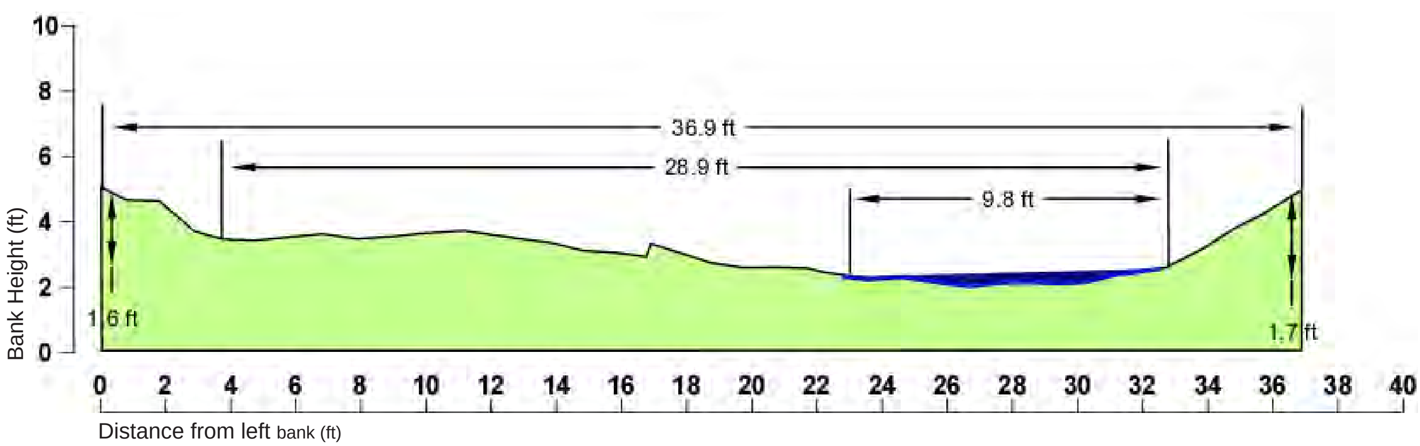
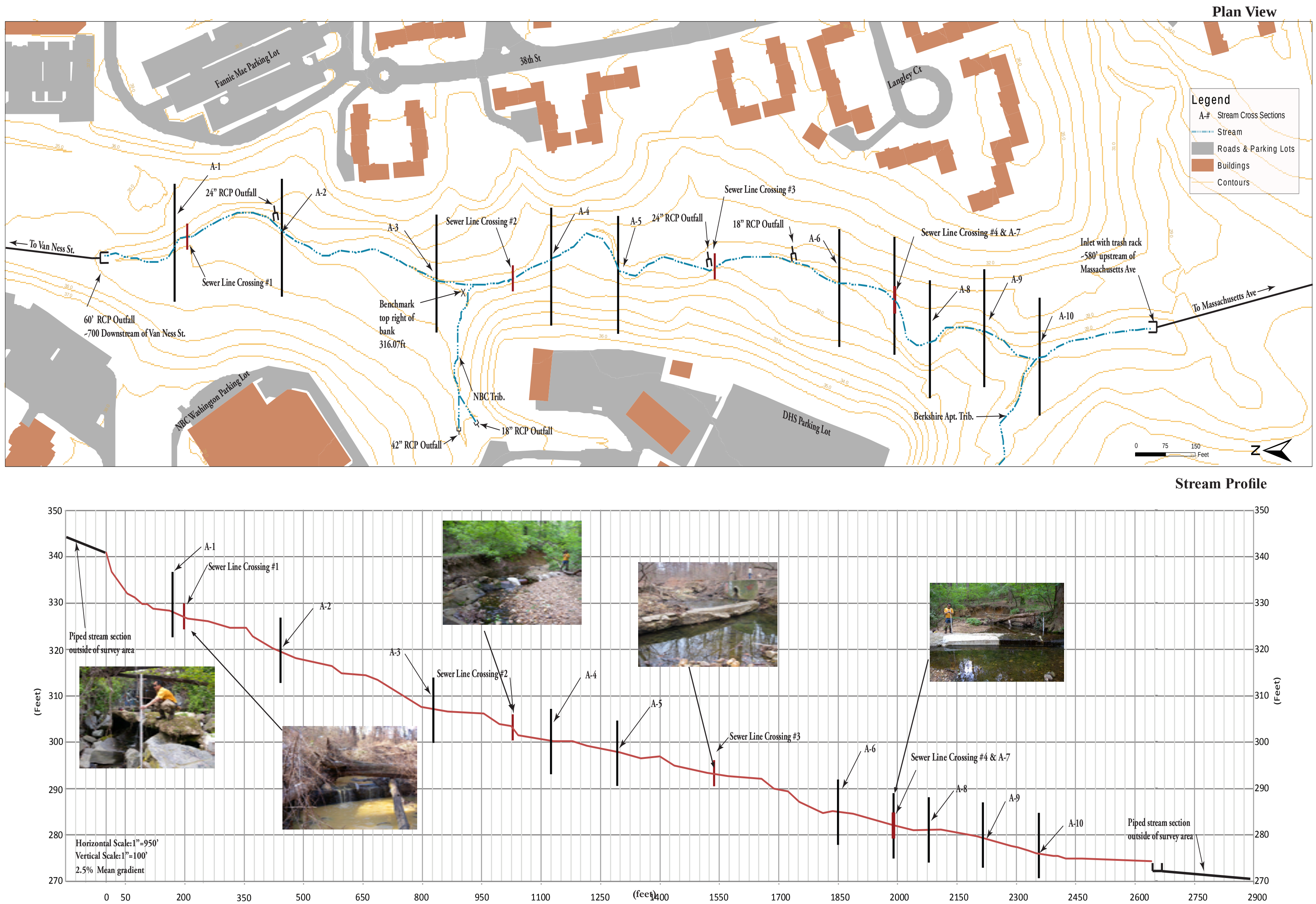


Figure 18. Upper Foundry Branch Stream Channel Cross-Sections and Profile



2. Relative Stream Bank Stability

As seen in Table 2, overall upper Foundry Branch bank stability was at the lower end of the good range (i.e., 73.8 percent). Results from the RSAT channel stability survey portion of the study also revealed that out of a total of 2,424 linear feet of stream length, 48.9 linear feet (2.0 percent) exhibited severe stream bank erosion condition. Under the RSAT system, a severe bank erosion designation implies that less than 50 percent of the bank network is stable and that major portions of the banks are unraveling. Furthermore, 77.3 linear feet, representing approximately 3.1 percent of the upper main stem is experiencing moderate/severe bank erosion (Figure 19) (i.e., 50-60 percent of the bank network is stable and that signs of lateral bank erosion are very common). In addition, 448.3 linear feet (18.4 percent) exhibited moderate stream bank erosion conditions (i.e., 61-70 percent of the bank network is stable and signs of lateral bank erosion are common). It should be noted that stream areas experiencing moderate to moderate/severe bank erosion conditions were observed in all Foundry Branch stream channel patterns (i.e., straight, meanders and bends, etc).

Table 2. Summary: Upper Foundry Branch - Stream Bank Erosion Conditions

RSAT Stream Segments	Stream Length (mi.)	Bank Erosion Conditions						No. of Recent Tee Falls[1]		Mean Bank Stability[2]
		Severe		Mod/Severe		Moderate		No.	No./mi.	
		(LF)	(LF/mi.)	(LF)	(LF/mi.)	(LF)	(LF/mi.)			
Upper Foundry Branch	0.46	48.9	106.3	77.3	168.0	448.3	974.6	2	4.3	73.8

Dry channel conditions were observed for Cross-Section Stations 9 & 10

[1] Tree fall interpretation: 0-1/mi. = Excellent, 2-3/mi. = Good, 4-5/mi. = Fair, ≥6 = Poor.

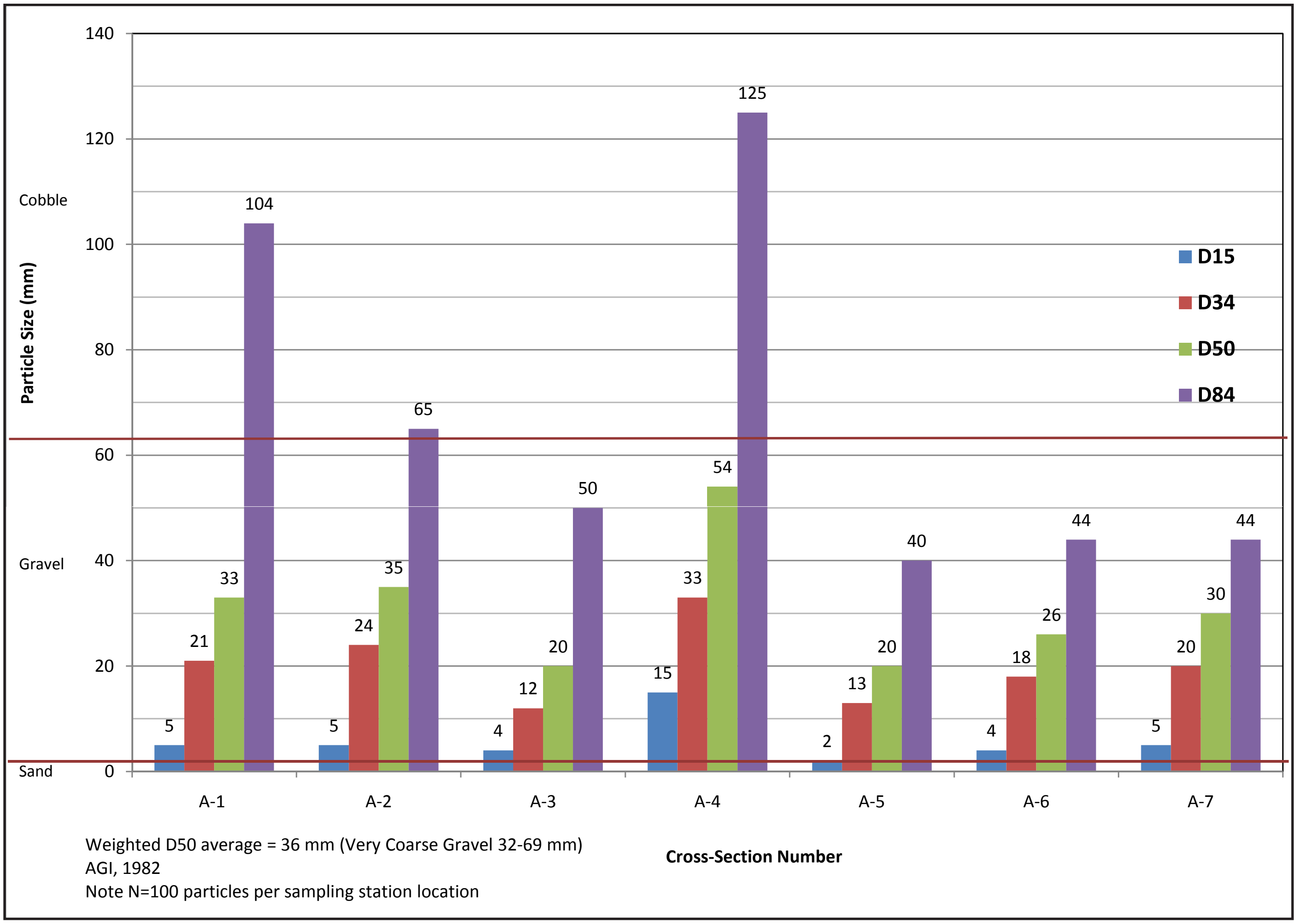
[2] Bank stability interpretation: >80% = Excellent, 71-80% = Good, 50-70% = Fair, <50% = Poor.

Figure 19. Upper Foundry Branch - Moderate/Severe Stream Bank Erosion Condition

3. Substrate Size/Pebble Count

Pebble count results (Figure 20) indicated that the median (i.e., D-50) Foundry Branch particle size is very coarse gravel (i.e., 36 mm). In addition, the D-84 sized particle for all seven surveyed reaches was very coarse gravel to small cobble (i.e., 32.00-127.99 mm). The preceding findings confirm that the Foundry Branch streambed material is generally gravel with some small cobble upstream of cross-section station No. A-4, and predominantly gravel below. Typically, gravel-sized material with small diameter and round shape is inherently unstable and prone to rolling during stormflows.

Figure 20. Upper Foundry Branch - Substrate Particle Size Distribution[1] - D15, D34, D50 and D84



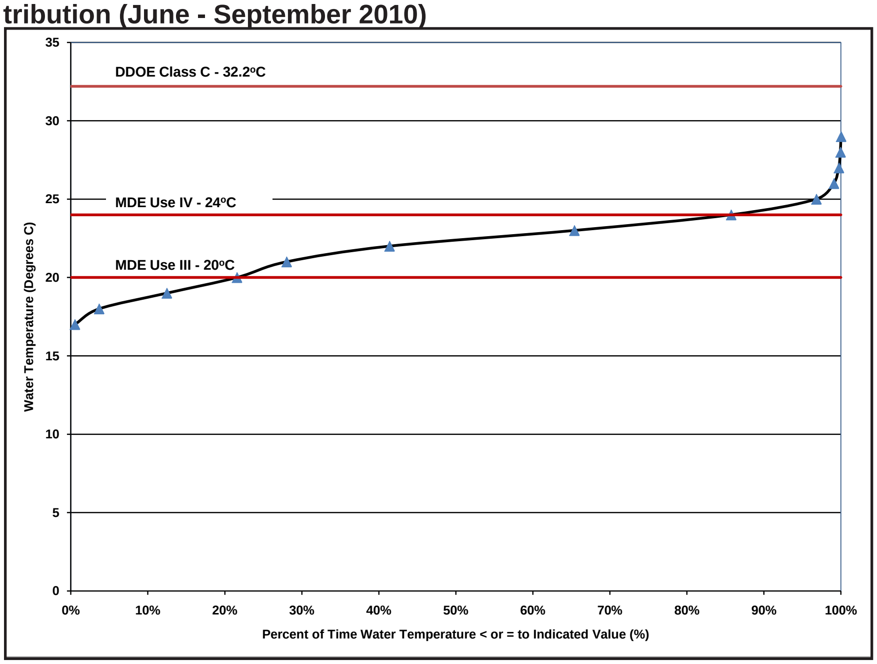
1

Substrate Class (AGI, 1982)	Size (mm)
Very Fine Sand	0.06-0.13
Coarse Sand	1.00-1.31
Very Coarse Sand	1.01-1.99
Very Fine Gravel	2.00-7.99
Medium Gravel	8.0-15.99
Coarse Gravel	16.00-31.99
Very Coarse Gravel	32.0-63.99
Small Cobble	64.00-127.99
Large Cobble	128.00-255.99
Boulder	256.00-4,095.99
Bedrock	>4,096.00

4. Stream Thermal Regime Characterization

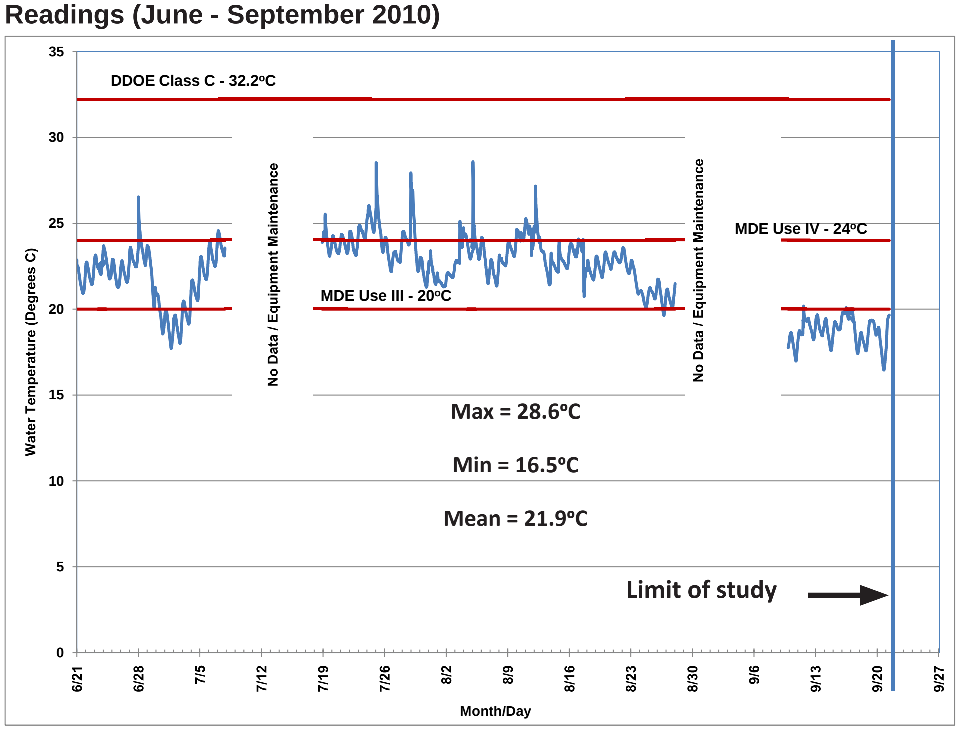
Results from the June to September 2010 continuous stream temperature monitoring portion of the study (104 days) are summarized in Figures 21 and 22. In addition to the 32.2°C (90 °F) DDOE Class 'C' temperature standard for the stream, COG staff has included both the MDE 24°C (75°F) Use IV recreational trout and 20°C (68°F) Use III natural trout waters criteria for further comparison.

Figure 21. Upper Foundry Branch - Summer Water Temperature Distribution (June - September 2010)



As seen in Figures 21 and 22, Foundry Branch stream temperatures were well below the DDOE Class 'C' standard. Not surprisingly, the stream exhibited water temperature 'spikes' in response to stormflow inputs and high air temperatures. Additional results from the monitoring period are as follows: 1) the maximum daily water temperature recorded during the study (28.6°C) occurred on August 5, 2010; and 2) because of its relatively small baseflow discharge, the Foundry Branch thermal regime is strongly influenced by prevailing air temperatures. However, it should be noted that like many urban streams, Foundry Branch does receive some artificial inflow of cool water from sources such as the condensate from the large, Mclean Garden Apartment's air conditioning system and sump pumping of building-related groundwater. Additional analysis revealed that water temperatures were at or below 20°C 21 percent of the time, and were at or below 24°C 86 percent of the time.

Figure 22. Upper Foundry Branch - Twelve Minute Summer Temperature Readings (June - September 2010)



Based on the preceding water temperature monitoring results, the temperature regime for the entire Foundry Branch main stem can be generally categorized, per Galli (1990) as being that of a coolwater stream system. Summer temperatures regularly exceeded temperature levels considered optimal (i.e., less than 17 to 20°C) for many temperature sensitive stonefly, mayfly and caddisfly species (Gaufin and Nebecker, 1973; Ward and Stanford, 1979; Fraley, 1979). Also, it should be noted that temperatures exceeding 21°C have been shown to stress most coldwater organisms and that as a group stoneflies (Plecoptera) are least temperature tolerant and are restricted to cold to cool flowing waters.

B. Baseflow and Stormflow/Stage Discharges

1. Baseflow

Between April 1st and November 18, 2010, COG staff made a total of 15 baseflow discharge measurements at the sewer line no. 4 (monitoring station 3). Baseflow results are shown in (Table 3). Throughout the study period, Foundry Branch maintained a small baseflow from the sewer line #4 and upstream. However, below the sewer line, intermittent surface flow was observed from approximately May through September 2010. Mean main stem baseflow during the study period was a fairly anemic 0.064 cfs (i.e., or approximately 0.19 cfs/mi^2). COG staff observations revealed that some infiltration of baseflow into portions of the 80 -90 year old sanitary sewer line system is occurring (Figure 23). It should be noted that this discharge was (based on total "water year", October through September, precipitation levels) less than the expected 'normal' average. During the 2010 water year, monthly precipitation was below normal in six out of the 12 months (DCA weather station).

Table 3. Upper Foundry Branch - Baseflow Discharge Measurements (April - November 2010)

Date	Time (hr:mm)	Discharge (cfs)
4/1/2010	10:00	0.168
4/9/2010	9:33	0.151
4/12/2010	1:00	0.068
4/26/2010	3:20	0.063
5/3/2010	11:00	0.057
5/4/2010	9:00	0.103
6/17/2010	11:00	0.001
6/21/2010	11:30	0.061
7/19/2010	12:00	0.075
8/5/2010	12:30	0.036
8/17/2010	11:55	0.106
9/17/2010	12:05	0.032
9/24/2010	12:08	0.005
10/7/2010	14:20	0.009
11/18/2010	11:00	0.020
Mean	--	0.064

2. Stormflow/Stage Discharge

In an effort to better predict stormflow discharges in the upper Foundry Branch main stem, COG staff developed a stage-discharge rating curve. As shown in Figure 24, 13 stormfall events (43 discharge measurements, total, taken during the ascending portion of the hydrograph) were used to generate the rating curve. From the "Rational Method", the following general storm frequency/discharge levels were additionally calculated:

weekly (0.25" rainfall/24 hours) = ~41.3 cfs;

one month (0.75" rainfall/24 hours) = ~124.2 cfs;

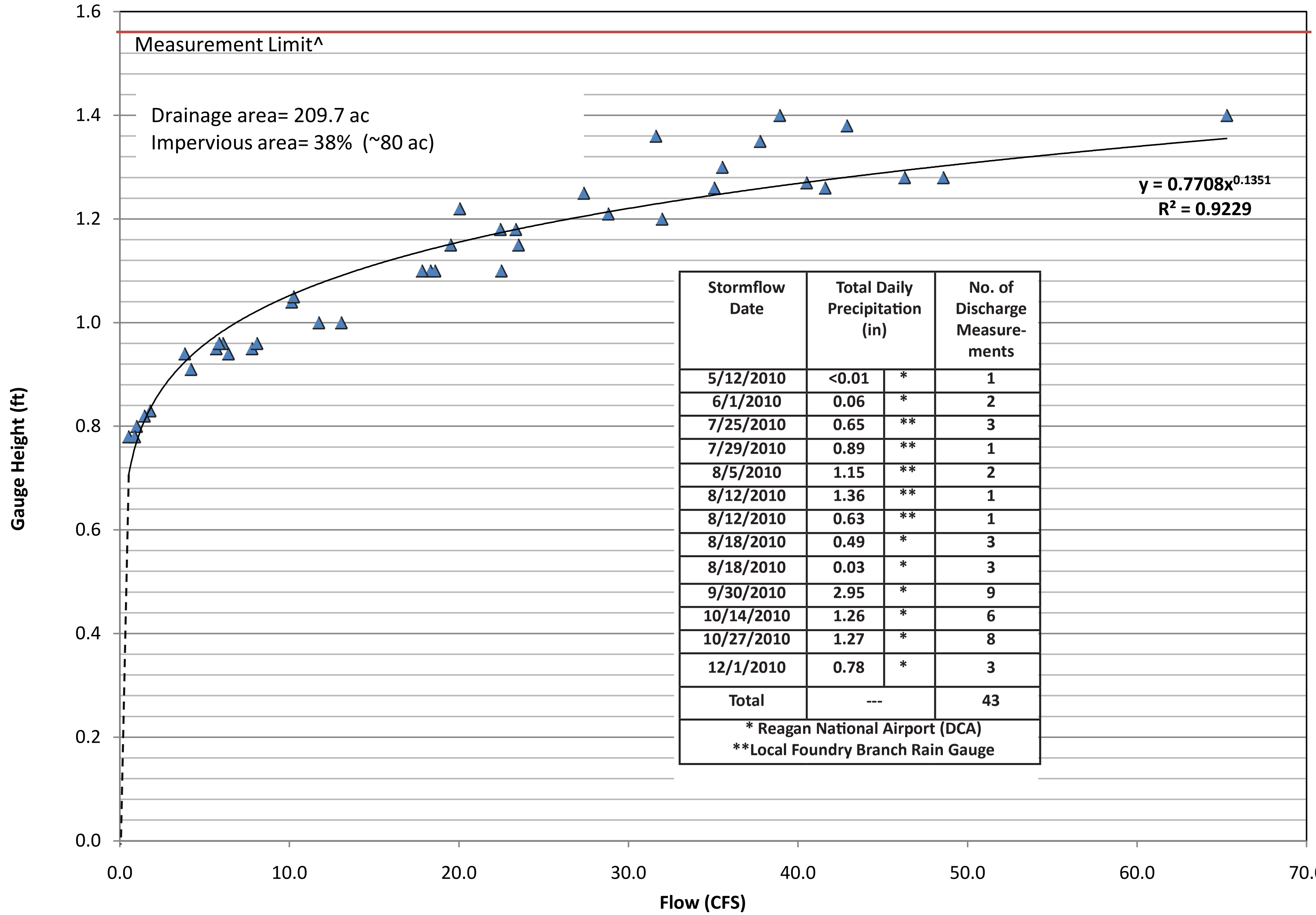
six month (1.65" rainfall/24 hours) = ~273.2 cfs; and

1-year (2.60" rainfall/24 hours) = ~430.4 cfs

Figure 23. Upper Foundry Branch - Station 2 - Terra cotta sewer line pipe junction without grout, crossing the stream bed (May 2010)

Importantly, at stream discharges in the approximately 100-200 cfs range, backwater conditions created by the partially clogged Massachusetts Avenue storm drain debris/trash grate precluded further measurements. However, the preceding results provide a solid starting point for detailed follow up Foundry Branch hydraulic modeling, sediment transport, stormwater management, storm drainage and/or stream restoration evaluations (to be performed by others).

Figure 24. Upper Foundry Branch - Station 3 - Stage Discharge Rating Curve (Storm Flow)*



Stormflow Date	Total Daily Precipitation (in)		No. of Discharge Measure-ments
5/12/2010	<0.01	*	1
6/1/2010	0.06	*	2
7/25/2010	0.65	**	3
7/29/2010	0.89	**	1
8/5/2010	1.15	**	2
8/12/2010	1.36	**	1
8/12/2010	0.63	**	1
8/18/2010	0.49	*	3
8/18/2010	0.03	*	3
9/30/2010	2.95	*	9
10/14/2010	1.26	*	6
10/27/2010	1.27	*	8
12/1/2010	0.78	*	3
Total	---		43

* Reagan National Airport (DCA)
**Local Foundry Branch Rain Gauge

*1 CFS ~ 440 gpm

^Discharge measurements limited at CFS greater than 100 - 200 cfs due to stream backing up created by downstream clogged debris/trash storm drain grate

C. Baseflow Water Quality

Instantaneous water quality meter/grab sampling results for DO, pH, nitrate, fluoride, orthophosphate, total phosphorous, total dissolved solids and conductivity are presented in Figures 26-27. Results from the WSSC Laboratory analyzed bacterial and water quality parameters (i.e., *E. coli*, Enterococci, BOD, nitrite, nitrate, TSS, TKN and total phosphorous) are summarized in Tables 4- 6. In addition, results from the single, November 10, 2010 Virginia Tech analyzed, bacterial source tracking (BST) sample are included as Table 5. A brief summary description for select parameters of interest follows.

Figure 25. Upper Foundry Branch - Station 3 - Sewer Line Crossing No. 4 (July 2010)

1. Instantaneous Baseflow DO

No violations of the District of Columbia's Department of the Environment (DDOE) 5.0 mg/L dissolved oxygen (DO) concentration standard were observed for the 16 instantaneous baseflow measurements taken (by COG staff during daylight hours between March 2010 and June 2010) at the monitoring station 3 upstream of the sewer line (Figure 25). However, DO concentrations (< 1.0 mg/L) were recorded in the pool immediately downstream of the sewer line at station 3 during the low baseflow period (i.e., May - July, 2010) prior to the DC Water sewer line repairs. In sharp contrast, continuous Foundry Branch DO measurements measured via the employment of YSI Sonde probes at stations No.s 1 and 3 revealed the following: 1) between 3/31/10 and 7/31/10, the mean DO concentration was 3.4 mg/L, and the percent of time that DO was less than 5.0 mg/L was 55 percent; 2) between 8/1/10 and 11/21/10, the mean DO concentration was 6.2 mg/L, and the percent of time that DO was less than 5.0 mg/L was 20.0 percent; and 3) between 3/8/11 and 6/28/11, the mean DO concentration was 7.4 mg/L and the percent of time that DO was less than 5.0 mg/L was 12 percent. These marked post-August 2010 improvements in DO concentrations reflect the positive effect of multiple, temporary sewer line leak stoppage/repair-related actions by DC Water.

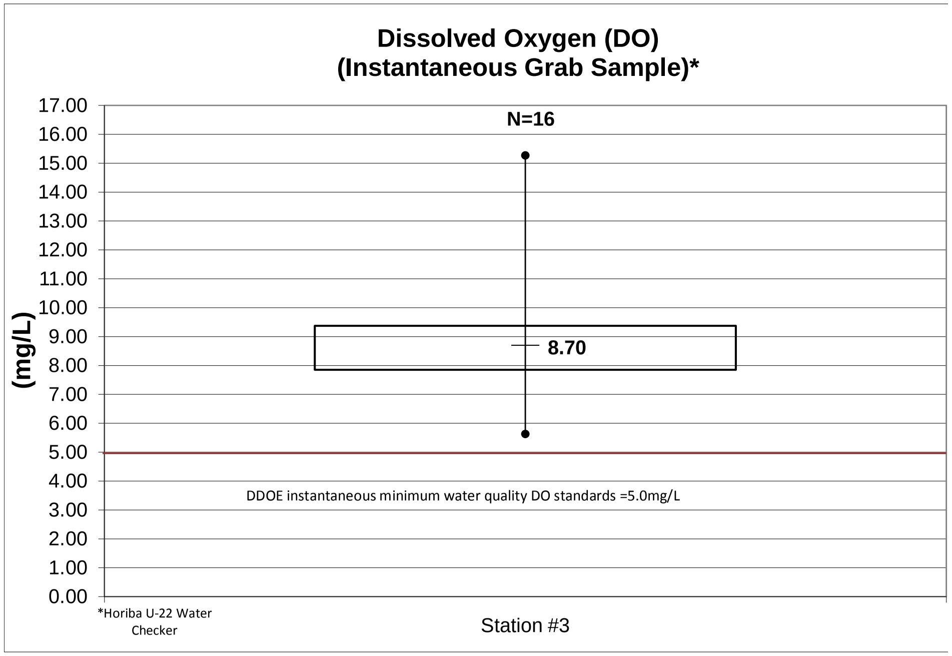
2. Baseflow pH

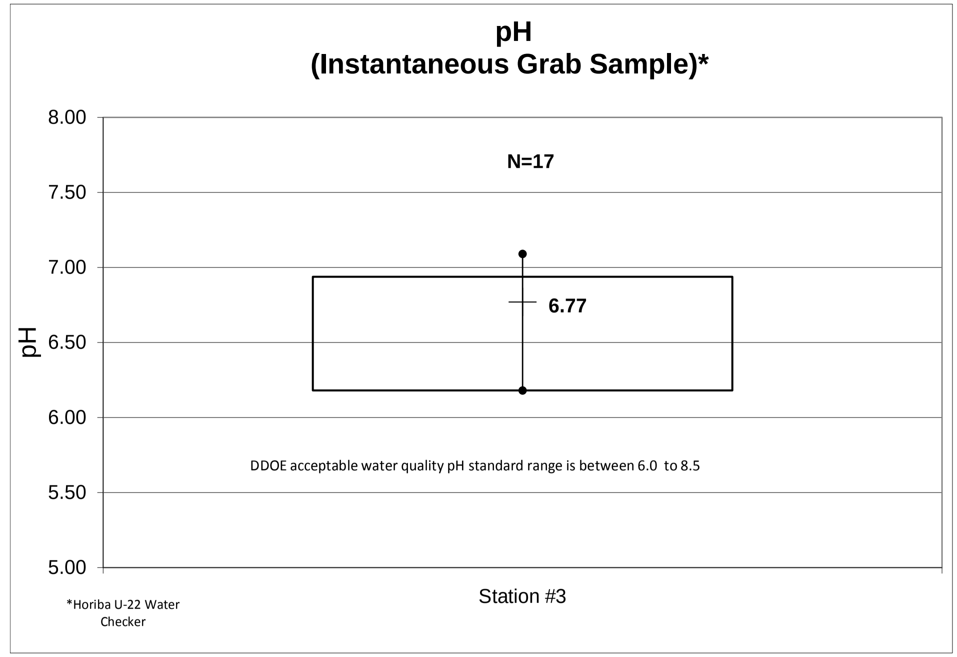
pH, which is used to indicate the acidity or alkalinity of water, ranged from 6.20 to 7.20 (Figure 26). Generally, naturally occurring fresh water streams have a pH range of 6.5 to 8.0. This is the same range favored by most freshwater aquatic organisms (EPA, 2002). In addition, typical treated municipal water pH levels, such as those found in the District of Columbia, range is 7.5 -7.8 (DC Water, 2010).

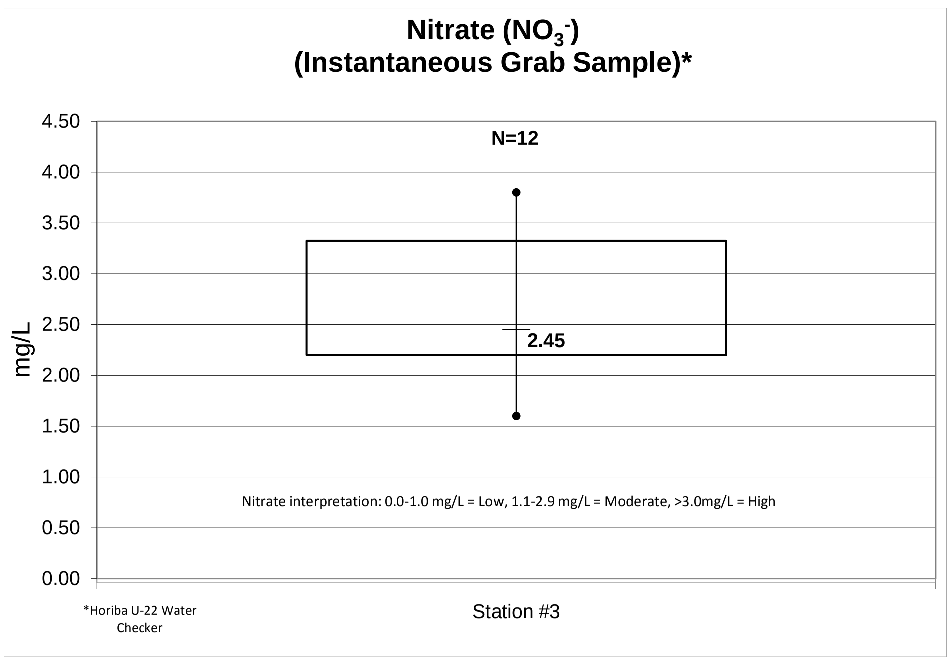
3. Baseflow Nitrate

Instantaneous baseflow nitrate (NO_3) readings (Figure 26) revealed: 1) concentrations ranged from a low of 1.6 to a high of 3.8 mg/L and 2) the observed median value was 2.45 mg/L. For interpretation purposes, NO_3 concentrations were grouped, per USGS (1993), into three concentration classes: 1) low, < 1.0 mg/L, 2) moderate, 1.0-3.0 mg/L, and 3) high, >3.0 mg/L. All of the observed values (N=12) were in the moderate to high range. This suggests that anthropogenic- related activities and sources (such as sewage from sanitary sewer line exfiltration/leakage, fertilizer applications, homeless human populations, etc) are contributing to the streams enrichment.

Figure 26. Upper Foundry Branch - Station 3 - Baseflow Dissolved Oxygen, pH, Nitrate, and Fluoride







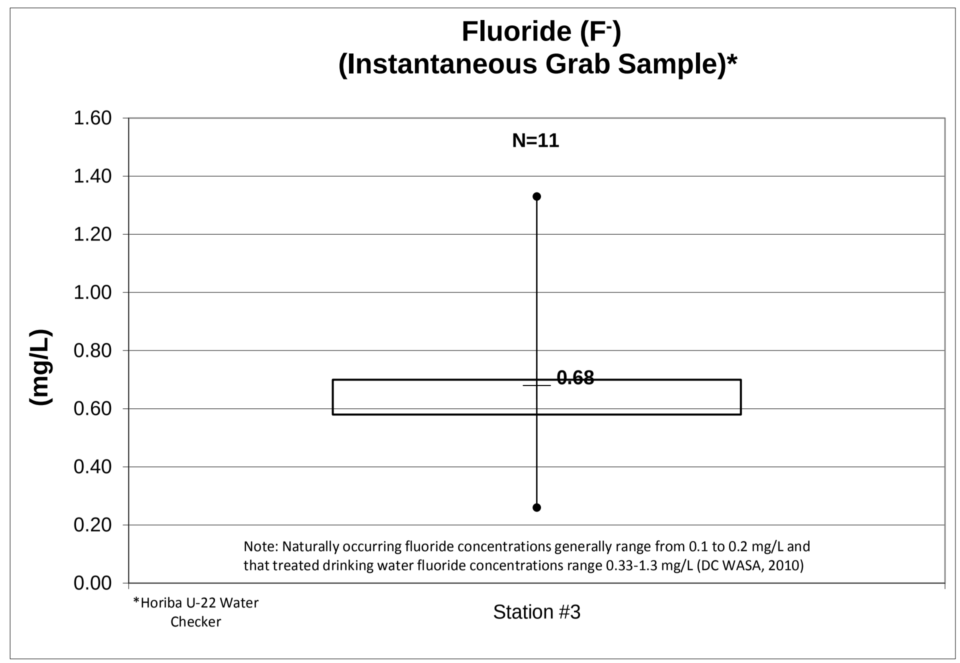
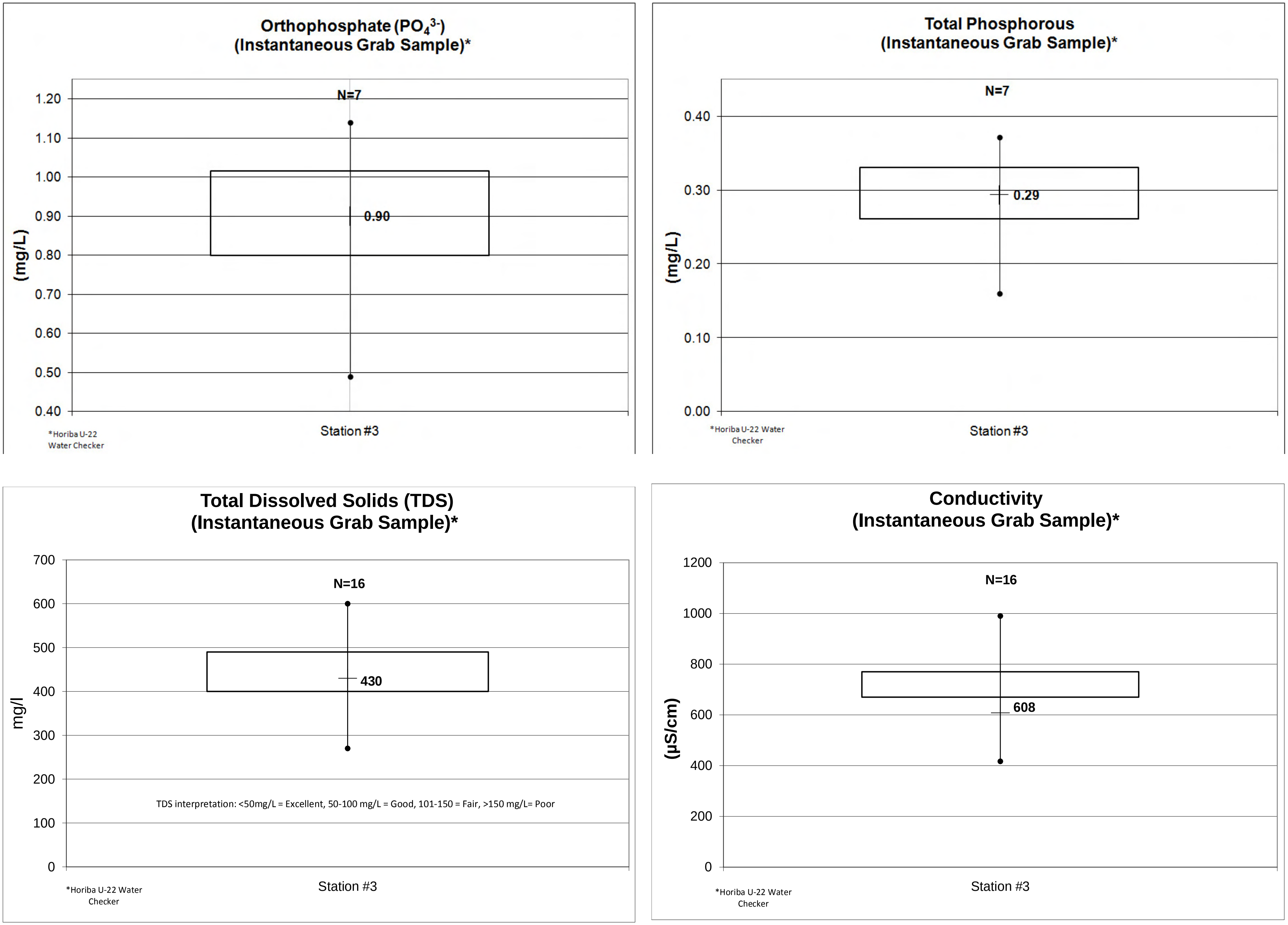


Figure 27. Upper Foundry Branch - Station 3 - Baseflow Orthophosphate, Total Phosphorus, Total Dissolved Solids, Conductivity



4. Baseflow Fluoride

Foundry Branch instantaneous baseflow fluoride (F^-) concentrations ranged from a low of 0.28 mg/L to an extremely high 1.33 mg/L, with a median value of 0.68 mg/L (Figure 26). It should be noted that naturally occurring fluoride concentrations for local, non-urban streams generally ranges from 0.1 to 0.2 mg/L, and that the District of Columbia reports concentrations of 0.33-1.30 mg/L for its treated water (DC Water, 2010). These results strongly suggest that treated municipal water and/or sewage (from sanitary sewer line exfiltration/ leakage) are entering the stream.

5. Baseflow Conductivity

Conductivity, which provides an indirect measure of dissolved anions and cations present in water (e.g., carbonates, chlorides, sulfates, nitrates, sodium, potassium, calcium and magnesium), was very high. As seen in Figure 27, instantaneous baseflow conductivity ranged from 400 mS/cm to 1,000 mS/cm, with a median value of 608 mS/cm. Limited water quality surveys of relatively undisturbed Piedmont and Coastal Plain streams in Maryland and other mid-Atlantic states strongly suggest that Foundry Branch baseflow conductivity levels should be in the 60-160 mS/cm range (Thomas, 1966; Janicki et al., 1995; Galli et al., 1997, MCDEP, 1998; Stribling et al., 1999). The preceding findings further suggest a variety of anthropogenic- related activities and pollutant sources (such as sewage from sanitary sewer line exfiltration/leakage, municipal water leaks, fertilizer applications, road salting, etc).

6. WSSC Laboratory- Analyzed Baseflow Water Quality Grab Samples

Between July 2010 and March 2011, five separate baseflow grab samples (Table 4) were collected by COG staff and brought to WSSC's Water Quality Laboratory in White Oak, MD for analysis of the following eight bacterial and water quality parameters: 1) *E. coli* bacteria, 2) Enterococci bacteria, 3) BOD_5, 4) nitrite (No_2), 5) nitrate (NO_3), 6) total suspended solids (TSS), 7) total Kjeldahl nitrogen (TKN) and 8) total phosphorous (TP).

As seen in Table 4, on two out of the five sampling dates (i.e., 7/8 and 8/3/10), E. Coli bacteria levels far exceeded the DDOE Class 'A' 410 MPN/100 ml standard; whereas, on all five sampling dates, Enterococci bacteria levels exceeded the more rigorous EPA/MDE Use I Waters 33 MPN/100 ml standard. However, results from the November 10, 2010 bacterial source tracking (BST) sample collected at station No. 3, suggest that non-human sources (i.e., birds, dogs, deer and other wildlife) are the main contributors (Table 5).

Table 4. Upper Foundry Branch - Station 3 - Baseflow Grab Sampling WSSC Laboratory Results

Date	BOD mg/L	E. Coli MPN/100 m	Enterococci MPN/100 m	Nitrite mg/L	Nitrate mg/L	Nitrate & Nitrite mg/L	Total Suspended Solids mg/L	Total Kjeldahl Nitrogen mg/L	Total Phosphorus mg/L
7/8/2010	<2	2,420	921	0.02	2.34	2.36	<1	0.62	0.30
8/30/2010	<2	770	99	0.003	3.22	3.22	4.10	<0.5	0.21
9/24/2010	<2	162	261	<0.05	2.34	2.39	1.20	0.54	0.31
10/25/2010	<2	62	80	0.010	3.59	3.60	1.50	<0.5	<0.2
11/10/2010	<2	108	108	0.01	2.84	2.85	<1	<0.5	<0.2
Number of Data Point	5	5	5	3	4	5	5	5	5
Maximum	N/A	2,420	921	0.020	3.59	3.60	4.10	0.62	0.31
Minimum	N/A	62	80	<0.05	2.34	2.36	<1	<0.5	<0.2
Mean	N/A	704	294	0.01	2.86	2.88	2.27	0.58	0.27
Median	N/A	162	108	0.01	2.84	2.85	1.50	0.58	0.30

Table 5. Upper Foundry Branch - Station 1 and 3 - Baseflow and Stormflow Grab Sampling Laboratory Results for Bacterial Source Tracking (BST)

Date	Sample Site	Flow Event	Rainfall (Inches)	Average Hourly Intensity (in/hr)	CFU/ 100 ml	% Human	% Avian	% Canine	% Deer	% Horse	% Misc. Wildlife	% Unknown	Total %
11/10/2010	Station 3	Baseflow	N/A	N/A	168	0	24	12	9	0	25	30	100
4/12/2011	Station 1	Stormflow	0.19	0.03	2,160	0	39	9	13	0	23	16	100
4/12/2011	Station 3	Stormflow	0.19	0.03	16,400	17	36	12	4	0	19	12	100

Throughout the survey period, both baseflow BOD_5 and TSS levels were low (i.e., below the WSSC 2.0 mg/L BOD_5 detection limit and maximum TSS level were < 4.10 mg/L). In contrast, NO_3 levels were all either in the moderate (i.e., 1.0-3.0 mg/L) or high (i.e., >3.0 mg/L) range.

D. Stormflow Water Quality

1. Stormflow Bacteria, BOD_5, NO_3, TSS and TP Levels

Among the several stormflow-related observations made by COG staff during the study was that: 1) runoff from even relatively small rainfall events (i.e., <0.20 inches rainfall/24 hrs) produced turbid dark-brown to dark-gray color conditions in Foundry Branch that are generally related to road runoff, 2) the stream returned to baseflow condition within approximately four to six hours following the cessation of rainfall, and 3) water clarity for smaller rainfall events (i.e., storms generating less than one-inch total rainfall and that did not create a backwater effect downstream of station 3 returned to near baseflow condition within the span of approximately two to three hours.

Not surprisingly, bacteria, BOD_5, NO_3, TSS and TP levels all experienced marked increases under stormflow conditions. As seen in Table 6, *E. coli* levels ranged from 488 to 20,100 MPN/100 ml (mean=10,072 MPN/100 ml), far exceeding DDOE Class 'A' 410 MPN/100 ml standard. Similarly, Enterococci bacteria levels (range: 1,020-21,900 MPN/100 ml; mean= 10,546 MPN/100 ml) also greatly exceeded the EPA/MDE Use I Waters 33 MPN/100 ml standard. In addition, the one BST sample collected from station No. 3 on April 12, 2011 confirmed that humans are among the top three contributors, accounting for 17 percent of that storms bacterial load (Table 5). This BST sampling result strongly suggests that leakage/exfiltration is occurring somewhere between stations No.1 and 3 in the Foundry Branch sewer line system.

While relatively low, BOD_5 stormflow levels (Table 6) were up to seven times higher (i.e., range: 4.7-15.4 mg/L; mean=8.3 mg/L) than for those observed under baseflow conditions (i.e., < 2 mg/L). Compared to baseflow conditions, median stormflow NO_3 levels were much lower (i.e., 0.57 mg/L versus 3.03 mg/L) reflecting a rainfall/runoff dilution effect.

Stormflow TSS levels (i.e., range: 20-255 mg/L; mean= 96.2 mg/L) generally reflected both rainfall amount and intensity. For example, the medium size 8/12/10 event (0.82 inches, total) had a maximum intensity of 0.53 inches per hour, occurred seven days after the previous rainfall date, and produced the highest TSS level (i.e., 255 mg/L). In contrast, the much smaller 9/27/10 event (0.03 inches, total) occurred nine days after the previous rainfall date, had a maximum intensity of 0.01 inches per hour, and generated a relatively low TSS level of 29.0 mg/L.

Stormflow TP range for four of the five storms (i.e., 0.24 - 0.52 mg/L), were well above the low level (i.e., <0.10 mg/L). Thus, it is apparent that the 0.10 mg/L TP concentration level recommended by EPA (1986) for the reduction and/or avoidance of nuisance plant growth in streams is periodically exceeded.

Table 6. Upper Foundry Branch - Station 3 - Grab Sampling WSSC Laboratory Results

Date	Rainfall Inches/24 hr	Max. Hourly Intensity in/hr	BOD mg/L	E. Coli MPN/100 m	Enterococci MPN/100 m	Nitrite mg/L	Nitrate mg/L	Nitrate & Nitrite mg/L	Total Suspended Solids mg/L	Total Kjeldahl Nitrogen mg/L	Total Phosphorus mg/L
7/29/2010	0.70	0.35	12.1	4,500	17,200	0.03	0.47	0.50	91.00	1.72	0.28
8/12/2010	0.98	0.53	6.6	20,100	5,170	0.02	0.54	0.56	255.00	1.52	0.52
9/27/2010	0.20	0.01	4.7	No Data	21,900	0.00	0.84	0.84	29.00	0.98	0.24
10/14/2010	1.26	0.37	15.4	15,200	7,440	0.05	1.93	1.98	86.00	2.40	0.30
3/10/2011	1.41	0.15	2.60	488	1,020	0.06	0.59	0.65	20.00	0.72	<0.2
Number of Data Point			5	4	5	5	5	5	5	5	5
Maximum			15.4	20,100	21,900	0.06	1.93	1.98	255.00	2.40	0.52
Minimum			2.6	488	1,020	0.00	0.47	0.50	20.00	0.72	<0.2
Mean			8.3	10,072	10,546	0.03	0.87	0.91	96.20	1.47	0.33
Median			6.6	9,850	7,440	0.03	0.59	0.65	86.00	1.52	0.29

E. Continuous DO Monitoring

Continuous DO monitoring results for the March 31, 2010 to June 28, 2011 study period are summarized in Table 7 and Figures 28-30. Table 7 provides summary highlights for calendar year 2010 (and discrete pre and post sewer line repair periods, thereof) and 2011. Figures 28-30 show general baseflow (dry weather) diurnal patterns and stormflow (wet weather) conditions under typical rainfall scenarios. In addition, YSI Sondes continuous DO plots for both calendar years are included in Appendix C.

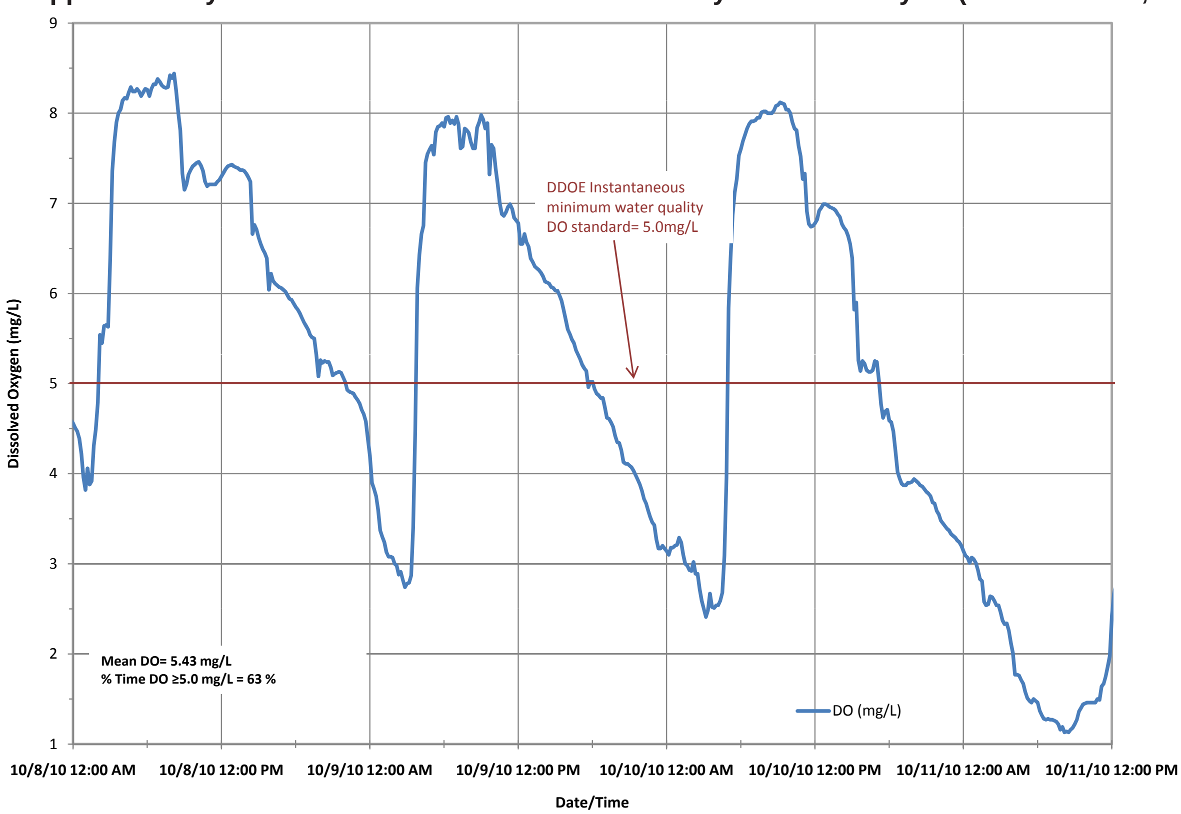
Table 7. Upper Foundry Branch - Continuous Dissolved Oxygen Monitoring Periods

Time Period	Maximum DO (mg/L)	Mean DO (mg/L)	Minimum DO (mg/L)	% Time DO ≤ 5 mg/L
March 31, 2010 - November 21, 2010	12.47	4.82	0.0	37
• March 31, 2010 - July 31, 2010	12.47	3.39	0.0	55
DCWATER emergency sewer line repair work 7/19-7/31				
• August 1, 2010 - November 21, 2010	10.29	6.14	0.0	20
March 8, 2011 - June 29, 2011	14.51	7.39	0.0	12

As seen in Table 7, Foundry Branch calendar year 2010 baseflow DO levels for the March 31 - July 31 period (i.e., pre-sewer line repair completion) were below DDOE's 5.0 mg/L standard 55 percent of the time. During this period DO levels ranged from zero to 12.47 mg/L, with a mean concentration of 3.39 mg/L. DO levels for the August 1- November 21, 2010 period (i.e., post sewer line repair) improved slightly, and ranged from a high of 10.29 mg/L to a low of zero, with a mean concentration of 6.14 mg/L.

Throughout the study, the lowest observed DO levels (i.e., 2.0 mg/L, or less) occurred intermittently at both probes at station Nos. 1 and 3 during baseflow conditions. As seen in Figure 28, these extremely low levels were generally recorded between late afternoon and 2 a.m., with highest DO readings observed in the early morning hours; exactly the opposite of the normally expected diurnal pattern. The maximum 2010

Figure 28. Upper Foundry Branch - Station 3 - Baseflow Three Day DO Diurnal Cycle (October 8 - 11, 2010)



baseflow DO level was 12.47 mg/L (i.e., 110 percent saturation) most likely reflecting high photosynthetic activity in the stream during early leaf-off conditions.

Under stormflow (wet weather) conditions, Foundry Branch DO levels actually increased. As seen in Figures 29 and 30, the increased stream discharge (associated with the inflow of stormwater runoff) generally resulted in a temporary DO increase on the order of 3-4 mg/L (i.e., the Delta DO).

Figure 29. Upper Foundry Branch - Station 3 - DO and Discharge Conditions During The August 2010 Storm Event

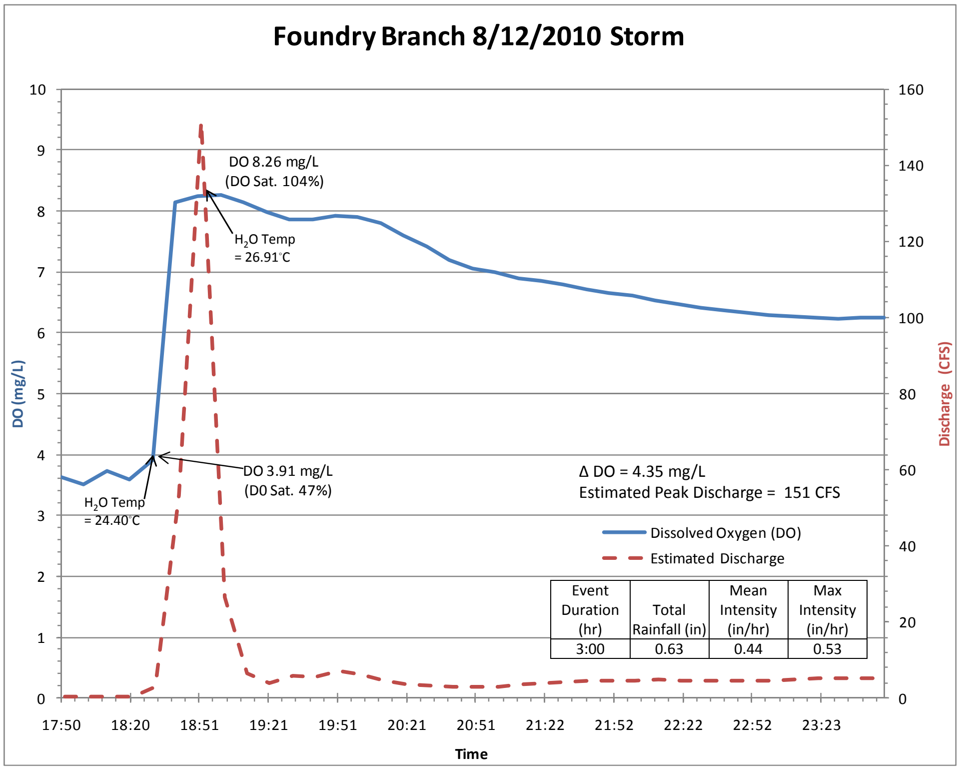
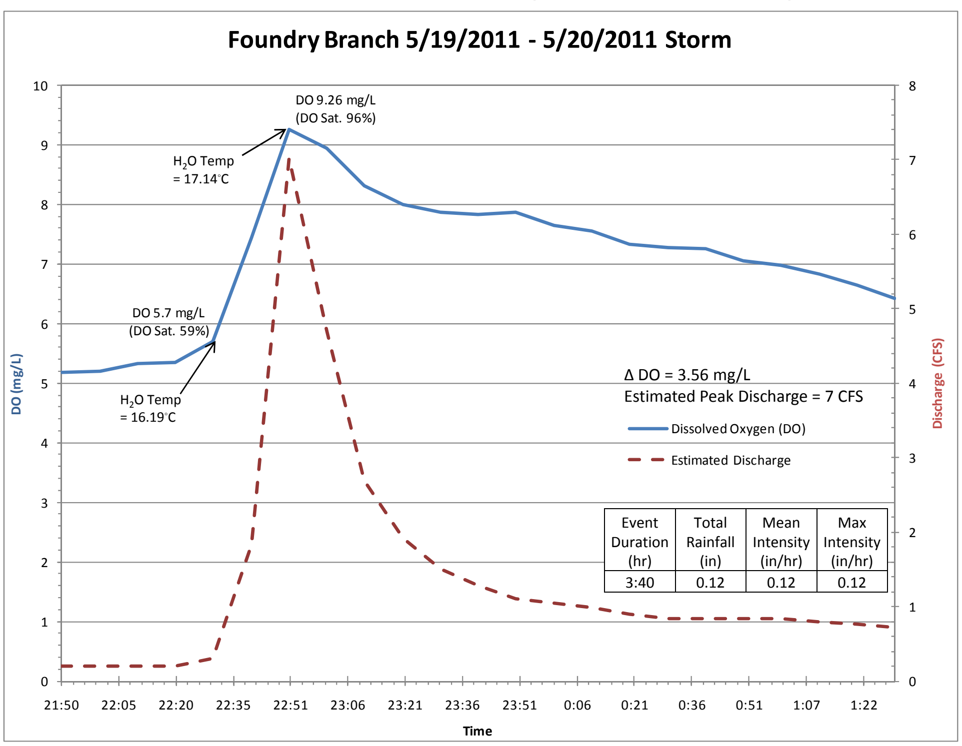


Figure 30. Upper Foundry Branch - Station 3 - DO and Discharge Conditions During The May 2011 Storm Event



F. Aquatic Community

During the course of the study, a total of 8 macroinvertebrate taxa were identified for the upper Foundry Branch (Appendix C). A total of 4 and 6 taxa, were identified for the summer 2010 RSAT voucher and the 20-jab surveys, respectively. As seen in Table 8, the highest number of taxa collected (6, poor range) was associated with the spring 2010 20-jab sample.

As previously stated, the spring 20-jab macroinvertebrate sampling includes a more quantitative interpretative approach, featuring the employment of six individual MBSS Piedmont stream metrics. As seen in Table 8, spring MBSS IBI scores for upper Foundry Branch were verbally rated as being very poor (i.e., IBI scores < 2.0). In addition, the associated verbal ratings for the individual metrics were all in the very poor categories. A narrative description of stream biological integrity associated with the four IBI categories is provided in Table 8.

Both the summer voucher and 20-jab samples corroborate that the upper Foundry Branch aquatic community is severely impaired. While poor water quality may be a major limiting factor, other factors such as streambed instability, altered water temperature regime, the discharge of toxic products, etc., may also be limiting. It should be noted that there are still two tributaries (i.e., 'W' Street Tributary and Phillips Run) located in the lower Foundry Branch that feature individuals from the stonefly (*Amphinemura spp.*) and caddisfly (*Diplectrona spp.*) groups. Their presence generally indicates both a cooler summer stream temperature regime and a stable streambed.

Table 8. Summary - Upper Foundry Branch - 20-Jab Macroinvertebrate Sample Metrics and MBSS Eastern Piedmont IBI Scores

Sample Date	No of Organisms	Taxa Richness[1]	Total No. of EPT Taxa[2]	Total No. Ephemeroptera Taxa[3] (%)	Percent Intolerant Urban[4] (%)	Percent Chironomidae[5] (%)	Percent Clingers (%)[6]	MBSS IBI Score[7]	MBSS IBI Verbal Ranking
4/24/2009	244	6	0	0	0	98	>1	1	Very Poor

[1]Taxa richness represents the total number of taxa collected and is interpreted by MBSS as follows: >25=Good, 14-24=Fair, <14=Poor

[2]Counts distinct taxa considered pollution intolerant within the groups of Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (Caddisflies). EPT taxa are interpreted as follows: >11=Good, 5-11=Fair and <5=Poor.

[3]Counts the generally pollution intolerant Ephemeroptera (mayflies) taxa and is interpreted as follows: >4=Good, 2-3=Fair and <2=Poor

[4]Measures the abundance of generally pollution intolerant individuals relative to the total number of individuals collected in the sample and is interpreted as follows: >50%=Good, 12-50%=Fair and <12%=Poor

[5]Measures the abundance of generally pollution tolerant Chironomidae (midgeflies) relative to the total number of individuals collected in the sample and is interpreted as follows: <5%=Good, 5-63%=Fair and >63%=Poor

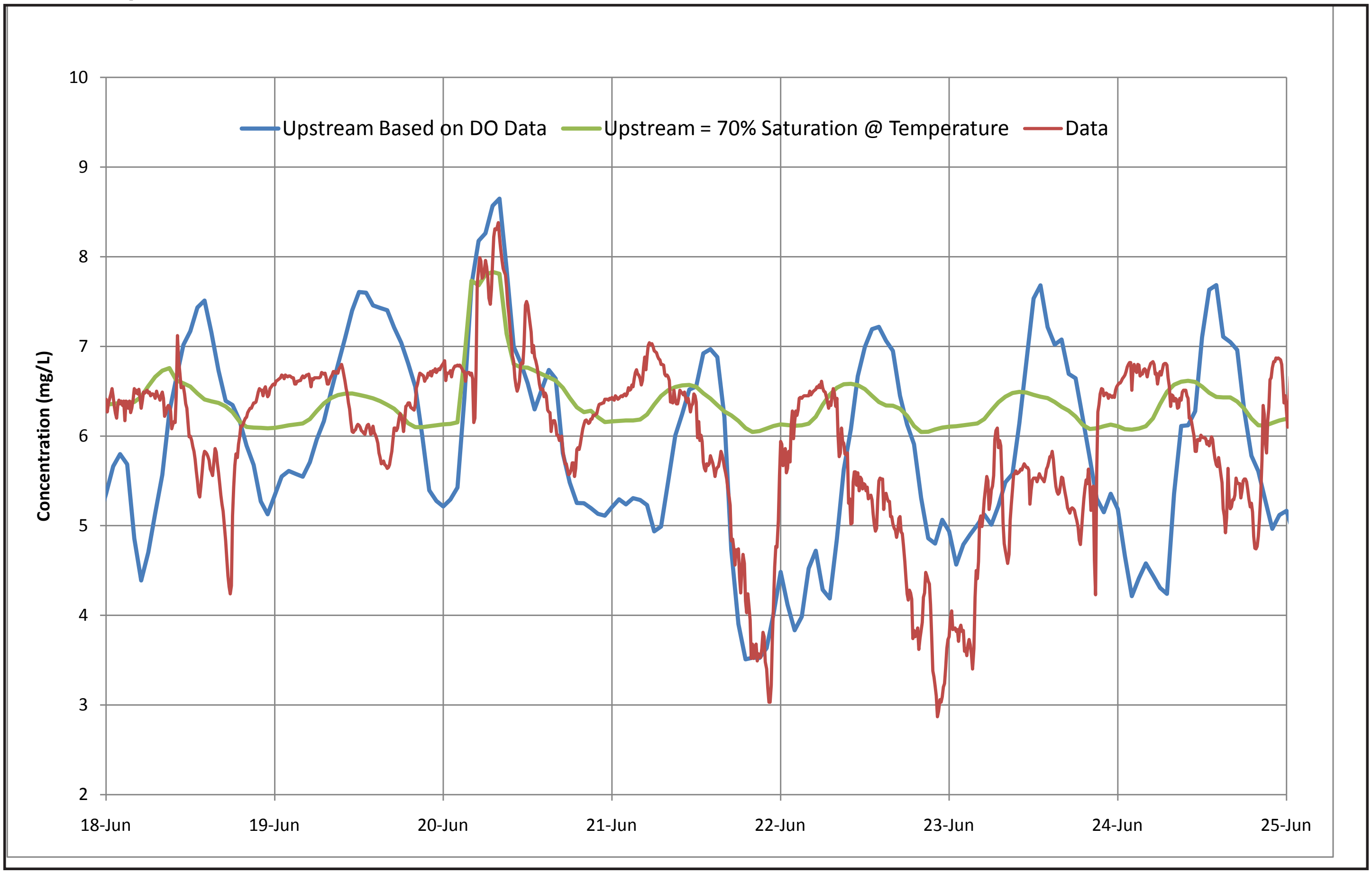
[6]Measures the organisms that are behaviorally and morphologically adapted to clinging to surfaces in fast moving riffles. Percent rations are interpreted as follows: >73%=Good, 31-73%=Fair and <31=Poor.

[7]Index of biological integrity developed by the Maryland Department of Natural Resources, Maryland Biological Stream Survey System (MBSS). MBSS IBI Score interpretation 4.0-5.0=Good, 3.0-3.9=Fair, 2.0-2.9=Poor and <1.9=Very Poor.

G. Modeling

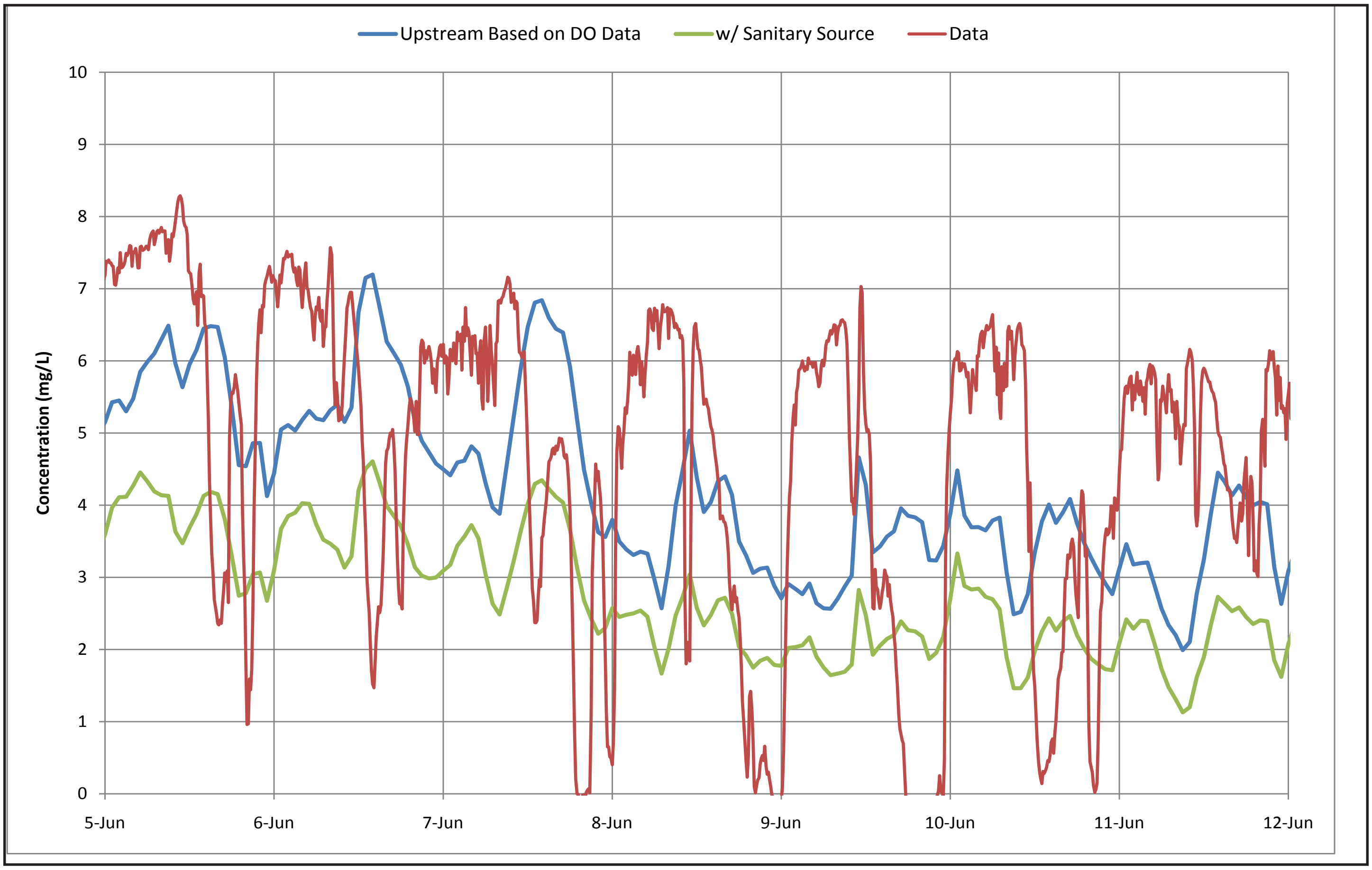
Per LimnoTech modeling results, Figure 31 shows a wet weather event that is, like the 2010 events, not especially sensitive to the upstream DO formulation. It is notable that the diurnal pattern in the data in Figure 31 "does not appear to represent conventional photosynthesis effects with respect to timing; that is, the highest DO levels in the data occur in the early morning with the lowest DO levels in the late afternoon, roughly the opposite of the expected pattern."

Figure 31. Upper Foundry Branch - DO Comparison at Sewer Crossing #4 (Wet Weather, June 2011 event) (LimnoTech, 2011)



Additional LimnoTech modeling results (Figure 32) show the effects of the inclusion of a hypothetical dry weather sanitary source. This simulation used the data-based upstream DO boundary condition, and results are shown with and without the sanitary source for comparison. "While the sanitary source does reduce DO levels, it does not drive it as low as observed in the data."

Figure 32. Upper Foundry Branch - Effect of Sanitary Source on DO at Sewer Crossing #4 (2011 Dry Weather) (LimnoTech, 2011)



Not surprisingly, wet weather loads for NO_3, TKN, NH_3 and BOD_5 were much higher than dry weather loads (Tables 9-10). Pollutant loadings also increased with increasing stormflow discharge (Table 10).

Table 9. Upper Foundry Branch - Estimated Dry Weather Loads (LimnoTech, 2011)

NO_3		TKN		NH^3		BOD_5	
(kg/day)	(lbs/day)	(kg/day)	(lbs/day)	(kg/day)	(lbs/day)	(kg/day)	(lbs/day)
0.49	1.072	0.035	0.078	0.024	0.053	0.119	0.26

Table 10. Upper Foundry Branch - Summary of Wet Weather Load Ranges (LimnoTech, 2011)

Rain Event Group	Number of Events	Average Value for Group								
		Peak Flow Rate	NO_3		TKN		NH3		BOD_5	
		(cfs)	(kg)	(lbs)	(kg)	(lbs)	(kg)	(lbs)	(kg)	(lbs)
up to 0.5 inches	15	8.62	0.43	0.94	1.47	3.24	0.74	1.64	7.72	16.98
0.5 to 1.0 inches	8	36.8	0.83	1.82	8.56	18.82	4.29	9.44	52.7	116.0
greater than 1.0 inches	3	41.0	1.82	4.01	18.75	41.3	9.41	20.7	126.0	277

V. Discussion

Due to Foundry Branch's small drainage area and the presence of high amounts of impervious surfaces (coupled with a lack of stormwater management controls and high number of storm drain outfalls), both stream flow and DO levels/water quality were highly responsive to even small rainfall events. Typical of small urban watersheds, the Foundry Branch stormflow hydrograph exhibited a short duration, sharp, spike-shaped peak with rapid rising and falling limbs. Dissolved oxygen levels also generally followed this pattern, rising in response to increased stream discharge and mechanical reaeration (i.e., turbulent flow conditions, created by the presence of several perched sewer line crossings and storm drain outfalls, with corresponding high atmospheric mixing and entrainment, Figure 33). Stormflow maximum water temperatures for the May - August 2010 and May-June 2011 periods were in the 22.1 – 28.6 range with associated DO levels that were generally in the 8.85 – 9.64 mg/L range. These DO levels reflect slightly supersaturated conditions.

Figure 33. Upper Foundry Branch - Station 3 - Mechanical Reaeration During Stormflow

At infrequent stormflow discharge rates greater than approximately 90-100 cfs, a backwater effect was observed in the vicinity of DO probe No. 1 (i.e., caused by the partially clogged storm drain system's trash rack, located some 400 feet downstream). Given that this backwater effect was of relatively short duration and that neither stormflow oxygen demanding BOD_5 (i.e., range: 2.6 - 15.4 mg/L) nor nitrate/nitrite levels (i.e., range: 0.5 -1.9 mg/L) were overly high, it did not have an appreciable influence on stormflow DO levels.

In sharp contrast, the lowest observed DO levels (i.e., 2.0 mg/L, or less) occurred intermittently at both probes at station No.s 1 and 3 during baseflow conditions. Interestingly, these extremely low levels were generally recorded in the late afternoon to 2 a.m. time period, with highest DO readings observed in the early morning hours. This pattern is directly opposite of the normally expected diurnal algal photosynthesis-driven one, wherein maximum DO levels occur in the afternoon.

Importantly, the low baseflow DO levels were neither directly correlated with pH, decreased stream discharges nor with higher oxygen demanding BOD_5 (i.e., range: less than 2.0 mg/L) or nitrate/nitrite levels (i.e., range: 2.3 - 3.6 mg/L). However, while the cause for these observed low DO readings are unclear, a plausible explanation for them is that the intermittent exfiltration of sewage to groundwater, illicit discharges from the storm drain/tributary systems, or a combination of both, may be at play. This hypothetical scenario is partially supported by the relatively high baseflow fluoride and nitrate levels observed throughout the study.

During the early part of the study period (i.e., pre-August 2010), multiple sewer line leaks were reported by COG staff to DC Water and subsequent temporary repairs were made. However, the overall integrity of the approximately 80-90 year-old sanitary sewer system remains highly questionable. Compounding the age of the system is the shallow depth to bedrock and the highly fractured crystalline rock geology of the Upper Foundry Branch stream valley, which provides potential avenues of exchange between the groundwater/sewer system and surface waters. Unfortunately, the small number and time of collection of the Foundry Branch baseflow water quality laboratory grab samples (i.e., five samples collected during daylight hours, only) do not reflect potential conditions during the evening portion of the diurnal cycle. In addition, maximum 2010 and 2011 baseflow DO levels were in the 12.5 - 14.6 mg/L range (i.e., approximately 100-120 percent saturation) at both DO probe stations, most likely reflecting high photosynthetic activity in the stream. It should be noted that while DO modeling results accurately reproduced observed stormflow DO levels they did not do so for base-flow conditions.

VI. Recommendations

In an effort to comprehensively address both existing problems and restoration opportunities for Foundry Branch, COG staff developed the following suite of recommendations. Importantly, it is understood that the comprehensive restoration of Foundry Branch is dependent upon DDOE, DC Water, NPS, the District of Columbia Department of Public Works and Transportation (DC-DPWT), the U.S. Army Corps of Engineers and other organizations working together to pursue a variety of sewer system upgrades, stormwater management, storm drainage, and stream restoration options, which will significantly reduce erosive stormflows, improve water quality and enhance aquatic and terrestrial habitat conditions throughout the subwatershed. Other and more specific recommendations are as follows:

Figure 34. Upper Foundry Branch - Sewer line crossing #4 (Station 3) leaking into the downstream pool (turbid/grey colored water) (July 2010)

1. The aging, main trunk and lateral sanitary sewer lines, which may date as far back as the mid-to-late 1930's and that parallel much of Foundry Branch, have had a long history of breaks and leaks (Figure 34). In fact, decades of uncontrolled stormwater runoff have, at several channel locations, severely compromised the structural integrity of the sewer system. Given the overall age and condition of the sewer system, it is strongly recommended that DC Water continue to inspect the sewer system with state-of the art closed circuit television (CCTV) and with sonar technology to acquire accurate and comprehensive assessments of trunk and lateral sewer line integrity.

2. Following inspection of the sewer system, DC Water should strongly consider the following near-term actions:


Figure 35. Upper Foundry Branch - Repaired six inch PVC sanitary lateral line located in the stream channel downstream of 60" RCP outfall

- Current in stream location (Figure 35) of the recent, temporary repair of the six inch PVC lateral line (located in the upper Foundry Branch, immediately downstream of the 60" RCP outfall) is anticipated to again break under higher stormflow conditions. It is strongly recommended that this pipe be replaced and relocated out of this high velocity area as soon as possible;

- Replace and relocate the sewer manhole stack located in the stream channel (upper Foundry Branch at transect No. 9);

- Replace, or at a minimum rehabilitate, all sewer lines crossing the stream channel, specifically the older vitreous clay pipes (Figure 36), via the employment of an Insituform® or equivalent lining. Subsequently, in-stream grade control structures (such as rock vanes) should be installed to prevent additional streambed downcutting and channel widening; and

- Replace and/or rehabilitate the entire trunk sewer line system and associated manholes. In addition, if at all possible this work should be done in concert with the restoration of Foundry Branch's stream morphology.

Figure 36. Upper Foundry Branch - DC Water staff inspecting a VCP sewer line with missing grout crossing upper Foundry Branch main stem

3. DDOE and/or DC Water should perform an illicit discharge detection survey looking for illegal pipe hookups in the storm drain network that may chronically contribute the following: raw sewage, nutrients, toxic pollutants, etc. This survey should be conducted, at a minimum, for upper Foundry Branch outfalls the north and east that include the following storm drain systems: No.s 1, 2, 3, and 5. This survey method may include the employment of various EPA recommended illicit discharge detection and elimination (IDDE) methods with follow up CCTV of storm drain network systems that have been positively IDDE verified.

4. Given the major technical, institutional and financial challenges associated with the implementation of subwatershed-wide stormwater management controls (which significantly reduce runoff volumes entering Foundry Branch), a Rosgen-based main stem stream channel restoration project for the entire length of open channel (i.e., approximately 1.6 miles) is recommended. This would include the repair (Figure 37) and/or the installation of more effective velocity dissipation features at the preceding four storm drain outfall locations (No.s 1, 2, 3, and 5).

Figure 37. Upper Foundry Branch - Storm drain outfall # 5 with broken headwall lying within the stream channel

5. To the greatest practical extent, the employment of various stormwater management water quality control techniques (such as, but not limited to, environmental site design/low impact development (ESD/LID), DDOE approved water quality inserts and inlets, sand filters, porous pavement, green roofs, etc) are needed throughout the Foundry Branch watershed. This is especially true for major roadways and commercial areas, which typically generate higher runoff volumes and pollutant loads.

6. Perform flow discharge , DO and water quality monitoring of upper Foundry Branch storm drain out-

falls, specifically targeting dry weather, 12 hour period (i.e., 6 p.m. to 6 a.m.), baseflow conditions at storm drain outfall No.s 1 and 3; so as to provide additional insight on contributing factors to the upper Foundry Branch low dissolved oxygen problem.

7. Perform post-restoration physical, chemical (to include chemical and bacterial laboratory analysis of water grab samples collected under baseflow and stormflow conditions) and biological monitoring of Foundry Branch, so as to evaluate stream recovery from proposed DC Water sewer line man hole replacement and rehabilitation and other watershed environmental restoration projects. It is strongly recommended that bacterial source tracking (BST) be performed so as to better determine the origin(s) of the bacteria contamination (i.e., bird, deer, human, etc.

8. In collaboration with DC Water and the National Park Service, the debris/trash grate located in the upper Foundry Branch at the terminus of the open stream channel section should be cleaned and maintained, free of debris and trash (on a regular basis), so as to both eliminate backwater conditions and reduce the likelihood of associated episodic low dissolved oxygen levels in the lower portion of the stream.

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