Pope Branch Subwatershed Restoration: 2002 Baseline Stream Assessment Study – Physical, Chemical, and Biological Conditions

Pope Branch Damselfly *Lestes sp.*

Prepared for:
District of Columbia
Department of Health/
Environmental Health Administration
Watershed Protection Division

Prepared by:
Department of Environmental Programs
Metropolitan Washington Council of Governments

May 2003

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Executive Summary

With funding support from the District of Columbia Department of Health/Environmental Health Administration (DC-DOH/EHA), the Metropolitan Washington Council of Governments (COG) was contracted in September 2001 to: 1) conduct a comprehensive baseline assessment of existing physical, chemical and biological conditions in Pope Branch, and 2) assess aquatic community restoration potential in Pope Branch. The 18 month-long Pope Branch stream baseline assessment study, described herein consisted of nine parts: 1) employment of the Rapid Stream Assessment Technique (RSAT Level III) to evaluate a total of 1.3 miles of the Pope Branch system[1], 2) the establishment of permanent channel cross-section stations, 3) continuous water temperature monitoring, 4) baseflow and stormflow water chemistry grab sampling, 5) sediment chemistry characterization, 6) an electrofishing survey to qualitatively document both the present composition and relative abundance of fish species, 7) baseflow and stormflow discharge characterization, 8) fish community restoration potential evaluation and 9) development of restoration-related recommendations based on study results.

The results of this study generally support the findings from previous investigations (Johnson, 1989; Banta, 1993) that Pope Branch's biological community is moderately impaired. Not surprisingly, decades of uncontrolled stormwater runoff in combination with periodically leaking sanitary sewer lines, episodic discharges of toxic materials such as petroleum products, and major channel alterations have: 1) created a characteristically 'flashy', urban stream flow regime; 2) modified channel morphology and increased levels of stream channel erosion, particularly in Upper Reach 'B'; 3) exposed a total of seven sewer line areas; 4) increased stormflow levels of Cu and various other pollutants; 5) reduced both streambed stability and physical aquatic habitat quality; 6) resulted in the enclosure of 1,700 linear feet of the stream system and the creation of 14 major fish blockages; and 7) with the exception of the American eel, *Anguilla rostrata*, eliminated all resident fishes from the stream.

Despite the aforementioned problems, Pope Branch's macroinvertebrate community still continues to support 37 taxa. Not surprisingly, pollution intolerant stoneflies, flathead mayflies and cased caddisflies have long since been eliminated from the stream. In fact, only relatively low numbers of pollution tolerant mayflies and caddisflies currently remain.

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

[1] Note: the Upper Reach 'A' and 'B' portions of Pope Branch were only partially RSAT surveyed due to dry channel conditions experienced during the drought-plagued study period.

1. Stream Channel Erosion

A. Out of a total RSAT-surveyed stream length of 6,820 feet (1.3 mi.), roughly 2,214 linear feet representing approximately 33.0 percent of the channel network is experiencing either severe, moderate/severe or moderate stream bank erosion conditions. Additional stream channel stability results revealed that Upper Reach 'B' had both highest amount and rate of severe stream bank erosion (400 lf and 1,333 lf/mi, respectively).

B. Cross-sectional analysis results revealed that the mean cross-sectional area of the Upper Reach 'A' (9.2 ft^2) is approximately one-fourth the size of those for Upper Reach 'B' (42.3 ft^2), Middle Reach (43.5ft^2), Lower Reach 'A' (41.4ft^2) or Lower Reach 'B' (37.5ft^2). Bank heights for Upper Reach 'A' and 'B' were approximately 1.5 feet higher than the expected or reference condition, reflecting decades of uncontrolled stormwater runoff and associated streambed downcutting.

2. Channel Scouring/Sediment Deposition

A. Channel scouring and sediment deposition conditions were rated fair in all three surveyed Pope Branch reaches. Mean riffle embeddedness levels were lowest in the Middle Reach (54.0 percent) and highest in Lower Reach 'A' (71.5 percent).

3. Physical Aquatic Habitat

A. Overall, Pope Branch physical instream habitat conditions were rated fair. The relatively low number of deep quality pools, high riffle embeddedness levels and high number of fish barriers present contributed to the fair ratings.

B. Pebble count results indicated that the median (i.e., D-50) Pope Branch particle size is medium to coarse gravel (i.e., 8.00-31.00 mm). The typically small diameter and round shape of this gravelly material makes it inherently unstable and prone to rolling during stormflows.

C. A total of 14 fish blockages (13 complete and one partial) were identified in the study. Among these, the single largest barrier to fish movement and migration within Pope Branch is the 1,385 foot long piped section downstream of Fairlawn Avenue.

4. Water Quality

A. Based on both RSAT and laboratory water chemistry grab sampling results, Pope Branch baseflow water quality was rated fair. Generally, low dissolved oxygen (DO) levels, coupled with episodic inputs of sewage and petroleum products contributed to this rating. Regarding DO, 11 out of the 27 instantaneous measurements taken (i.e., 40 percent) violated the minimum 5.0 mg/l DC-DOH/EHA water quality standard.

B. Stormflow grab sampling results revealed that median nitrate (NO_3^-) and total phosphorus (TP) concentrations were, compared to baseflow levels, approximately two and four times higher, respectively. Stormflow Fe concentrations ranged from 0.86 mg/l to 10.0 mg/l, with a median of 1.95 mg/l. Copper (Cu) concentrations ranged from 6.3 mg/l to 21.0 mg/l, with a median of 11.5 mg/l. Based on the limited stormflow monitoring results it appears that Cu may be limiting to Pope Branch's benthic community.

5. Riparian Habitat Conditions

A. Based on RSAT riparian buffer survey results, overall Pope Branch riparian habitat conditions were rated as being good to excellent in both the Upper and Middle reach areas, and fair in the lower reaches.

6. Biological Indicators-Benthic Macroinvertebrate Survey

A. Under the RSAT system, the three Pope Branch reaches surveyed (i.e., Middle Reach, and Lower Reach 'A' and 'B') were rated as having fair macroinvertebrate conditions present. However, were it not for the fair to good taxa richness present, all three reaches would have been rated as being poor.

B. The absence of individuals belonging to representative pollution intolerant groups (e.g., stoneflies, flathead mayflies and cased caddisflies) provides additional evidence of generally moderate levels of stream quality impairment. The only representative mayflies and caddisflies collected were pollution tolerant individuals belonging to the Baetidae and Hydropsychidae families. Furthermore, with the exception of mosquitoes, beetles and aquatic worms, all other taxa were present in low numbers.

C. Both spring and fall MBSS IBI scores for the Middle and Lower Reach 'A' and 'B' areas were verbally rated as being very poor (i.e., IBI scores < 2.0). The associated verbal ratings for individual metrics fell into either the poor or fair categories. According to Stribling et al. (1998), the general response for all seven metrics to increasing perturbation is a decrease in number, percent or score.

7. Pope Branch One-Pass Electrofishing Survey

A. Due to the severity of the drought, multiple visual observations of the stream by COG staff in which no fishes were noted, and the presence of a 1,385 foot long pipe section, which effectively precludes the natural migration, and movement of fishes between the Pope Branch and the Anacostia River, the planned electrofishing survey was deleted from the study. During the study, COG staff collected only one small (approximately 8 inches-long) American eel, *Anguilla rostrata,* elver. The only other vertebrates collected were larvae of the northern two-lined salamander, *Eurycea bislineata,* which were extremely scarce.

8. Summer 2002, Temperature Regime Characterization

A. Stream temperatures in the three Pope Branch monitoring reaches (i.e., Middle Reach, and Lower Reach 'A' and 'B') were well below the DC-DOH/EHA Class 'C' 32.2 °C (90 °F) standard.

B. Major results from the 111 day monitoring period are as follows: 1) all three stream reach stations had maximum summer daily temperatures that exceeded 24 °C (75 °F); 2) through August 1st, Lower Reach 'A' did not exceed the 24 °C MDE Use IV temperature criterion, whereas the Middle and Lower Reach 'B' areas exceeded this criterion on a total of one and twenty days, respectively, 3) the maximum daily water temperature recorded during the study (32.8 °C) was measured in the Middle Reach on September 9, 2002 and coincided with a water hydrant release event that lasted for approximately six hours; 4) the thermal regime of Lower Reach 'B' was far more strongly influenced by prevailing air temperatures than those of either the Middle or Lower Reach 'A' areas; and 5) Lower Reach 'B' also experienced a thermal "spike" where the maximum stream temperature reached 28.3 °C, coincident with another water hydrant release event that lasted for approximately five hours.

9. Flow Regime Characterization

A. Not surprisingly, baseflow between mid-June through mid-October was markedly reduced by the severe drought. Mean mainstem baseflow during the study period was 0.08 cfs.

10. Fish Community Restoration Potential

A. It is believed that, historically, the Pope Branch may have once supported 6-10 resident fish species. Current limiting factors include episodic water quality problems, the presence of major fish barriers, the relatively low number of deep quality pools and the general lack of stormwater management controls in the subwatershed. Despite these problems, Pope Branch should (in COG staff's opinion) be capable of supporting pollution tolerant, pioneer fish species such as the blacknose dace, *Rhinicthys atratulus,* and northern creek chub, *Semotilus atromaculatus.* Therefore, an experimental reintroduction of these two native species, using individuals collected from other Anacostia tributaries, should be considered after the existing main trunk sanitary sewer line problems have been satisfactorily addressed. If the two preceding species survive as expected, then other pollution tolerant species could subsequently be reintroduced using a phased approach.

11. Recommendations

In an effort to comprehensively address both existing problems and restoration opportunities for

Pope Branch, COG staff developed the following suite of recommendations. Importantly, it is understood that the comprehensive restoration of Pope Branch is dependent upon DC-DOH/EHA, the U.S. Army Corps of Engineers (USACE), District of Columbia Water and Sewer Authority (DC-WASA), National Park Service (NPS), District of Columbia Department of Public Works (DC-DPW), District of Columbia Office of Planning (DC-OP), and the District of Columbia Department of Parks and Recreation (DC-DPR) working together to pursue a variety of stormwater management, storm drainage, sewer system upgrade and stream restoration options which will significantly reduce erosive stormflows, improve water quality and enhance aquatic and terrestrial habitat conditions throughout the subwatershed. Therefore, COG staff suggest that those agencies responsible for current and/or planned future Pope Branch restoration-related activities, carefully review the more specific recommendations which follow:

1. The aging, main trunk sanitary sewer line which dates from the late 1930's and which parallels much of Pope Branch, has had a long history of both sewer line-related breaks and leaks. In fact, decades of uncontrolled stormwater runoff have, at several channel locations, severely compromised the structural integrity of the sewer system. This is particularly the case for the approximately 3,600 foot long Texas Avenue to Branch Avenue section. Given the overall age and condition of the sewer system, it is strongly recommended that DC-WASA either replace the trunk line in its entirety (i.e., construct a new relief sewer) or rehabilitate the existing pipe network via the employment of an Insituform® lining. Because the cost differential between the two options is relatively small for the existing 10 and 12-inch diameter Pope Branch trunk lines (i.e., approximately $ 50-60/lf for pipe replacement versus $45-55/lf for Insituform®), COG staff recommends the longer-lived replacement option. In addition, if at all possible this work should be done in concert with the restoration of Pope Branch's stream morphology.

2. Given the major technical, institutional and financial challenges associated with the implementation of subwatershed-wide, stormwater management controls which significantly reduce runoff volumes entering Pope Branch, a Rosgen-based stream channel restoration project for the entire length of open channel (i.e., approximately 1.3 miles) is recommended. As part of this work, it is recommended that: a) the large sand bar and meander which has formed immediately upstream of Branch Avenue be removed and b) the stream be realigned at this location with the culvert entrance, so as to reduce both existing sediment deposition and lateral stream channel erosion conditions.

3. The inadvertent collapse of the endwall section of the 8'x 8' Branch Avenue concrete arch culvert is providing defacto stormwater management quantity control for both Lower Reach 'A' and 'B' (i.e., the original cross-sectional area has been effectively reduced to an approximately 2'x 8' opening). While this collapsed section should be repaired it is recommended that, as part of the repair project, DC-DOH/EHA and DC-DPW investigate the possibility of constructing a formal, flow-reducing weir on the upstream side of the culvert.

4. As the lowermost piped portion of Pope Branch may ultimately provide the best opportunity for supporting a permanent resident fish community, the "daylighting" of this 1,385 feet long piped section (i.e., from Fairlawn Avenue downstream to the Anacostia River) should be a top priority. Not surprisingly, this work will have to be coordinated closely with the Fort Dupont stream

restoration project, as well as with the planned or potential use of this portion of Anacostia River Park by both the NPS and the Anacostia Waterfront Restoration Initative.

5. The six following storm drain system outfall locations are either in need of major repair and/or the installation of more effective velocity dissipation features: 'O' Street, Texas Avenue, 35th Street, 33rd Place, 34th Street and Branch Avenue.

6. To the greatest practical extent, the employment of various stormwater management water quality control techniques (such as but not limited to Low Impact Development (LID), DC-DOH/EHA approved water quality inserts and inlets, sand filters, porous pavement, green roofs, etc.) are needed throughout the Pope Branch subwatershed. This is especially true for major roadways and commercial areas, which typically generate higher pollutant loads.

7. Lower Reach 'B' - reforest the right hand bank (looking downstream) from Minnesota Avenue to Fairlawn Avenue, so as to create a minimum 50-foot wide, continuous forested buffer.

8. Fish passage-remove or modify the following culverts and/or obstructions, which are either partial or complete barriers:

- Lower Reach 'B' - Minnesota Avenue culvert, 1.5' drop, complete blockage (employ riffle grade control structure);
- Middle Reach - perched concrete sewer line crossing in the vicinity of X-19, 2.0' drop, complete blockage (employ riffle grade control structure);
- Middle Reach - nick point in the vicinity of X-16, 0.5' drop, partial blockage (employ rock vanes or equivalent);
- Upper Reach 'B' - perched concrete sewer line crossing, in the vicinity of X-6, 1.5' drop, complete blockage (employ riffle grade control structure); and
- Upper Reach 'B' - perched concrete sewer line crossing in the vicinity of X-5, 1.7' drop, complete blockage (employ riffle grade control structure).

9. Create vernal pools for amphibian habitat in one or more of the following general areas: Upper Reach 'A' and 'B' (as part of a larger proposed stream restoration project, cut off portions of one or more stream meanders and convert into vernal pools); Middle Reach (X-15 and X-19 areas) - excavate vernal pools along right hand bank; and Lower Reach 'B' (X-29 area) - excavate vernal pool along right hand bank. Note: several of these vernal pool sites can be excavated by hand using Earth Conservation Corps or other local volunteer labor. Also, in all likelihood the reintroduction of native amphibians such as spotted salamanders (*Ambystoma maculatum*), wood frogs (*Rana sylvatica*) and spring peepers (*Hyla crucifer*) will require the physical transplantation of eggs and/or larvae from other Anacostia sites.

10. Create an approximately 0.15 acre, off-line excavated wetland along the right hand bank portion of Lower Reach 'B' immediately upstream of Fairlawn Avenue. Potential water supply for the wetland includes interception of the water table and/or diversion of stormwater runoff from nearby 'M' Place.

11. The boulder/rubble fill slope located along the left hand bank in the Middle Reach X-14 to X-18 area is exhibiting signs of localized slope failure. In COG staff's opinion, a geotechnical study should be undertaken of this area to determine its potential long-term stability.

12. A community-based clean up of trash and debris from the entire Pope Branch stream valley park system is needed. Major trash/dump sites include Upper Reach 'A' (left hand bank, X-2 and X-3 areas) and Lower Reach 'A' (left hand bank, X-25 and Minnesota Avenue areas).

13. At a minimum, appropriate stream signage and no dumping signs should be installed at major stream crossings such as Branch and Minnesota Avenues. In addition, the stenciling of all storm drain inlets in the Pope Branch subwatershed with a "No Dumping-Drains to Pope Branch" message should be made a high priority.

14. A volunteer-based exotic/invasive plant management initiative modeled after Montgomery County's "Weed Warriors" program should be seriously considered for the Pope Branch stream valley park system.

15. Based on recent success in the neighboring Fort Dupont Tributary, reintroduce native fishes (after the main trunk sewer line problems have been addressed) into the Middle and Lower Reach portions of Pope Branch. The recommended species and approach are described below:

    a. Using COG's previous stream restoration experience in the Anacostia's Sligo Creek subwatershed and Table 17 as reference, the following six pollution tolerant species should be considered for reintroduction: blacknose dace (*Rhinichthys atratulus*), northern creek chub *(Semotilus atromaculatus*), white sucker (*Catostomus commersoni*), tessellated darter (*Etheostoma olmstedi*), swallowtail shiner (*Notropis procne*) and satinfin shiner (*Notropis analostanus*). The preceding species may be easily collected in good numbers from various Anacostia streams, including the Northeast and Northwest Branches, Lower Beaverdam Creek, Watts Branch, etc.

    b. Stocking should be phased, with the hardiest pioneer species, such as the blacknose dace and northern creek chub, being introduced first. As a rough stocking density guide, COG staff recommend that approximately 10-12 blacknose dace and two to four northern creek chub individuals be stocked per mainstem pool (i.e., approximately 120-150 blacknose dace and 25-35 northern creek chubs, total). If the two preceding species survive as expected, then the four remaining recommended species should be reintroduced; with white suckers being introduced last and only after overall physical aquatic habitat conditions have markedly improved. Additional future stockings beyond the recommended six target species should only occur after both stream restoration and stormwater management retrofitting-related work has been completed and monitoring results indicate a recovering stream system.

16. Continue physical, chemical and biological monitoring of Pope branch so as to evaluate stream recovery from both the recent drought and restoration projects.

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1.0 Introduction

1.1 Project Background

Over the past 300 years, farming, urbanization, loss of wetland and forest habitat, erosion, sedimentation and toxic pollution have all taken a tremendous toll on the 176 square mile Anacostia River watershed. After centuries of neglect, the signing of the historic 1987 Anacostia River Watershed Restoration Agreement and formation of the Anacostia Watershed Restoration Committee (AWRC) marked the beginning of a concerted and focused effort to restore and protect the river and its tributaries. Over the past 15 years, the AWRC has worked closely with local, State and Federal resource agencies and landowners such as the District of Columbia Department of Health/Environmental Health Administration (DC-DOH/EHA), Montgomery County Department of Environmental Protection (MCDEP), Prince George's County Department of Environmental Resources (PGDER), Maryland Department of Natural Resources (MDDNR), Maryland Department of the Environment (MDE), the National Park Service (NPS), the U.S. Army Corps of Engineers (USACE), the U.S. Environmental Protection Agency (EPA) the U.S. Geological Survey (USGS), and the U.S. Fish and Wildlife Service (USFWS), and others to integrate their related programmatic responsibilities and resources into the overall restoration effort.

This report is the second part of a three-phase, multi-year study that involves the assessment of three adjacent Anacostia subwatersheds (i.e., Fort Dupont Tributary, Pope Branch and Fort Chaplin Tributary) all located within the District of Columbia's east bank of the Anacostia River. Having completed the extensive <u>Fort Dupont Subwatershed Restoration: 1999 Baseline Stream Assessment Study – Physical, Chemical and Biological Conditions</u> report (Galli and Trieu, 2000), the Metropolitan Washington Council of Governments (COG) was contracted by DC-DOH/EHA in September 2001 to: 1) conduct a comprehensive baseline assessment of existing physical, chemical and biological conditions in Pope Branch, and 2) assess aquatic community restoration potential for the stream in its entirety.

1.2 Pope Branch Subwatershed

Pope Branch is a small first-order tributary to the Anacostia River, draining a 248.5-acre[1] (0.39 mi^2) watershed area within the southeast quadrant of the District of Columbia (Figure 1)[2]. Pope Branch originates immediately downstream of Fort Davis Drive and flows in a slight northwesterly direction for approximately 1.3 miles. The total length down to the Anacostia River including all the piped stream sections is estimated at 1.6 miles. Along the way, the stream flows underneath Branch and Minnesota Avenues and the CSX rail line area. Approximately 1,700 linear feet of the stream system (20.0 percent of the total length) is piped. The piped portion includes a 1,385 foot-long section that begins at Fairmont Avenue and which terminates at the Anacostia River sea wall. This lower pipe section precludes the normal movement and exchange of fishes between river and stream. The mean stream gradient for Pope Branch is, at 2.6 percent, relatively high for a Coastal Plain stream. This relatively high gradient is a function of the stream's river terrace-influenced morphology.

[1] Drainage acreage reflects area draining down to Fairlawn Avenue. Drainage area estimate below Fairlawn Avenue are an additional 17.0 acres

[2] Stream order determination made using 200-foot scale topographic maps

For the purpose of this study, the Pope Branch subwatershed and its stream channel was subdivided into five smaller and discrete sub-catchment areas (Figure 1 and Table 1). The associated drainage area and channel network boundaries for the five sub-catchments are defined as follows:

1. Upper Reach 'A' – headwaters area located upstream of Texas Avenue, characterized as having an open channel with intermittent flow;

2. Upper Reach 'B' – headwaters area located between 35th Street and Texas Avenue, also having an open channel with intermittent flow;

3. Middle Reach – perennial stream section extending between 35th Street and Branch Avenue;

4. Lower Reach 'A' – perennial stream section located between Branch and Minnesota Avenues; and

5. Lower Reach 'B' – lower most open and perennial stream section extending from Minnesota Avenue downstream to the 1,385 foot long piped section at Fairlawn Avenue.

It is important to note that the stream has been designated by the District of Columbia Department of Health/Environmental Health Administration (DC-DOH/EHA) as a class 'C' stream (i.e., protection and propagation of fish, shellfish and wildlife).

The Pope Branch subwatershed is located entirely within the Coastal Plain Province. This geologically complex subwatershed is underlain by sedimentary gravel, sand and clay materials associated with the geologic Cretaceous Potomac Group, Miocene Calvert Formation, and Pliocene river terrace deposits. The unaltered soil groups in the study area include Christiana and Chillum silt loams; Galestown and Muirkirk loamy sands; Croom, Iuka, Keyport, Sassafras and Sunnyside sandy loams; and two Udorothent urban soils (fill soil). However, in much of the study area these soils have been altered/disturbed by construction grading associated with urban development. Consequently, the preceding soil groups are generally classified with Urban Land (i.e., Christiana-Urban Land, Chillum-Urban Land, etc.; USDA, 1976), since topographical and soil characteristics such as relief and drainage have changed.

As seen in Table 2, impervious surfaces (e.g., rooftops, roads, sidewalks and parking lots) comprise 69.6 acres (28.0 percent) of the 248.5-acre Pope Branch subwatershed. The upper watershed (i.e., Upper Reaches 'A' and 'B'), which drains 108.4 acres, is approximately 20.1 percent impervious. Approximately 50.5 acres (46 percent) is deciduous forest, with the remaining 57.9 acres (54 percent) associated with single-family residential homes. Heading downstream, the middle portion of the watershed, which drains 78.8 acres, is approximately 29.3 percent impervious. Of the 78.8 acres, 17.8 acres (22.0 percent) are deciduous forest, with the remaining 61.0 acres (78.0 percent) associated with single-family residential homes. In contrast, the highest imperviousness level, 40.4 percent, is associated with the Lower Reach 'A' and 'B' portion of the watershed which drains 61.3 acres. Further analysis revealed that the forest coverage totaled approximately 8.2 acres, and that 51.4 acres (84 percent of the catchment) are associated with single-family and/or row house residential homes. There is also a small 1.7-acre (i.e., 2.7 percent of the catchment) commercial land use area located along Minnesota Avenue directly south of the stream. Overall, the mean Pope Branch

Table 1 - Pope Branch - General Study Area Information

RSAT Stream Segment	Drainage Area (ac)	Estimated Existing Imperviousness (%)	Stream Order	Stream Length		Stream Gradient (%)	Flow Condition/Mean Baseflow (cfs)	No. of RSAT Transects	Corresponding 200-Foot Scale Topographic Maps
				Feet	Miles				
Upper									
Reach 'A'	54.3	20.5	1	1,129.5	0.21	5.3	Intermittent	4	6268
Reach 'B'	54.1	19.8	1	1,557.9	0.30	2.6	Intermittent	8	6268-6168
Subtotal	108.4	-	-	2,687.4	0.51	3.9	-	12	-
Middle									
	78.8	29.3	1	2,330.3	0.44	1.6	0.06	10	6168
Lower									
Reach 'A'	35.9	40.0	1	922.0	0.17	1.5	0.08	4	6168
Reach 'B'	25.4	40.9	1	880.4	0.17	1.1	Perenial	4	6169
Subtotal	61.3	40.4	-	1,802.4	0.34	2.5	-	8	6168-6169
Total	248.5[1]	28.0	-	6,820.1	1.29	2.6	0.08	30	-

[1] Drainage acreage reflects area draining down to Fairlawn Avenue. Drainage area estimate below Fairlawn Avenue are an additional 17.0 acres

imperviousness level of 28.0 percent is more than double that of the adjacent Fort Dupont Tributary (13.3 percent). In summary, the Pope Branch imperviousness levels increased in a downstream fashion. Conversely, the deciduous forest acreage decreased in a downstream fashion, with forested areas being generally replaced by residential land uses, many of which encroach into the riparian buffer zone.

Table 2 - Summary: Pope Branch - Estimated Impervious and Forest Areas

RSAT Stream Segment	Drainage Area (Acres)	Estimated Impervious Surface Area Type (Acres)					Estimated Forest Area (Acres)	
		Building Rooftops	Roads	Sidewalks	Total	Percent Total Area	Total	Percent Total Area
Upper								
Reach 'A'	54.3	4.0	6.4	0.7	11.1	20.5	24.4	45.0
Reach 'B'	54.1	3.7	6.2	0.8	10.7	19.8	26.0	48.2
Subtotal	108.4	7.7	12.7	1.5	21.8	20.1	50.5	46.6
Middle								
	78.8	9.0	12.8	1.2	23.0	29.3	17.8	22.6
Lower								
Reach 'A'	35.9	4.9	8.3	1.1	14.3	40.0	5.2	14.4
Reach 'B'	25.5	3.8	5.5	1.1	10.4	40.9	3.0	11.8
Subtotal	61.3	8.7	13.8	2.2	24.7	40.5	8.2	13.1
Total	248.5 [1]	25.3	39.3	5.0	69.6	28.0	76.5	30.8

Climate in the Anacostia watershed is generally referred to as being continental. Annual precipitation averages around 39 inches. Mean Pope Branch tributary baseflow during the March-December 2002 monitoring period was approximately 0.08 cubic feet per second (cfs). It is important to note that this study coincided with a prolonged and severe drought, which began in the summer of 2001 and did not officially end until February 2003. The severity of the drought intensified during 2001 and 2002 producing a two-year precipitation deficit total of 14.4 inches at the National Oceanic and Atmospheric Administration (NOAA) Ronald Reagan National Airport rainfall gauging station.

1.3 Problem Assessment

Decades of uncontrolled stormwater runoff from this urbanized catchment have adversely impacted the stream and its biota. The upstream catchment area is served by two storm drain systems, the 'O' Street (1.1 acre drainage area) and the 35th Street system (34.6 acre drainage area). Combined, they drain approximately 35.7 acres comprised primarily of older, single-family residential housing with small wooded lots. Both systems discharge stormwater runnoff directly into the stream via 33-inch diameter reinforced concrete pipes (RCP). Similarly, both the middle and lower portions of the Pope Branch subwatershed are served by storm drain systems which discharge stormwater directly into the stream. The large volumes of uncontrolled runoff in combination with moderate to highly erosive stream bank and streambed materials and a relatively high stream gradient have: 1) accelerated channel widening and downcutting (i.e., exposing sewer lines at seven different locations), 2) resulted in the loss of numerous mature deciduous trees, and 3) increased pollutant and sediment loads and deliveries, with attendant aquatic habitat and biological community loss in Pope Branch.

[1] Drainage acreage reflects area draining down to Fairlawn Avenue. Drainage area estimate below Fairlawn Avenue are an additional 17.0 acres

Another major problem is the portion of the aging sanitary sewer line system located between Texas and Branch Avenues. This 3,600-foot long sewer section, which runs parallel to the stream channel for the most part, crosses the stream four times. Within this section there are a total of seven exposed sewer line areas, reflecting decades of channel widening and downcutting. At four of the seven sites, the original earthen foundation around the pipe and its concrete encasement has been eroded away, resulting in structural sagging. On several occasions, COG staff smelled and observed raw sewage leaking from one of these exposed sewer lines. In response, in April 2002 DCWASA repaired the leaking pipe section. Though repairs have been made, the potential for additional leaks and breakage for this nearly 70-year old sewer system remains high. The many anthropogenic water quantity and quality related problems, such as uncontrolled stormwater runoff and leaking sewer lines, contribute to the adverse impacts on Pope Branch.

Figure 1 - Pope Branch Study Area

2.0 Study Design/Methods

2.1 Pope Branch Study Area

Figure 2 - Pope Branch - Upper Reach 'B' (X-6)

On December 18, 2001, COG staff performed a preliminary reconnaissance field survey of Pope Branch tributary in which a total open stream channel network length of 1.3 miles was identified (Figure 2). As part of this survey, a total of 30 permanent stream transects (spaced on average 200 to 300 feet apart) were established for the Rapid Stream Assessment Technique (RSAT) evaluation portion of the study (Figure 3). The entire open section of Pope Branch was RSAT surveyed. However, due to the severity of the drought which effectively dried up riffle and run habitat areas in the entire upper section (i.e., Upper Reach 'A' and 'B' from Fort Davis Drive to 35th Street), only two of the six RSAT Stream Evaluation Categories were scored (i.e., Bank Stability and Riparian Habitat) for this upper area.

As previously stated, for study purposes, the 1.3 mile-long Pope Branch channel network was subdivided into five distinct reaches (i.e., Upper Reach 'A', Upper Reach 'B', Middle Reach, Lower Reach 'A' and Lower Reach 'B'). Of the 30 total RSAT transects, four were located between Fort Davis Drive and Texas Avenue (Upper Reach 'A'), eight were located between Texas Avenue and 35th Street (Upper Reach 'B'), 10 were located between 35th Street and Branch Avenue (Middle Reach), four were located between Branch Avenue and Minnesota Avenue (Lower Reach 'A') and four were located between Minnesota Avenue and Fairlawn Avenue (Lower Reach 'B').

Each RSAT stream transect site was both permanently marked in the field with a corresponding numbered aluminum tag (which was nailed to a nearby tree) and geo-referenced using a Garmin GPS III series unit. The associated GPS-derived latitude/longitude coordinates for each transect have been included as Appendix 1.

It should be noted that due to the relatively high gradient, river terrace nature of Pope Branch, COG staff were unable to find a comparable, unimpaired Coastal Plain reference stream within either the 176 square mile Anacostia watershed or immediate Washington metropolitan area. Consequently, COG staff's prior survey experience in the adjacent Fort Dupont Tributary and other Coastal Plain stream systems, and MBSS-based Coastal Plain data were relied upon for evaluation purposes.[3]

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[3] Note: results from COG's spring 1999 and fall 2002 Maryland Biological Stream Survey (MBSS) macroinvertebrate index of biological integrity (IBI) analyses for the Fort Dupont Tributary, Upper Beaverdam Creek and Silverwood Tributary, which were used for comparison, are provided in Appendix 2.

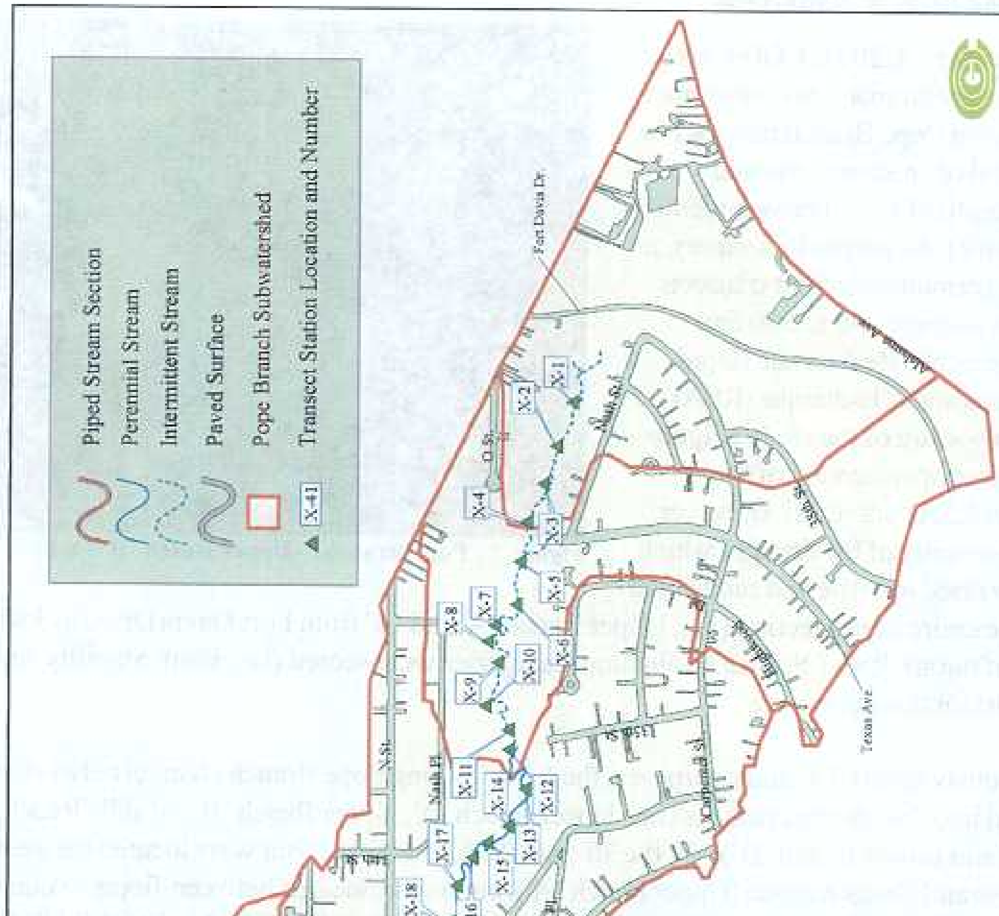

Figure 3 - Pope Branch - RSAT Transect Station Locations

2.2 *RSAT Level III Survey*

The Rapid Stream Assessment Technique (RSAT) was developed by COG in 1992 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 RSAT Level III method used in this study features quantitative macroinvertebrate community metric calculations, greater use of hand-held water quality meters for enhanced baseflow water quality characterization, pebble counts and the capacity to assess both Piedmont and Coastal Plain streams. RSAT employs both a reference stream and an integrated numerical scoring and verbal ranking approach.

The following six standard RSAT survey evaluation categories were assessed to compute the overall RSAT stream evaluation scores: 1) Bank Stability, 2) Channel Scouring/Sediment Deposition, 3) Physical Instream Habitat, 4) Water Quality, 5) Riparian Habitat Condition and 6) Biological Indicators. As previously indicated, the Level III evaluation included two-meter square ($2m^2$) streambed sampling for macroinvertebrate metric calculations and MBSS macroinvertebrate IBI scoring of surveyed stream reaches. Sample metrics included: 1) taxa richness, 2) total number of EPT taxa, 3) percent Ephemeroptera, 4) percent Tanytarsini of Chironomidae, 5) Beck's Biotic Index, 6) number of scraper taxa and 7) percent clingers. A brief overview of the types of field measurements and observations made for each of the preceding six RSAT evaluation categories are as follows.

1. Bank Stability

One of the primary assessments of channel stability is overall bank stability which is evaluated through both a visual estimation of the percentage of bank that is stable along each transect surveyed (expressed as a percentage) and a generalized approximation of the degree of erosion between transects (categorized verbally as stable, slight, slight/moderate, moderate, moderate/severe, or severe). Additional observations factored into the bank stability evaluation include the stability of stream bend areas and the number of recent, large tree falls per stream mile. The relative erodibility of the soil material comprising the bottom one-third of the bank (the area most susceptible to erosion) is also considered.[4] Another factor considered in assessing channel stability is the degree of channel downcutting, which is evaluated by a set of indicators that includes bank heights, exposed utility lines and nick points.[5]

2. Channel Scouring/Sediment Deposition

A key factor in evaluating the degree of sediment deposition occurring along the stream channel is the mean embeddedness level of riffle substrate material.[6] Other important indicators of sediment

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[4] Relative erodibility describes the erosion potential and is classified as low, moderate or high. Low potential denotes predominantly clay-textured soils, bedrock, saprolite and rip-rap; moderate potential characterizes non-silt or non-clay dominant soil textures; and high potential describes predominantly silt-textured soils.

[5] Mean bank heights of one to two feet for small first and second-order Coastal Plain streams and two to three feet for third-order streams approximate reference conditions. Sewer lines are typically laid three to four feet below the bottom of the streambed; therefore, their exposure offers insight into the depth of downcutting that has occurred. A nick point is an erosional feature in the streambed, marked by an abrupt drop in elevation, which is caused by stream headcutting.

[6] Embeddedness is the amount of sand and/or silt that surrounds or covers larger riffle materials such as gravel, cobble, and rubble; it is expressed as a percentage.

load and transport include pool depths and the amount of silt and sand in pools; sand and silt deposits within run areas and along the tops of banks; and the number of large, unstable point bars. Point bars also provide insight into the degree of channel scouring. For example, point bars armored by cobble-sized materials generally reflect frequent, intense storm flows unlike point bars comprised of smaller, gravelly or sandy material. Scouring is also sometimes evidenced by riffle areas where lower-lying resistant streambed materials such as bedrock or clay have been exposed and the upper layers of loose substrate material have been stripped away.

3. Physical Instream Habitat

One of the first criteria considered in evaluating physical instream habitat is the stream channel's wetted perimeter at riffle areas.[7] Diverse depths of flow and velocities through riffles are important to the sustainability of diverse macroinvertebrate communities. Two other important criteria include the quality of both riffle substrate material and pools. For higher gradient Coastal Plain streams such as Pope Branch, the ideal riffle substrate includes a mix of coarser gravels and cobble, with some larger rubble or boulder-sized stones and little sand. Gravel and cobble-sized materials should be the dominant and co-dominant materials present, respectively. Poor riffle substrate quality is generally associated with a very high and disproportionate amount of sand, silt and fine gravel. Small riffle substrate, such as sand and fine gravel provides limited habitat for macroinvertebrates and fish is inherently unstable and generally supports a limited biological community. Individual pool quality is assessed relative to its value as fish habitat and is based on five factors: 1) size and maximum pool depth, 2) substrate composition, 3) amount and type of overhead cover, 4) amount and type of submerged cover and 5) proximity to key food producing areas such as the nearest upstream riffle area. Additional factors considered in assessing overall physical instream habitat include: the degree to which riffles, runs and pools are equally represented; channel alteration or significant point bar formation; the riffle/pool ratio and the number of fish barriers (either partial or complete) present.[8]

4. Water Quality

Two key RSAT indicators of baseflow water quality are substrate fouling and total dissolved solids (TDS). Substrate fouling provides a qualitative indirect measure of the chronic nutrient (primarily nitrogen) and organic carbon loading to a stream.[9] TDS levels often increase in response to the introduction of a variety of pollutants such as sewage from septic field/sanitary sewer line exfiltration, road salts, fertilizers, etc. Additional parameters measured include 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), iron, fluoride concentrations (which may indicate the inflow of treated water or sewage), turbidity, water temperature, pH, dissolved oxygen (DO) and conductivity. Water clarity and odor are also documented.

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[7] Wetted perimeter is the percentage of the bottom channel width at riffle areas that contains flowing water.

[8] Partial barriers denote any obstruction, which would likely prohibit or impede normal upstream-downstream fish movements during certain times of the year (e.g., low summer baseflow conditions). Complete barriers describe obstructions, which totally prevent the normal movement of fish throughout the year (e.g., a perched culvert, which features a three-foot-high vertical drop).

[9] Substrate fouling is defined as the percentage of the underside surface area of a cobble-sized stone (or larger) lying free on the streambed, which is coated with a biological film or growth.

Baseflow water quality readings were taken using a Horiba U-10 water quality meter, Hach total dissolved solids (TDS) meter and Hach nitrate, orthophosphate, iron and fluoride pocket colorimeters.

5. Riparian Habitat

The quality of riparian habitat is evaluated based on 1) the width of the vegetated buffer zone on the left and right banks and the type of vegetation (a forested buffer rating highest) and 2) the percent canopy coverage (i.e., shading) over the stream.

6. Biological Indicators-Benthic Macroinvertebrate Biosurvey

Benthic macroinvertebrates are often used for biological monitoring because they are a ubiquitous diverse group of sedentary and relatively long-lived taxa, which often respond predictably to human watershed perturbations. Importantly, a stream's biological community normally responds to and is reflective of prevailing water quality and physical habitat conditions. The two principal factors considered in evaluating the benthic macroinvertebrate communities are: 1) the number of taxa present (i.e., species richness) and 2) the relative abundances (i.e., total number of individuals) of taxa present. Two types of macroinvertebrate samples were collected. For every survey reach, taxa were collected at each riffle transect area by compositing two one-square foot kick and two one-square foot jab samples. Representative individuals were preserved in ethyl alcohol and placed in the RSAT voucher collection. All reaches with baseflow were also quantitatively sampled by compositing the 20 jabs collected from all representative available habitats that totaled approximately 2.0-m^2 streambed area. As previously stated, the 20 jab samples were used for MBSS macroinvertebrate IBI scoring evaluations. An RSAT biological indicator scoring is based on both the taxa observed and collected as well as relative abundances over the entire survey reach.

An example of the RSAT scoring system has been included as Table 3. As seen in Table 3, the channel stability evaluation category is weighted slightly more heavily than the other five categories. This was done intentionally to reflect the major influence, which the stream flow regime exerts on all six-evaluation categories. For more detailed information regarding RSAT field protocols the reader is referred to Appendix 'A' of "Technical Memorandum: Rapid Stream Assessment Technique (RSAT) Field Methods, Galli, 1996a".

2.3 Water and Sediment Chemistry Characterization

2.3.1 Baseflow and Stormflow Grab Sampling

In addition to the RSAT water quality grab sampling, three baseflow and six stormflow water chemistry grab samples were collected between July and November 2002 for the purpose of conducting EPA priority pollutant scans. Both baseflow and stormflow water-grab samples were collected at transect station location X-26 (Lower Reach 'A'), which corresponds to the stage-discharge characterization site. Each water sample included 18 separate collection containers, each containing their respective preservative.

For stormflow grab samples, storm events that were likely to produce 0.10 inches of rainfall or greater were tracked using local weather and radar maps provided by AccuWeather.com,

Table 3 - RSAT Scoring System

RSAT Evaluation Category	General Verbal Rating Categories and Associated Point Range			
	Excellent	Good	Fair	Poor
1. Bank Stability	9-11	6-8	3-5	0-2
2. Channel Scouring/Sediment Deposition	7-8	5-6	3-4	0-2
3. Physical In-Stream Habitat	7-8	5-6	3-4	0-2
4. Water Quality	7-8	5-6	3-4	0-2
5. Riparian Habitat Conditions	6-7	4-5	2-3	0-1
6. Biological Indicators	7-8	5-6	3-4	0-2
Verbal Ranking (based on total score: 42-50 pts = Excellent, 30-41 pts = Good, 16-29 pts = Fair, <16 pts = Poor)				

Intellicast.com and WeatherNet.com. From such storms, water chemistry grab samples were collected by completely submerging the collection containers into a pool to collect the initial runoff associated with the rising limb of the hydrograph (i.e., first flush). Baseflow water grab samples were collected using the same method, but from an undisturbed pool. Both baseflow and stormflow water samples were iced and transferred to CT&E Environmental Services Incorporated Baltimore, Maryland within six hours. Both sample types were collected between 0700 and 1800 hours. In addition, when possible, the Horiba U-10 water quality meter was used to further measure DO, water temperature, conductivity, pH and turbidity levels.

2.3.2 Sediment Chemistry

One composite sediment grab sample was collected from a total of eight pool sites located in both the upper, middle and lower Pope Branch areas. In order to have enough material to perform an EPA priority pollutant scan, a total of 32 ounces of fine sediment was collected using a long-handled, polyethylene dipper which featured a 500 ml bowl set at a 45° angle. The composite was homogenized in a large porcelain mixing bowl, transferred into eight sterilized four ounce glass sample containers, appropriately labeled and placed in an ice cooler. The cooled sample was then delivered to CT&E Environmental Services Incorporated in Baltimore, Maryland within six hours for analysis.

2.4 Physical/Hydrological Condition Monitoring

2.4.1 Baseflow Discharge

For baseflow measurement, a temporary low-profile, four-inch high broadcrested wooden weir was installed on the upstream side of the Minnesota Avenue road culvert (RSAT transect X-26). The weir, which extended across the face of the culvert, effectively constricted baseflow through a 6.0-inch wide rectangular sluiceway (Figure 4). Baseflow discharges were measured in the sluiceway 20 times using a Marsh-McBirney Incorporated, model 2000 Flowmate flow probe. Measurements were taken from different dates (i.e., at least once a month between May 25th and August 10th and less frequently between August 10th and December 3rd). Again, the time was recorded for each discharge measurement that corresponded to the time that a stage height was recorded by the water level data logger. It should be noted that during the height of the drought (i.e., between June and September 2002) baseflow was dramatically reduced, with flow observed only from the Middle Reach on downstream.

Figure 4 - Lower Reach 'A' - Four-Inch High Broadcrested Weir At Minnesota Avenue

2.4.2 Rainfall Measurement

For the June-December 2002 portion of the study, rainfall was measured at the NPS Fort Dupont Activity Center building via the use of a RainWise® RGEL Tipping Bucket Recording Rain Gauge. The rain gauge was calibrated to measure, at 15-minute intervals, every hundredth of an inch (0.01 inches) of rainfall. Precipitation data from the recording rain gauge was used in the development of the stage-discharge curve for Pope Branch, as well as in the characterization of stormflow water quality.

2.4.3 Stormflow Discharge

Stormflow discharges were measured for storms that produced between 0.04 and 1.92 inches of rainfall. At least one and up to 16 discharge measurements were taken per storm, for a total of 35 measurements from 12 storms. Importantly, date and time were recorded for each discharge measurement to correspond with the information recorded by the water level data logger.

2.4.4 Stage-Discharge Curve Development

A stage-discharge curve, which characterizes and predicts flows according to water depths, was established for Pope Branch. These measurements were taken at station X-26 (Lower Reach 'A'), from late spring through late fall, via the Global Water automated water level logger and a manually operated Marsh-McBirney Incorporated model 2000 Flowmate flowmeter. The stage level logger, which features a data logger encased in a waterproof cylinder connecting to a 15 foot cable that terminates at a pressure transducer sensor, was deployed from May 31st to December 31st to record various pools stages (ft) at 20-minute intervals. It should be noted that for the month of September, the logger was decommissioned and serviced and reinstalled in October. The installation entailed carefully burying the data logger cylinder, housed in a PVC pipe, into the top of an approximately four foot high bank to reduce the risk of damage or loss from flooding and/or vandalism. The sensor cable was also buried and snaked through the roots down the embankment to a pool approximately 12.0 inches deep. Finally, the terminal sensor, housed in a 3.0 inch diameter, 15 inch long perforated PVC pipe, was submerged. It should be noted that the sensor tip was pointed downstream to reduce silt deposition and clogging of the sensor.

The discharge flow probe was used to measure mean stream velocity at the weir immediately downstream of the water level logger pool site. Parameters such as average stream velocity; the wetted perimeter width and riffle depths were measured. Again, date and time were noted and recorded to correspond with the information recorded by the water level data logger. It should be noted that the stage-discharge measurement site corresponds to those of the baseflow and stormflow water chemistry grab sampling locations. Discharge was calculated using the following simple formula: Discharge (ft^3/sec) = riffle cross-sectional area (ft^2) * mean stream velocity (ft/sec). The stage and discharge data were downloaded and statistically analyzed using Microsoft Excel 2000 linear regression to test for a significant relationship between the stage and discharge data.

2.4.5 Permanent Channel Cross-Sections

As part of the channel morphology characterization portion of the study, COG staff established permanent channel cross-section stations at the following four locations: Upper Reach 'B' (X-9), Middle Reach (X-15), Lower Reach 'A' (X-25) and Lower Reach 'B' (X-29). At each preceding station location, 0.5 inch diameter rebar was driven into the top of each bank. A 100-foot long steel tape measure was next secured to the higher of the two rebars (flush to the ground), drawn tautly across the channel, re-secured to the opposite bank and leveled. Cross-sectional elevational differences were then recorded, at one-foot intervals, via an 11 foot-long fiberglass surveyor's rod with a leveler attached and Laser Tech Incorporated Impulse® 200 Laser. Channel measurements were made to the nearest 100^{th} of an inch. Permanent channel cross-sections are included in Appendix 3 of the report.

2.4.6 Pebble Count

A modified Wolman (1954) pebble count was performed at the following representative stream locations: Upper Reach 'B' (X-9), Middle Reach (X-15), Lower Reach 'A' (X-25) and Lower Reach 'B' (X-29). At each site, 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 measured across the entire 'wetted perimeter' width of the channel. The intermediate axis of each randomly chosen particle was 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.

2.4.7 Rosgen Level I and II – Steam Channel Morphological Description

The Pope Branch stream channel types were classified using the Level I Rosgen Stream Channel Classification Method. In addition a Level II morphological assessment was performed at the following representative stream locations: Upper Reach 'B' (X-9), Middle Reach (X-15), Lower Reach 'A' (X-25) and Lower Reach 'B' (X-29). Measurements to characterize Level I (e.g., Stream Type B, moderately entrenched, moderate gradient, riffle dominated channel with stable banks, width/depth ratio > 1.2, etc.) and Level II (e.g., bankfull width, mean depth, bankfull cross-section area, width/depth ratio, maximum depth of the bankfull cross-section, width of flood prone area, entrenchment ratio, water surface slope, etc.) conditions were performed employing both a Laser Tech Incorporated Impulse® 200 Laser and a LEICA Total Station model number TCR110. In addition to photographic documentation, "fixed" channel cross-sections were established at representative sites via the employment of both rebar bank pins and GPS-derived latitudinal and longitudinal coordinates. For further Rosgen Level I and II method descriptions, the reader is referred to "*Applied Stream Morphology*" (Rosgen, 1996).

2.4.8 2002 Summer Thermal Regime Characterization

Characterization of the "summer" thermal regime within key representative portions of Pope Branch was accomplished via the systematic employment of HOBO® temperature probes. The three station temperature monitoring network employed in the study included the following stream sites keyed to RSAT transect locations: Middle Reach (X-14 area), Lower Reach 'A' (X-25 area) and Lower Reach 'B' (X-29 area).

At each station, the temperature probe was placed into a waterproof HOBO® Clear Submersible plastic case and submerged in a pool area approximately six to 12 inches deep. The units were carefully cabled to trees in the overbank area so as to reduce the risk of damage or loss from flooding. All units were located in well-shaded areas of the stream where the depth of flow was sufficient to keep the unit completely submerged. HOBO® temperature probes were deployed from May 23, 2002 to September 10, 2002 and programmed to record water temperature every 15 minutes. Data were downloaded into a personal computer and statistically analyzed using Microsoft Excel 2000. Climatological information used during the study period was obtained from NOAA (1999) for Washington National Airport, as well as from the Fort Dupont recording rain gauge. It should be noted that the HOBO® temperature probe located at Lower Reach 'A' malfunctioned during the August – September period.

2.5 *Biological Monitoring*

2.5.1 RSAT Macroinvertebrate Voucher Sample

RSAT Level III surveys of Pope Branch were conducted on July 11th and 15-16th, 2002. For each RSAT riffle transect area, taxa were collected from representative riffle, run and pool habitat via the previously stated two one-square foot kick and two one-square foot jab protocol. A D-frame net with a 600-micron mesh was used to collect macroinvertebrates. In addition, macroinvertebrates were collected at each transect from the bottom side of 10 cobble-sized stones and included in the voucher collection.

2.5.2 Spring and Fall 2002 20 Jab Macroinvertebrate Sampling

Included as part of the RSAT Level III evaluation were spring and fall 2002, 20 jab macroinvertebrate sampling of the following Pope Branch transect sites: Middle Reach (X-14 area), Lower Reach 'A' (X-23 area) and Lower Reach 'B' (X-29 area). Spring samples were collected on March 22nd, whereas fall samples were collected on November 8th and 21st. In addition, for comparison purposes a 20-jab fall collection was also performed for the Fort Dupont Tributary middle mainstem area. The 20-jab collection is a quantitative survey that combines samples from multiple, representative habitats (i.e., riffles, runs, and pools). The total survey area encompassed an approximately 2.0-meter-square area of the streambed. Organisms were collected from representative habitat areas such as riffles, runs and pools using a 600-micron mesh D-frame net and field sorted using a 60-minute long sorting or a 200 organisms collected limit.

2.5.3 Taxonomy

RSAT voucher samples were identified in the field to the family level and preserved for laboratory identification to the lowest possible level via the following taxonomic references: Harper and Hynes, 1971; Merritt and Cummins, 1996; Pennak, 1989; Stewart and Stark, 1993; and Wiggins, 1998. All preserved organisms collected via the 20 jab surveys were counted and identified by COG staff to the lowest possible taxonomic level. For aquatic insects, identification was, with few exceptions, to the genus level.

2.5.4 Macroinvertebrate Biosurvey Scoring

RSAT biosurvey scoring is based on the taxa observed and collected in the field as well as from the voucher collection for the entire survey reach. The 20 jab scoring is based on the seven metrics currently employed by the Maryland Biological Stream Survey (Stribling et al., 1998) for Coastal Plain streams (i.e., taxa richness, total EPT taxa, percent Ephemeroptera, percent Tanytarsini, Beck's Biotic Index, number of scraper taxa, and percent clingers). It should be noted that the MBSS used these metrics to develop the Maryland Index of Biological Integrity (IBI) for Coastal Plain streams. This IBI was employed for the Pope Branch biosurvey scoring.

2.5.5 One-Pass Electrofishing Survey

As originally proposed, COG staff was to perform a summer 2002 single pass or "sweep pass" electrofishing survey of Pope Branch. The purpose of the survey was to determine if and where existing fishes were present in the stream. A Smith-Root Model XII backpack eletrofisher with two people netting was to be employed. However, as the study progressed, both COG and DC-DOH/EHA staff agreed that the one-pass electrofishing survey was unnecessary based on the following: 1) the presence of a 1,385 foot long pipe section from Fairlawn Avenue down to the Anacostia River, which effectively precludes fish migration from the River to Pope Branch; 2) multiple visual observations by COG staff over a nine-month period in which no fish in the Upper and Middle stream reaches, and only one small (approximately 8 inches-long) American eel, *Anguilla rostrata*, elver was observed and captured in Lower Reach 'B'; and 3) a joint conclusion by both COG and DC-DOH/EHA staff in which potential additional electrofishing-related stresses on fishes and other aquatic life during extreme low flow conditions and elevated summer water temperatures was to be avoided.

3.0 Results

3.1 Stream Channel Erosion

3.1.1 Background

Under the RSAT system, the following channel morphology-related data were collected at each riffle transect: top channel width, bottom channel width, average right and left bank height, general right and left bank material type and right and left bank stability. In addition, between each transect station, COG staff noted and recorded both the general level of bank stability in the channel network and the presence of recent tree falls, exposed sewer lines, perched road culverts or other tell-tale signs of lateral stream channel erosion and degradation. Bank stability conditions between transect stations were visually rated and placed into one of the following six categories:

1) Stable - Over 90 percent of bank network is stable, with no signs of major lateral bank erosion problems present;

2) Slight - 81 to 90 percent of bank network is stable and signs of major lateral bank erosion problems are rarely observed;

3) Slight/Moderate - 71 to 80 percent of bank network is stable and signs of major lateral bank erosion problems are uncommon to common;

4) Moderate – 61 to 70 percent of bank network is stable and signs of lateral bank erosion problems are common;

5) Moderate/Severe – 50 to 60 percent of bank network is stable and signs of lateral bank erosion problems are very common;

6) Severe – Less than 50 percent of bank network is stable and major portions of banks are unraveling.

The preceding information was mapped onto 1 inch = 200 feet horizontal scale topographic maps, photographed, logged on field survey forms and subsequently entered into a Microsoft Excel spreadsheet database for further analysis.

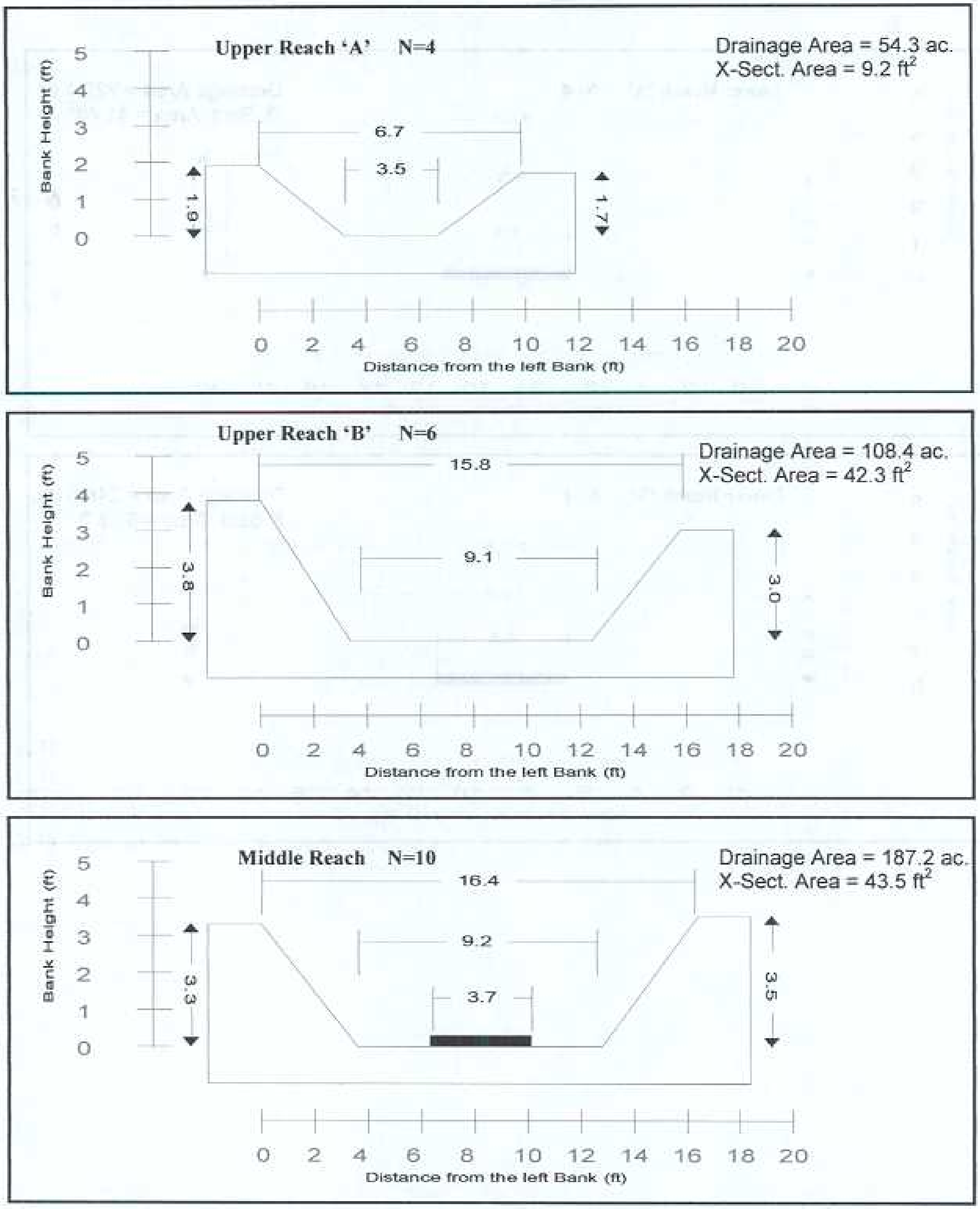
As the stream channel was walked, particularly close attention was paid to evidence of major channel downcutting or degradation. Again, average bank heights provided a good indication. For example, bank heights averaging four feet suggest that downcutting on the order of one to three feet has probably occurred. Other reliable indicators included the presence of nickpoints and exposed sewer lines crossing the stream, and undercut and/or collapsed concrete road culverts. A comparison of representative riffle transect stream channel cross-sections for Pope Branch, is presented in Figure 6. General stream channel erosion-related indicators are summarized in Figure 8. The approximate locations of severe, moderate/severe and moderate stream bank erosion areas are depicted in Figure 8. Summary stream channel erosion-related information has also been included as Table 4 and 5.

3.1.2 General Findings

Figure 5 - Upper Reach 'A' - Recent Tree Falls

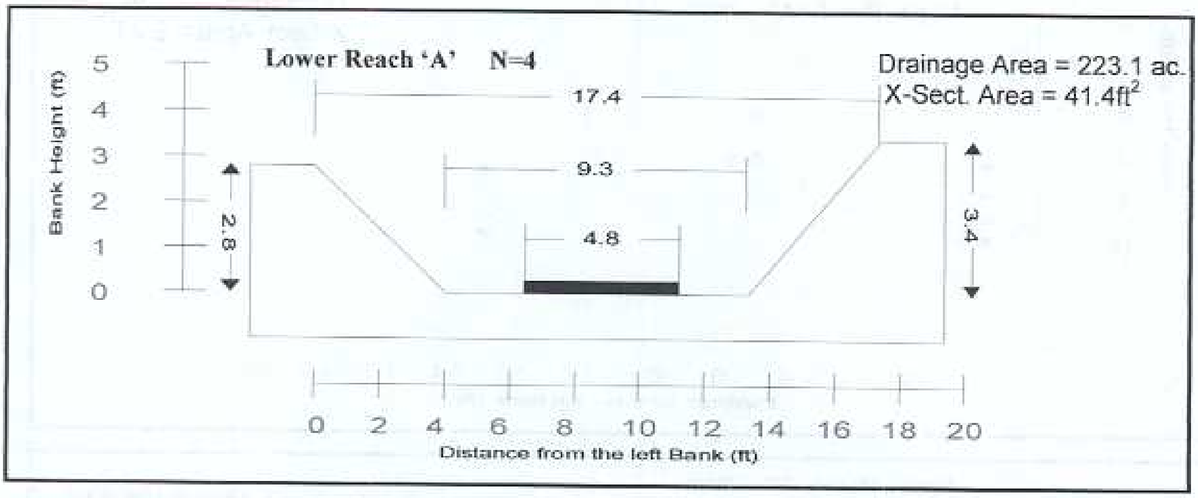
With the exception of Upper Reach 'A', Pope Branch appears to be actively eroding in its remaining open channel sections. Results from the channel stability portion of the study revealed that out of a total of 6,820 feet of RSAT-surveyed stream length, 520 linear feet, representing approximately 7.6 percent is experiencing severe bank erosion. Approximately 914 linear feet (13.0 percent) exhibited moderate/severe stream bank erosion conditions. An additional 780 linear feet (11.4 percent) exhibited moderate bank erosion conditions. Stream areas experiencing moderate, moderate/severe or severe stream bank erosion conditions were observed in both straight and meandering sections. As illustrated by Figure 5, these sections were frequently associated with numerous recent tree falls lying across the stream channel. Cross-sectional analysis results (Figure 5) indicated that the mean cross-sectional area of Upper Reach 'A' (9.2 ft^2) is approximately four times smaller than the cross sectional areas of all four following downstream reaches: Upper Reach 'B' (42.3 ft^2), Middle Reach (43.5 ft^2), and Lower Reach 'A' (41.4 ft^2), and 'B' (37.5ft^2).

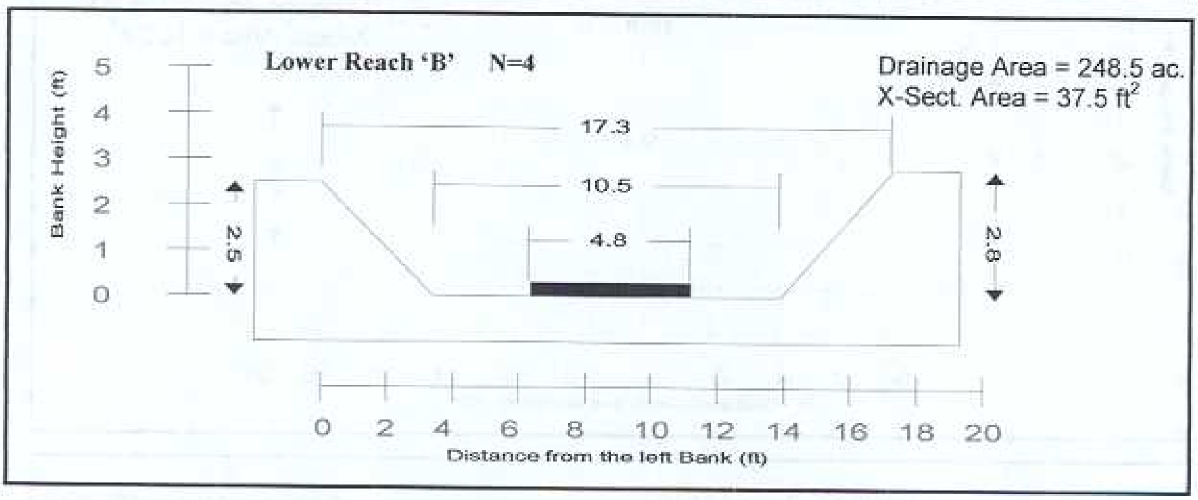
Figure 6 - Representative Channel Cross-Sections [1]



[1] Top channel width, bottom channel width and wetted perimeter area (heavy black line) depicted.
Note: Dry channel is indicated with absence of the heavy black line.

Figure 6 - Continued [1]





[1] Top channel width, bottom channel width and wetted perimeter area (heavy black line) depicted.

Based on previous COG staff surveys of comparably-sized Coastal Plain and Piedmont streams in the Washington metropolitan area, the generally expected Pope Branch bank height and channel width ranges are on the order of one to three feet and 10 to 12 feet, respectively (Galli et al., 1999; Trieu et al., 1998; Galli et al., 1996b; Corish et al., 1996; Galli and Trieu, 1994). The preceding results confirm that decades of uncontrolled stormwater runoff, beginning at the upper most portion of Upper Reach 'B' (Figure 7) and extending all the way downstream to the piped entrance at Fairlawn Avenue has produced a Pope Branch stream channel, which is with respect to forested, reference stream conditions, markedly wider and more incised.

Figure 7 - Upper Reach 'B' - 33-Inch RCP Texas Avenue Storm Drain Outfall Area

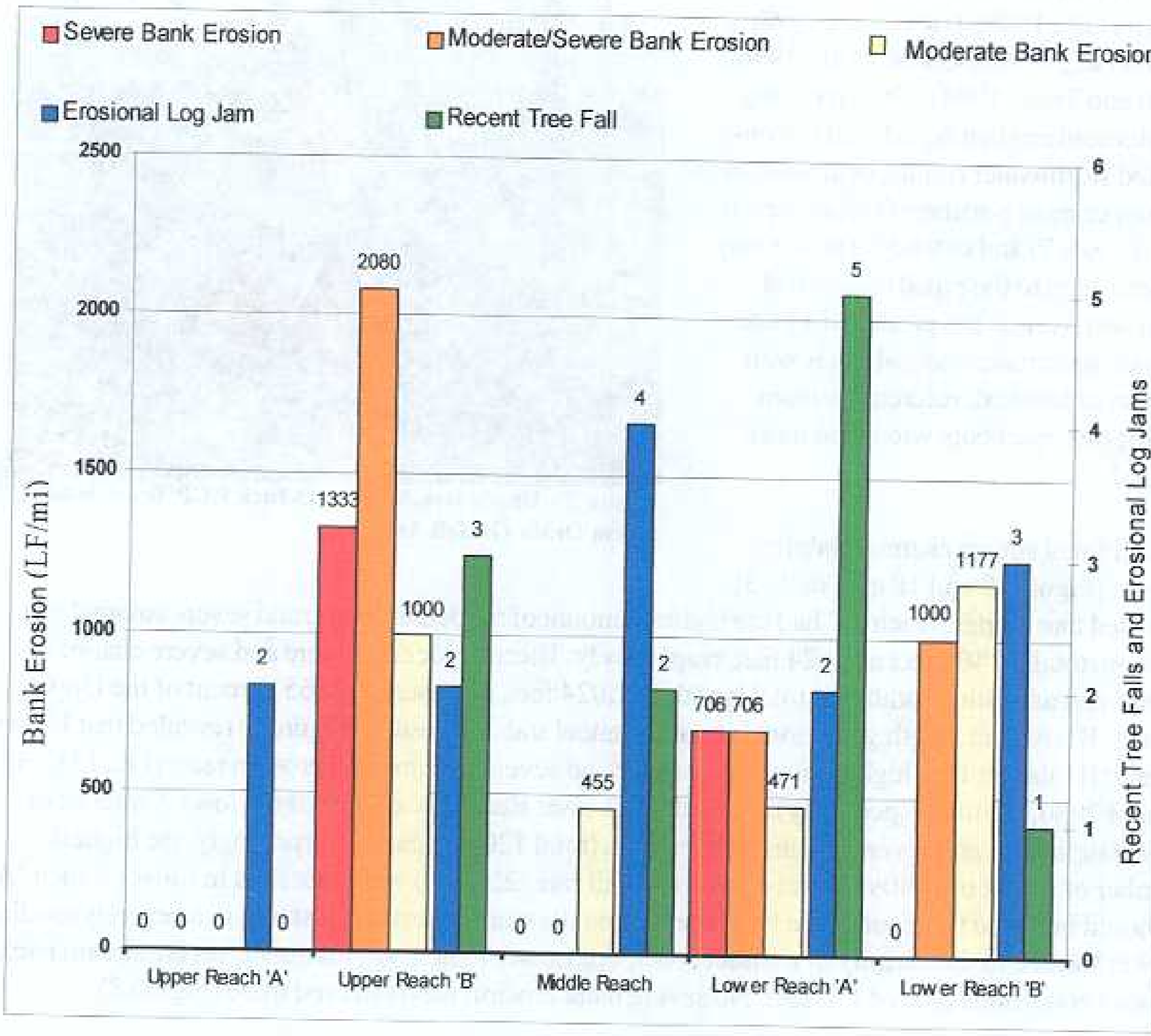
Additional stream channel stability results (Figures 8 and 10 and Table 3) revealed that Upper Reach 'B' had the highest amount of moderate/severe and severe stream bank erosion, totaling 400 feet and 624 feet, respectively. These moderate/severe and severe channel erosion areas, with a combined total length of 1,024 feet, represent over 65 percent of the Upper Reach 'B' channel length. Additional stream channel stability results (Figure 8) revealed that Upper Reach 'B' also had the highest moderate/severe and severe stream bank erosion rates (i.e., 1333.3 lf/mi and 2080.0 lf/mi, respectively). In contrast, Lower Reach 'A' exhibited the lowest amount of moderate/severe and severe stream bank erosion (total 120 feet each). Surprisingly, the highest number of recent tree falls (5) and related tree fall rate (25.0/mi) were recorded in Lower Reach 'A'. It should be noted that four of the five recent tree falls were observed clustered in a severely eroding pocket located in the vicinity of transect X-23. For Lower Reach 'B', moderate/severe stream bank erosion conditions totaled 170 feet. No severe bank erosion was observed there (Figure 8).

In summary, Pope Branch moderate, moderate/severe and severe stream bank erosion conditions totaled 780, 914, and 520 linear feet, respectively (Figure 9 and Table 3). This total represents approximately 33.0 percent of the Pope Branch stream channel length. The total number of recent tree falls observed was 11 and the associated rate per mile was 8.5. A total of 13 erosional log jams were also recorded. The preceding results indicate that the majority of the Pope Branch stream channel network is actively eroding.

3.1.3 Stream Bank Stability and Relative Erodibility

Both stream bank and soil texture survey data were examined to provide a reconnaissance-level assessment of mean stream bank stability and relative erodibility of existing bank materials. As seen in Figure 10, mean stream bank stability ranged from a low of 57 percent (Upper Reach 'B') to a high of 94 percent (Upper Reach 'A'). Both Upper Reach 'B' (57 percent) and Lower Reach 'B' (67 percent) were rated as having fair overall bank stability. Based on soil texture survey results, relative

Figure 8 - Pope Branch Stream Channel Erosion-Related Conditions[1]



[1] Actual numbers appear above each bar for recent tree falls and erosional log jams. lf/mi. rate shown above each bar for severe and moderate stream bank erosion.

Figure 9 - Pope Branch - Moderate, Moderate/Severe and Severe Stream Bank Erosion Areas

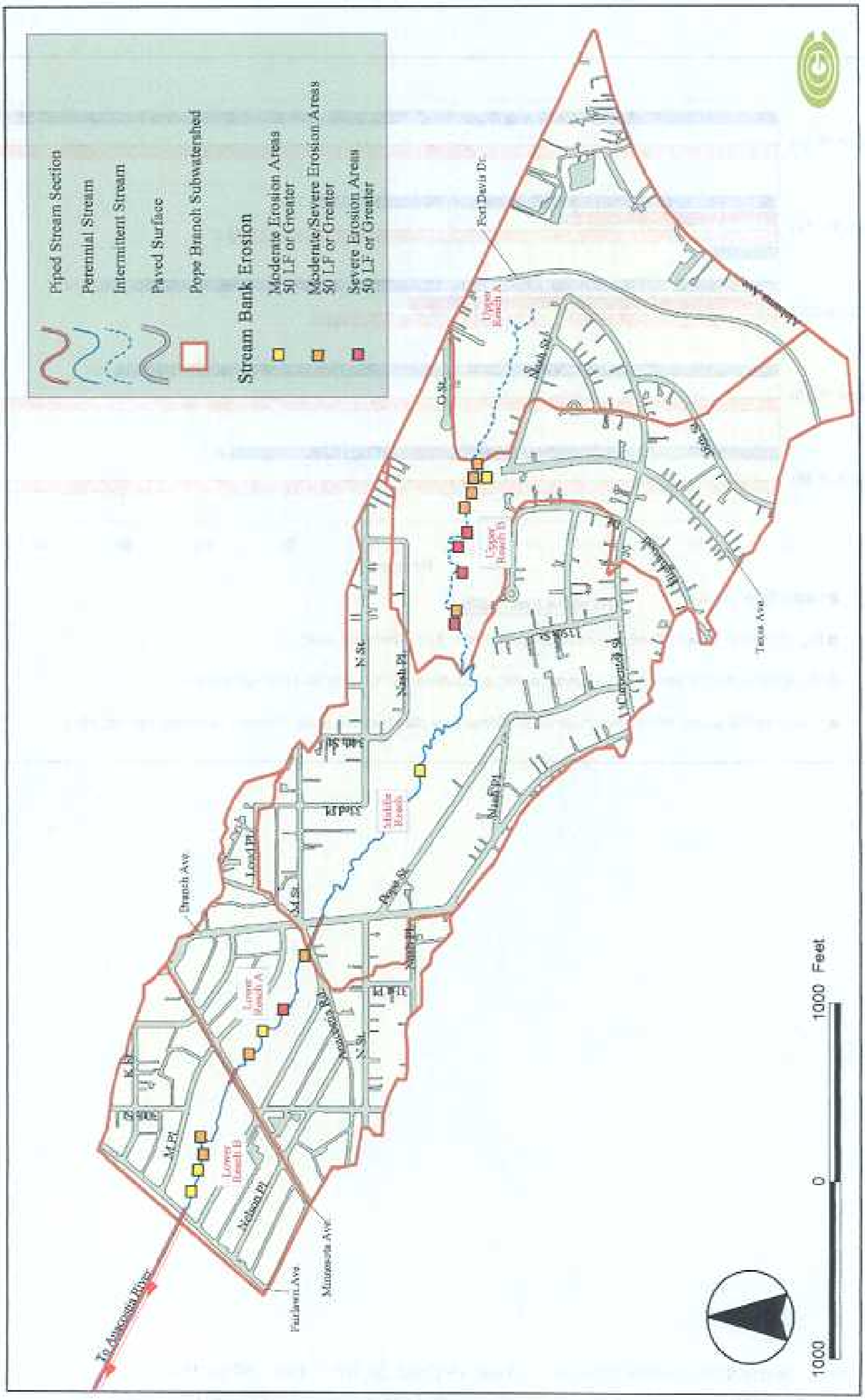
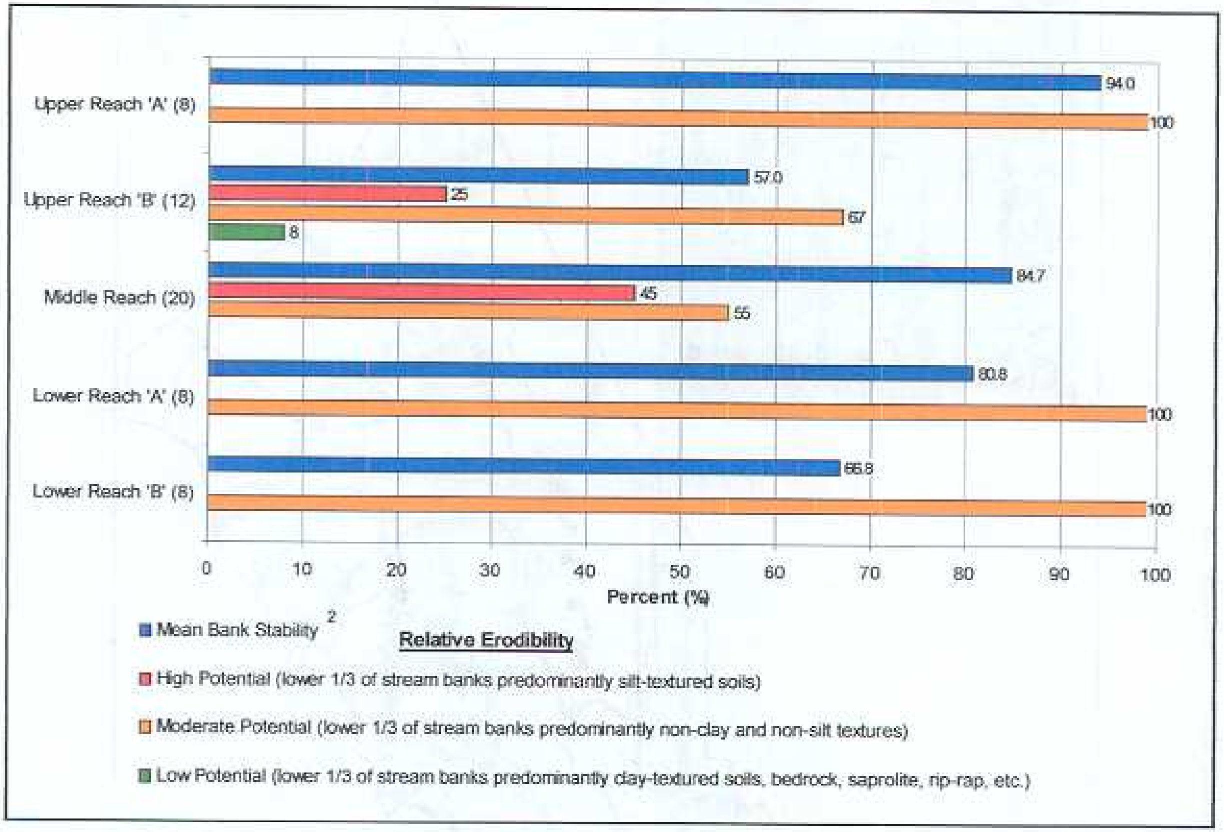


Figure 10 - Summary - Pope Branch Mean Stream Bank Stability and Relative Erodibility (%)[1]



[1] Mean bank stability interpretation: >80% = Excellent, 71-80% = Good, 50-70% = Fair, <50% = Poor
[2] Total number of observations to determine average bank stability and relative erodibility appear in parentheses

stream bank erodibility was rated as follows: 1) moderate in Upper Reach 'A' and Lower Reach 'A' and 'B' and 2) moderate/high in Upper Reach 'B' and Middle Reach.

3.1.4 Major Stream Channel Downcutting

Stream channel downcutting results (Table 5) revealed that Upper Reach 'A', Middle Reach and the two lower reaches fell either within or very close to the expected or reference condition stream bank height range. Conversely, mean bank heights for Upper Reach 'B' (average of 3.5 feet) were approximately 1.5 feet higher than expected. Also, as seen in Table 5, a total of seven nick points and seven exposed sewer lines were observed within the upper channel network. Five of these nick points were located within the Upper Reach 'A' area (i.e., the most stable section of Pope Branch). The vertical drops associated with these nick points ranged from 1.1 to 4.0 feet. Included within the Upper Reach 'B' channel is a major three-foot high nick point/debris jam located immediately downstream of the 'O' street 33-inch RCP storm drain outfall. All seven exposed sewer lines are located in this stream section (Figure 11). It should be noted that where a sewer line crosses a stream, the pipe is typically laid three to four feet below the invert of the streambed. Other findings are as follows: 1) approximately 22.0 percent of the Pope Branch channel network is moderately incised (i.e., bank heights 1.0-2.0 feet higher than the RSAT expected range), and 2) roughly 78.0 percent of the stream has experienced nominal degradation of its streambed (i.e., bank heights of 0.0 – 0.9 feet higher than the RSAT expected range).

Figure 11 - Upper Reach 'B' - Undermined Sewer Line Support Pillars

Table 4 - Summary: Pope Branch - Stream Bank Erosion Conditions

RSAT Stream Segment	Segment Length (mi.)	Bank Erosion Conditions						No. of Recent Tree Falls [1]		No. of Erosional Log Jams	Mean Bank Stability [2] (%)
		Severe		Mod/Severe		Moderate		No.	No./mi		
		(LF)	(LF/mi.)	(LF)	(LF/mi.)	(LF)	(LF/mi.)				
Upper											
Reach 'A'	0.21	0	0.0	0	0.0	0	0.0	0	0	2	94.0
Reach 'B'	0.30	400	1,333.3	624	2,080.0	300	1000.0	3	10.0	2	56.9
Subtotal	0.51	400	784.3	624	1,223.5	300	588.2	3	6.0	4	69.3[3]
Middle											
	0.44	0	0.0	0	0.0	200	454.5	2	5.0	4	84.3
Lower											
Reach 'A'	0.17	120	705.9	120	705.9	80	470.6	5	25.0	2	78.8
Reach 'B'	0.17	0	0.0	170	1,000.0	200	1176.5	1	11.0	3	73.3
Subtotal	0.34	120	352.9	290	852.9	280	823.5	6	15.0	5	76.0
Total	1.29	520	403.1	914	708.5	780	604.7	11	8.5	13	76.3[3]

[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.
[3] Weighted Mean.

Table 5 - Summary: Pope Branch - Stream Channel Downcutting[1]

RSAT Stream Segment	Drainage Area (ac)	Segment Length (ft)	Mean Bank Height Right [2] (ft)	Mean Bank Height Left [3] (ft)	Mean Bank Height (ft)	Expected Bank Height Range (ft)	Number of Nick Points	Number of Exposed Sewer Lines Within The Stream Channel
Upper								
Reach 'A'	54.3	1,129.5	1.7	1.9	1.8	1-2	5	0
Reach 'B'	54.1	1,557.9	3.2	3.8	3.5	1-2	2	7
Subtotal	108.4	2,687.4	2.7	3.2	3.0	1-2	0	7
Middle								
	78.8	2,330.3	3.5	3.3	3.4	2-3	0	3
Lower								
Reach 'A'	35.9	922.0	3.4	2.8	3.1	2-3	0	0
Reach 'B'	25.4	880.4	2.8	2.5	2.7	2-3	0	0
Subtotal	61.3	1,802.4	3.1[4]	2.7[4]	2.9[4]	-	0	0
Total	248.5	6,820.1	3.1[4]	3.1[4]	3.1[4]	-	7	10

[1] RSAT survey not conducted for Tributary No.1 and 3 due to dry riffle areas observed during study period.
[2] Right bank looking downstream.
[3] Left bank looking downstream.
[4] Weighted mean.

3.1.5 Channel Scouring and Sediment Deposition

As seen in Table 6, the Middle Reach recorded the highest total number of large unstable point bars (9). Lower Reach 'A' and 'B' totaled four and three unstable point bars, respectively. However, large unstable points bars presented as number per mile indicated that this rate is relatively constant, with 20.5 for the Middle Reach area, 23.5 for Lower Reach 'A' and 17.6 for Lower Reach 'B'. It is also worth noting that mean embeddedness levels (Figure 12) were rated as being in the fair range throughout. As a general trend, embeddedness increased heading downstream. Embeddedness levels ranged from a low of 54 percent (Middle Reach) to a high of 71.5 percent (Lower Reach 'A').

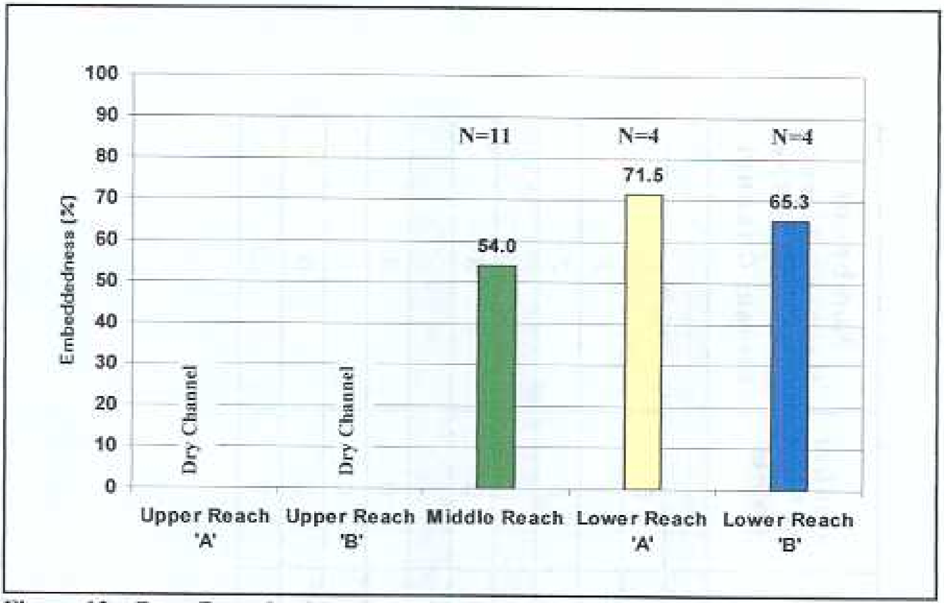


Figure 12 - Pope Branch - Mean Riffle Embeddedness Levels[1] (%)

It should be noted that during the study period, Upper Reach 'A' and 'B' channel areas were dry and therefore channel scouring/sediment deposition conditions were not fully assessed. However, the relative level of in-channel sand deposits were noted for all five study reaches (Table 6). Not surprisingly, Upper Reach 'B' was rated as having high amounts of sand deposited within its channel (Table 6 and Figure 13). This finding is consistent with earlier observations which generally indicated that, vis-à-vis the other four Pope Branch reaches, this section is experiencing higher levels of stream channel erosion.

Figure 13 - Upper Reach 'B' - Bank Erosion Contributing to High In-Channel Sand Deposition

[1] General Embeddedness Interpretation 0-24% = Excellent, 25-50% = Good; 51-75% = Fair; >76% = Poor.

Table 6 - Summary: Pope Branch - Channel Scouring/Sediment Deposition Conditions

RSAT Stream Segment	Segment Length		Percent Riffle Embeddedness			Large Point Bars			Relative Level of In-Channel Sand Deposits
	(ft)	(Mi)	Observed Range	Mean	Total Number Observed	No. Unstable	Percent Unstable (%)	No. of Unstable/Mi.	
Upper									
Reach 'A'	1,129.5	0.21	DRY CHANNEL						Low
Reach 'B'	1,557.9	0.30							High
Subtotal	2,687.4	0.51							-
Middle									
	2,330.3	0.44	40-80	54.0	29	9	31	20.5	Low
Lower									
Reach 'A'	922.0	0.17	43-90	71.5	8	4	50	23.5	Low/Moderate
Reach 'B'	880.4	0.17	49-72	65.3	5	3	60	17.6	Low/Moderate
Subtotal	1,802.4	0.34	-	-	13	7	54	20.6	-
Total	6,820.1	1.29	-	-	42	16	38	12.4	-

In summary, the high level of in-channel sand deposition indicates that there is a relatively high sandy sediment load source in Upper Reach 'B'. Furthermore, the lower level of in-channel sand deposition and embeddedness in the Middle Reach, suggests that this section transports its sandy sediment load more efficiently than the other surveyed reaches. Results also indicated that this sediment is more likely to be deposited in downstream reaches, where stream gradient is lower.

3.2 Physical Aquatic Habitat

General physical aquatic habitat conditions for Pope Branch are summarized in both Table 7 and in Figure 14. As seen in Table 7, overall RSAT aquatic habitat scores for Pope Branch fell within the fair range. Major contributing factors for the fair ratings included sub-optimal riffle substrate quality, moderate embeddedness levels, a shallow depth of flow in the riffle areas, and the presence of numerous fish barriers. As previously stated, physical aquatic habitat assessments for Upper Reach 'A' and 'B' were not performed due to the dry channel conditions.

As seen in Figure 14, overall riffle substrate quality remained relatively equal throughout (i.e., fair range); whereas pool quality was marginally better in the Middle Reach.

Figure 14 - Pope Branch Mean Riffle Substrate[1] and Pool Quality[2] Scores

[1] Riffle substrate quality point scale interpretation: 3.25-4.00 = Excellent, 2.50-3.24 = Good, 1.75-2.49 = Fair, 1.00-1.74 = Poor.
[2] Pool quality point interpretation: 4.5-5.0 = Excellent, 4.0-4.4 = Very Good, 3.0-3.9 = Good, 2.0-2.9 = Fair, 1.0-1.9 = Poor.

Table 7 - Summary: Pope Branches - General Physical Aquatic Habitat Conditions [1]

RSAT Stream Segment	Riffle Characteristics:				Pool Characteristics:					Fish Barriers		RSAT Physical Habitat Score (pts.)
	No. of Riffles	Mean Riffle Depth (in.)	Mean Riffle Substrate Quality (pts.)	Mean Riffle Embeddedness (%)	No. of Pools	Mean Max. Depth (in.)	Mean Pool Quality (pts.)	Number of Quality Pools	Riffle/Pool Ratio	Total No.	Per mile	
Upper												
Reach 'A'	DRY CHANNEL									5	23	-
Reach 'B'										4	14	-
Subtotal										9	18	-
Middle												
	27	1.2	2.3	54.0	26	20.2	3.0	6	1.0	2	5	4
Lower												
Reach 'A'	11	1.2	2.0	71.5	4	18.7	2.0	2	2.8	1	6	3
Reach 'B'	10	1.2	2.0	65.3	4	27.4	2.0	4	2.5	2	12	3
Subtotal	21	1.2	-	68.4	8	23.0	2.0	6	-	3	9	-
Total	48	1.2	-	63.6	34	22.1	2.3	12	-	14	11	-

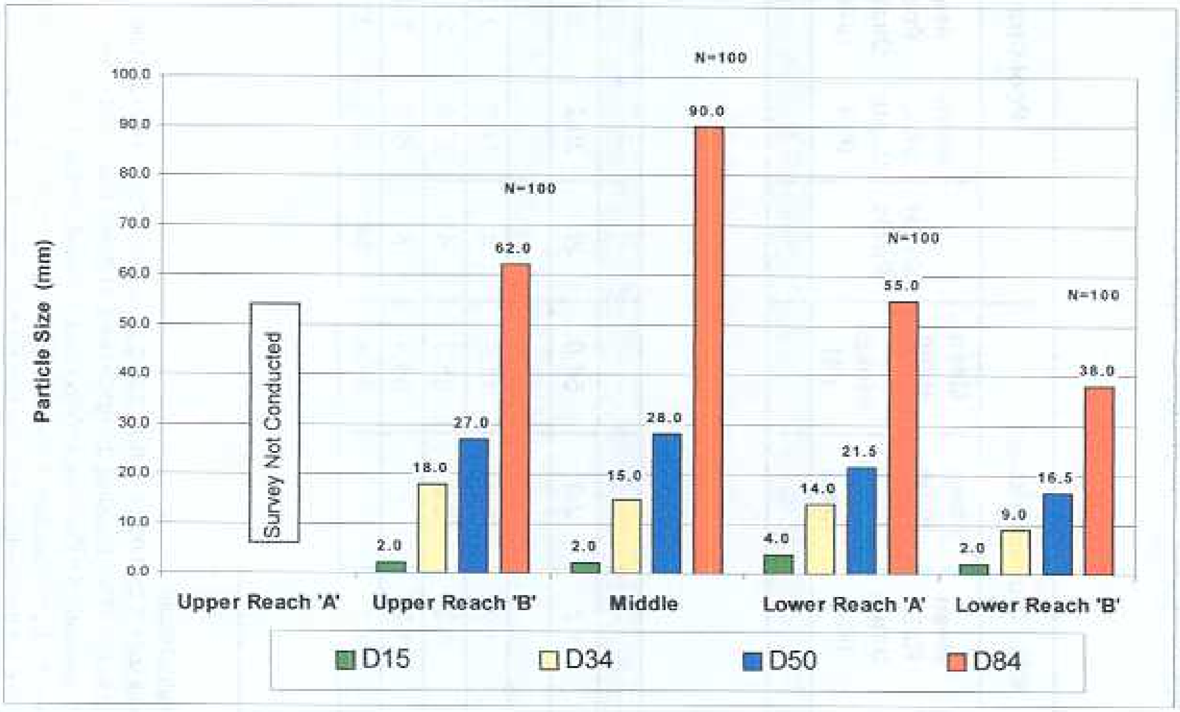
[1] Mean values shown are weighted means.
[2] Riffle substrate quality rating scale: 3.25-4.00 = Excellent, 2.50-3.24 = Good, 1.75 – 2.49 = Fair, 1.00- 1.74 = Poor.
[3] Riffle embeddedness rating scale: <25% = Excellent, 25-50% = Good, 51-75% = Fair, >75% = Poor.
[4] Quality pool point scale interpretation: 5 = Excellent, 4 = Very Good, 3 = Good, 2 = Fair, 1 = Poor.
[5] Riffle/pool ratio rating scale: 0.9-1.1:1 = Excellent, 0.70-0.89:1 or 1.11-1.3:1 = Good, 0.5-0.69 or 1.31-1.5:1 = Fair, 0.49:1≤ or ≥1.51:1 = Poor.
[6] Physical habitat rating scale: 6.5-8.0 = Excellent, 4.5-6.4 = Good, 2.5-4.4 = Fair, 1.0-2.4 = Poor.

Other relevant findings area as follows: 1) a total of 12 pools (35 percent) were rated good or better with six located in both the Middle Reach and Lower Reach 'A' and 'B' areas; 2) the deepest pool, located immediately below Minnesota Avenue (Figure 15), had a maximum depth of 42 inches. Owing to the severity of the drought, this pool probably measured one to two inches shallower than under more normal baseflow conditions; and 3) the majority of the pools surveyed featured woody debris of varying sizes with large amounts of highly unstable sandy material.

Figure 15 - Lower Reach 'B' - High Quality Deep Pool Below Minnesota Ave.

Pebble count results (Figure 16) indicated that the median (i.e., D-50) Pope Branch particle size is coarse gravel (i.e., 16.00-31.99 mm). In addition, the D-84 sized particle in all four surveyed reaches was very coarse gravel to small cobble (i.e., 32.00-127.99 mm). The

Figure 16 - Pope Branch - Substrate Particle Size Distribution[1] - D15, D34, D50, and D84 (N=100)



1

Substrate Class (AGI, 1982)	Very Fine Sand	Coarse Sand	Very Coarse Sand	Very Fine Gravel	Medium Gravel	Coarse Gravel	Very Coarse Gravel	Small Cobble	Large Cobble	Boulder	Bedrock
Size Range (mm)	0.06 – 0.13	1.00 – 1.31	1.01– 1.99	2.00 – 7.99	8.00 – 15.99	16.00 – 31.99	32.00 – 63.99	64.00 – 127.99	128.00 – 255.99	256.00 – 4095.99	>= 4096.00

preceding findings confirm that the Pope Branch streambed is made up of predominantly gravel-sized material with small cobble in the Middle Reach and predominantly gravel-sized material within the lower reaches. Typically, gravel-sized material with small diameters and round shapes is inherently unstable and prone to rolling during stormflows. This is particularly so in both Lower Reach areas, where D-15, D-50 and D-84 sized particles were the smallest surveyed.

3.2.1 Fish Blockages

A total of 14 fish blockages were identified during the RSAT survey. Of these, 13 were classified by COG staff as being complete barriers, with the remaining one classified as being a partial blockage. It should be noted that nine complete blockages were recorded for the Upper Reach 'A' and 'B' areas, where stream flow during the study period was characterized as being intermittent. A brief description of each blockage is provided in Table 8. In addition, the general location of each barrier is shown in Figure 18.

In summary, seven (50 percent) of the observed fish barriers were associated with nick points. Three (21 percent) of the barriers were associated with concrete sewer lines. Two (14 percent) of the blockages were associated with perched road culverts at Minnesota and Branch Avenues, with each one featuring one to four foot drops, respectively. As depicted in Figure 17, the complete fish blockage at Minnesota Avenue culvert channel has a shallow depth of flow (i.e., roughly 1.0 inch deep) that terminates in an 18.0-inch drop. Without question, the single largest barrier to fish movement and migration within Pope Branch is the 1,385 foot long piped stream section downstream of Fairlawn Avenue (Figure 18, Site No. 14). As previously stated, this blockage precludes, with the lone exception of the American eel (*Anguilla rostrata*), the exchange of fish species between river and stream.[10]

Figure 17 - Lower Reach 'B' - Complete Fish Barrier - 18.0-Inch Drop At Minnesota Avenue Culvert

[10] American eels (particularly young elvers) are renowned for their ability to temporarily leave the water and slither over moist terrain when migrating up streams.

Table 8 - Summary: Pope Branch - Existing Fish Blockages

RSAT Stream Segment	Fish Blockage Type	Blockage Height(ft)	Description	Location					
				Latitude			Longitude		
				Deg.	Min.	Sec.	Deg.	Min.	Sec.
Upper									
Reach 'A'									
1.	Complete	4.0	Natural Rock Cataract Area approx. 100' above X-1	76	56	58.92	38	52	19.60
2.	Complete	3.2	Debris Jam/Nick Point approx. 100' below X-1	76	57	1.69	38	52	19.92
3.	Complete	3.2	Nick point approx. 70' below X-2	76	57	3.60	38	52	20.75
4.	Complete	1.1	Nick point approx. 150' below X-2	76	57	4.57	38	52	20.93
5.	Complete	1.6	Nick point approx. 5' below X-3	76	57	6.01	38	52	21.22
Reach 'B'									
6.	Complete	3.0	Nick point approx. 115' above X-5	76	57	8.71	38	52	22.01
7.	Complete	1.7	Concrete Sewer Line approx. 175' below X-5	76	57	11.74	38	52	22.62
8.	Complete	1.5	Concrete Sewer Line approx. 100' below X-6	76	57	13.36	38	52	23.02
9.	Complete	2.0	Natural Rock Cataract Area approx. 100' below X-8	76	57	15.84	38	52	23.34
Middle									
10.	Partial	0.5	Nick point/debris jam approx. 25' below X-16	76	57	27.40	38	52	24.64
11.	Complete	2.0	Concrete Sewer Line @ 175' below X-20	76	57	34.78	38	52	28.85
Lower									
Reach 'A'									
12.	Complete	4.0	Collapsed culvert with a 4.0' drop @ the downstream end of the Branch Avenue 337 foot long, concrete arch culvert (originally 8' wide)	76	57	42.19	38	52	32.16
Reach 'B'									
13.	Complete	1.0	1.5 drop @ the downstream end of the Minnesota Avenue 8' wide, concrete arch culvert/shallow depth of flow (<0.1') within culvert	76	57	51.80	38	52	36.70
14.	Complete	0.5	0.5' drop down into a 7.5' wide, approx.1,385' long pipe culvert	76	57	59.90	38	52	38.89

[1] Two types of physical fish barriers are noted: 1) partial barriers, defined as any obstruction which would likely prohibit or impede normal upstream-downstream fish movement during certain times of the year (e.g., low summer baseflow conditions); and 2) complete barriers, described as obstructions which totally prevent the normal movement of fish throughout the year (e.g., a perched culvert which features a three-foot-high vertical drop).

Note: numbers in column one correspond to Figure 17 (Fish Blockages).

Figure 18 - Pope Branch - Fish Blockages[1]

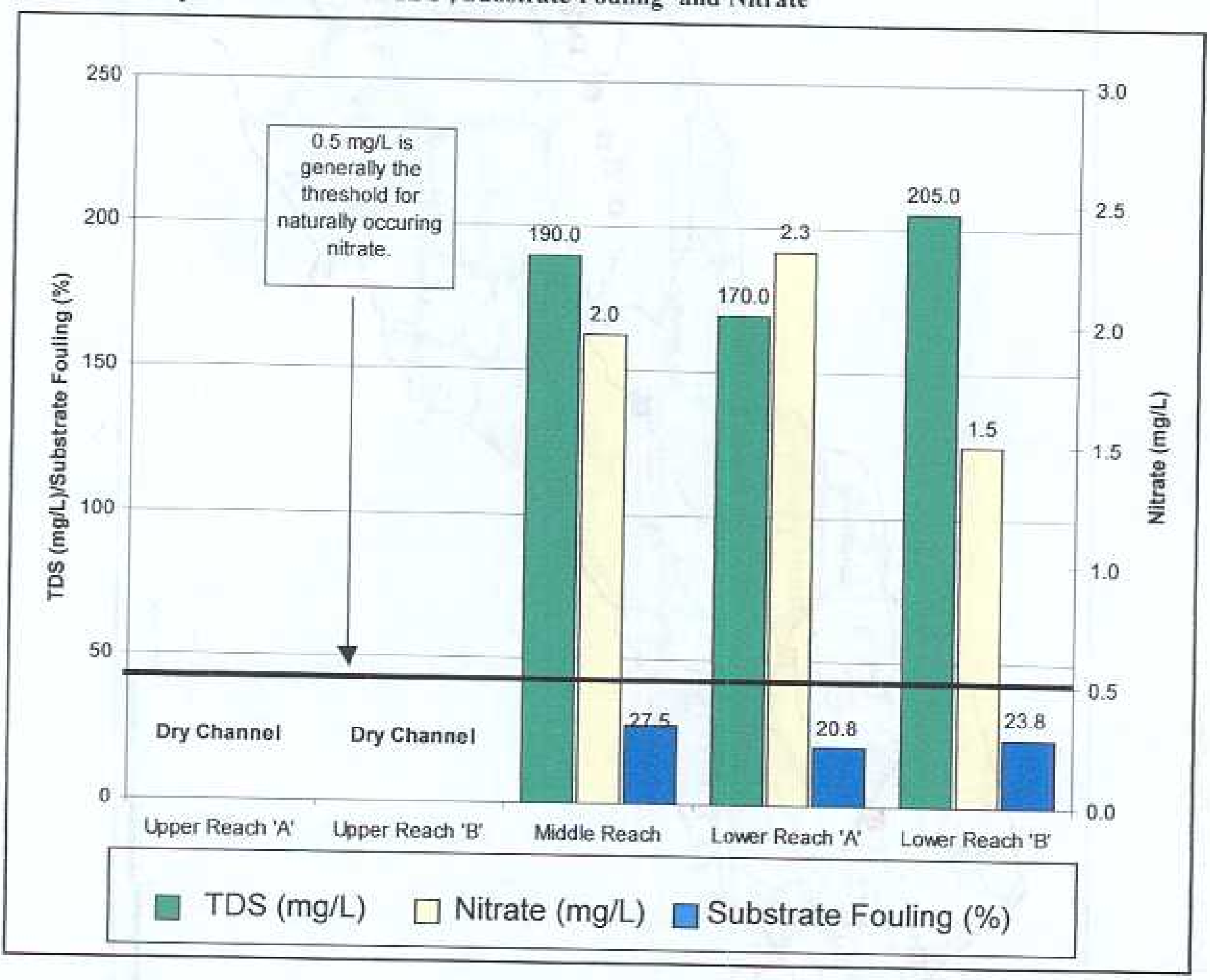
[1] Numbers next to fish blockages correspond to Table 8.

3.2 *RSAT Water Quality*

As part of the RSAT survey, baseflow grab sampling was conducted once to provide a snap-shot of water quality conditions in Pope Branch. Generally, the following 13 parameters were measured, at the top and bottom of each survey reach: air temperature, water temperature, dissolved oxygen (DO), pH, conductivity, turbidity, total dissolved solids (TDS), water color and odor, substrate fouling, nitrate-nitrogen (NO_3-), orthophosphate and fluoride (F-). Of the preceding 12 water quality parameters, TDS, nitrate and substrate fouling were selected for stream reach comparisons. Results are summarized in Figure 19 and Appendix 6.

As seen in Figure 19, TDS levels in all three stream reaches surveyed were in the poor range (i.e., >=150 mg/l). Furthermore, TDS levels were fairly consistent throughout, with the Middle Reach measuring 190 mg/l, decreasing slightly to 170 mg/l in Lower Reach 'A' and finally increasing to 205 mg/l in Lower Reach 'B'.

Figure 19 - Pope Branch - Mean TDS[1], Substrate Fouling[2] and Nitrate[3]



[1] TDS interpretation: <50 mg/L = Excellent, 50-100 mg/L = Good, 101-150 mg/L = Fair, >150 mg/L = Poor.
[2] Substrate fouling interpretation: 0-10% = Excellent, 11-20% = Good, 21-50% = Fair, >50% = Poor.
[3] Nitrate interpretation: 0.0-1.0 mg/L = Low, 1.1-2.9 mg/L = Moderate, >3.0 mg/L = High.

With regard to nitrate levels, all were in the moderate range (i.e., 1.1-2.9 mg/l). While no major difference was observed between the Middle and Lower Reach 'A' areas (i.e., nitrate levels of 2.0 and 2.3 mg/l, respectively), the nitrate concentration decreased to 1.5 mg/l in Lower Reach 'B'. Substrate fouling levels were rated as being in the fair range in all three stream reaches (i.e., 21-51 percent of the bottom side of cobble-sized stones were covered by an organic film). As seen in Figure 19, substrate fouling levels for all three sites were comparable and ranged from a low of 20.8 percent (Lower Reach 'A') to a high of 27.5 percent (Middle Reach).

Figure 20 - Upper Reach 'A' - Sewer Line Leak Near 35th Street (January 2001)

The preceding results suggest low to moderate levels of organic loading/ nutrient enrichment throughout Pope Branch. It should also be noted that spot fluoride readings revealed that both the Middle Reach and Lower Reach 'A' and 'B' areas periodically exceeded 0.3 mg/l (Appendix 6, Table 3). The highest fluoride reading (0.7 mg/l) occurred on August 2, 2002 in Lower Reach 'B'. Typically, natural background levels for fluoride in local surface waters are approximately 0.1 – 0.2 mg/l or less (Hannon, 1996; Thomas, 1966; Woll 1978; Otten and Hilleary, 1985), whereas concentrations of 0.3 mg/l or greater suggest the possible influence of either treated drinking water[11] or sewage.

Other water quality problem-related conditions that COG staff observed during the study period were as follows: 1) an active 12-inch sewer line leak (Upper Reach 'B' area) from January 2001 through April 2002 (Figure 20). Note: the problem was reported to DCWASA in January 2001 and repair was completed in April 2002) 2) extremely turbid water, related to construction activities, discharged from the Texas Avenue storm drain outfall on January 16, 2003 and 3) discharge of home heating oil via the 35th Street storm drain outfall and present downstream throughout Pope Branch on January 31, 2003.

3.4 Riparian Habitat Conditions

As previously stated, forestland within the Pope Branch subwatershed decreased in a downstream direction. Similarly, the forested riparian buffer zone also narrowed dramatically in a downstream direction. RSAT results (Table 9) revealed that Pope Branch riparian habitat conditions ranged from fair for Lower Reach 'A' and 'B' to good to excellent for the Upper and Middle Reach areas. As seen in Table 9, mean overall Pope Branch canopy coverage1[2] was rated as being excellent in both Upper

[11] Typically, fluoridated drinking water contains 0.4 to 0.5 mg/l of fluoride.

[12] Canopy coverage percentages are based on visual estimates.

Reach 'A' and 'B' and the Middle Reach. It too decreased, once again, in a downstream fashion to the good range in both Lower Reach 'A' and 'B'. Major canopy gaps in the Lower Reach 'A' and 'B' riparian buffers were generally associated with mowed areas. It should be noted that these mowed areas also contained a sprinkling of taller, old trees (i.e., along "M" place, X-28 through X-29).

With the exception of the Upper Reach 'A' left hand bank areas (i.e. left looking downstream), the Upper and Middle Reach riparian corridors were typically wide and heavily forested. As seen in Figure 21, a mature deciduous hardwood forest, with a laurel shrub understory was the dominant vegetative community in this portion of the stream valley. On average, the right bank riparian buffer width (181 feet) was considerably wider than that of the left bank (120 feet). In fact, 21 out of the 30 RSAT transect station sites (70 percent) featured forested riparian buffers 200 feet wide or greater for the right bank versus only 6 out of 30 (20 percent) for the left bank. It should be noted that along much of the left bank heading downstream, residential properties were frequently encroaching into the riparian buffer. Unfortunately, several of these areas included the illegal dumping of bulk trash items (i.e., mattresses, old sheds, couches, water heaters, etc.,) as well as the presence of non-native invasive plants such as English Ivy.

Figure 21 - Upper Reach 'A' and 'B' - Mature Hardwood Forest With Laurel Understory

Table 9 - Summary: Pope Branch – Upper, Middle and Lower Riparian Habitat Conditions

RSAT Stream Segment	Segment Length (mi.)	Number of Observations	Mean Canopy Coverage (%) [1]	Riparian Habitat Condition	
				RSAT Score [2]	Verbal Ranking
Upper					
Reach 'A'	0.21	6	90.2	4	Good
Reach 'B'	0.30	7	83.3	6	Excellent
Subtotal	0.51	13	86.1	5.5[3]	-
Middle					
	0.44	17	91.6	5	Good
Lower					
Reach 'A'	0.17	11	79.2	3	Fair
Reach 'B'	0.17	9	74.4	3	Fair
Subtotal	0.34	20	77.1	3	-
Total	1.29	50	84.4	4.4[3]	-

[1] Mean canopy coverage interpretations: > 80% = Excellent, 60-79% = Good, 50-59% = Fair, <50% = Poor.
[2] Point Score Interpretation: 6.0-7.0 = Excellent, 4.0-5.9 = Good, 2.0-3.9 = Fair, 0-1.9 = Poor.
[3] Weighted Mean

3.5 *Biological Condition – Benthic Macroinvertebrate Biosurvey*

3.5.1 Background

Macroinvertebrates are generally defined as animals without backbones that are large enough to be retained on a U.S. Standard No. 30 sieve (0.595 micron mesh openings). Benthic macroinvertebrates have long been used for biological monitoring purposes because they are a ubiquitous diverse group of sedentary and relatively long-lived species, which often respond predictably to human watershed perturbations. Importantly, a stream's biological community normally responds to and is reflective of prevailing water quality and physical habitat conditions. As part of the RSAT evaluation, an in-depth biosurvey of the stream's macroinvertebrate community was performed using both the RSAT voucher collection and more quantitative 20 jab samples from an approximately $2m^2$ streambed area. The purpose of the biosurvey was two-fold: 1) to characterize macroinvertebrate community composition and the relative abundance of major representative taxonomic groups, and 2) to quantify, through the employment of a suite of metrics, general stream quality/level of impairment. As previously described, the RSAT Level III RSAT voucher collection protocol employed in the study involved turning over 10 cobble-sized stones (or larger) and taking a combination of two one-square-foot kick and two one-square-foot jab samples per transect from representative riffle, run and pool habitat areas. Representative macroinvertebrate organisms collected at each transect were first identified in the field to family level and then composited and placed into an RSAT voucher for each individual stream segment. The D-nets used for the biosurvey featured 600-micron mesh.

In addition, companion spring 20 jab multiple-habitat sampling was performed at the following three sites:

- Middle Reach (X-13 area),
- Lower Reach 'A' (X-23 area), and
- Lower Reach 'B' (X-29 area).

The preceding 20-jab macroinvertebrate collection work was conducted for both spring (March 2002) and fall (November 2002) seasons. It should be noted that at each 20 jab sampling location, macroinvertebrates were similarly collected from multiple habitats (via a D-net) using both kick and jab techniques. All 20 jab samples and RSAT voucher collection samples were identified in the laboratory, to the lowest taxonomic level, by COG staff using a 60x stereoscope. As previously indicated, the following seven metric calculations were performed for each 20-jab sample: 1) taxa richness, 2) total number of EPT taxa, 3) percent Ephemeroptera, 4) percent Tanytarsini, 5) Beck's Biotic Index, 6) number of scraper taxa and 7) percent clingers. These seven metrics were employed for calculating the MBSS Coastal Plain macroinvertebrate index of biological integrity (IBI). IBI scores were used to help characterize existing biological community conditions, as well as to provide a basis for comparing different stream reaches. Finally, it is recommended that MBSS IBI scores for Pope Branch stream sites where the total number of organisms collected was less than 80 should be viewed with caution.

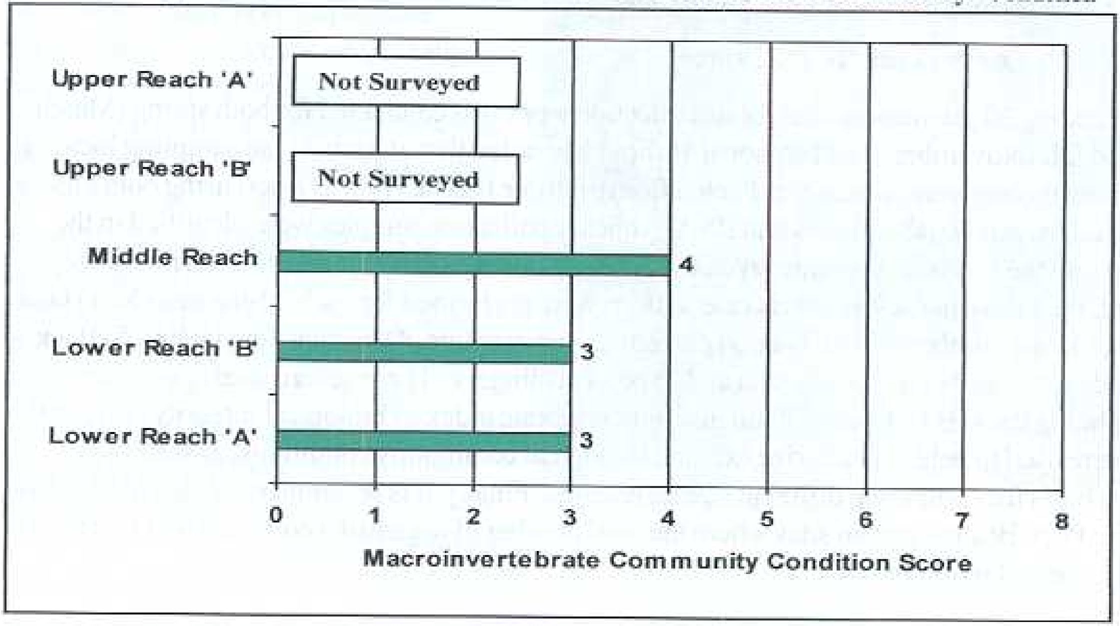
General pollution tolerance for major taxonomic groups was per Bode et al. (1991), Lenat (1993) and Stribling et al. (1998). Macroinvertebrate relative abundance categories used in the biosurvey are comparable to EPA's Rapid Bioassessment Protocol (RBP) Level I and are as follows: absent/no group found, scarce, scarce/common, common, common/abundant and abundant. Relative abundance is recorded, based on the investigator's experience and judgement, at each transect. In addition, the four generalized macroinvertebrate community condition-rating categories employed by the RSAT voucher collection are presented in Table 10. The general macroinvertebrate community condition for Pope Branch is summarized in Figure 22.

In addition, the mean relative abundance of observed macroinvertebrate taxa is presented in Figure 23. Macroinvertebrate taxa richness for both RSAT voucher and 20 jab samples are included in Table 11. For additional tributary-specific macroinvertebrate survey results, the reader is referred to Appendix 5.

Table 10 - RSAT Macroinvertebrate Community Condition

Verbal Rating Category and Representative Conditions			
Excellent	**Good**	**Fair**	**Poor**
- diverse macroinvertebrate community present, dominated by flathead mayflies, stoneflies and cased caddisflies, very few snails and/or leeches present; - moderate-high number of individuals.	- mayflies and caddisflies present (stoneflies absent, good overall diversity; - moderate-high number of individuals.	- pollution-tolerant caddisflies, snails, midgeflies, aquatic worms dominant; - low-moderate number of individuals.	- poor diversity generally dominated by midgeflies, aquatic worms and snails; -depauperate population-low number of individuals.

Figure 22 - Pope Branch - RSAT Voucher Collection Macroinvertebrate Community[1] Condition



[1]Macroinvertebrate scale interpretation: 7.0-8.0 pts. = Excellent, 5.0-6.9 pts. = Good, 2.1-4.9 pts. = Fair, 0.0-2.0 pts. = Poor.

3.5.2 General RSAT Voucher Collection Findings

As seen in Figure 22, all three surveyed Pope Branch reaches were rated as having fair macroinvertebrate community conditions. Individuals from the more pollution intolerant groups (i.e., stonefly, mayfly and caddisfly) were all conspicuously absent. Only mayfly and caddisfly representatives belonging to more pollution tolerant families (i.e., Baetidae and Hydropsychidae) were collected. Overall, the number of individuals collected in Pope Branch was low. Based on the RSAT system, the relative abundances of these macroinvertebrates were rated as being generally scarce, or in a few instances, scarce/common. In fact, were it not for the fair to good taxa richness ratings, Pope Branch RSAT scores would have all been in the poor range.

As previously stated, on January 31, 2003, COG staff observed the illegal discharge of a petroleum product (i.e., home heating fuel) that entered the stream via the 35th Street storm drain outfall. Immediately downstream, COG staff observed numerous dead aquatic worms in pool areas. Although COG staff walked the entire length of Pope Branch downstream to Fairlawn Avenue, noticing the presence of heating oil throughout, there was no further evidence of dead macroinvertebrates below Branch Avenue.

3.5.3 Macroinvertebrate Relative Abundance and Taxa Richness

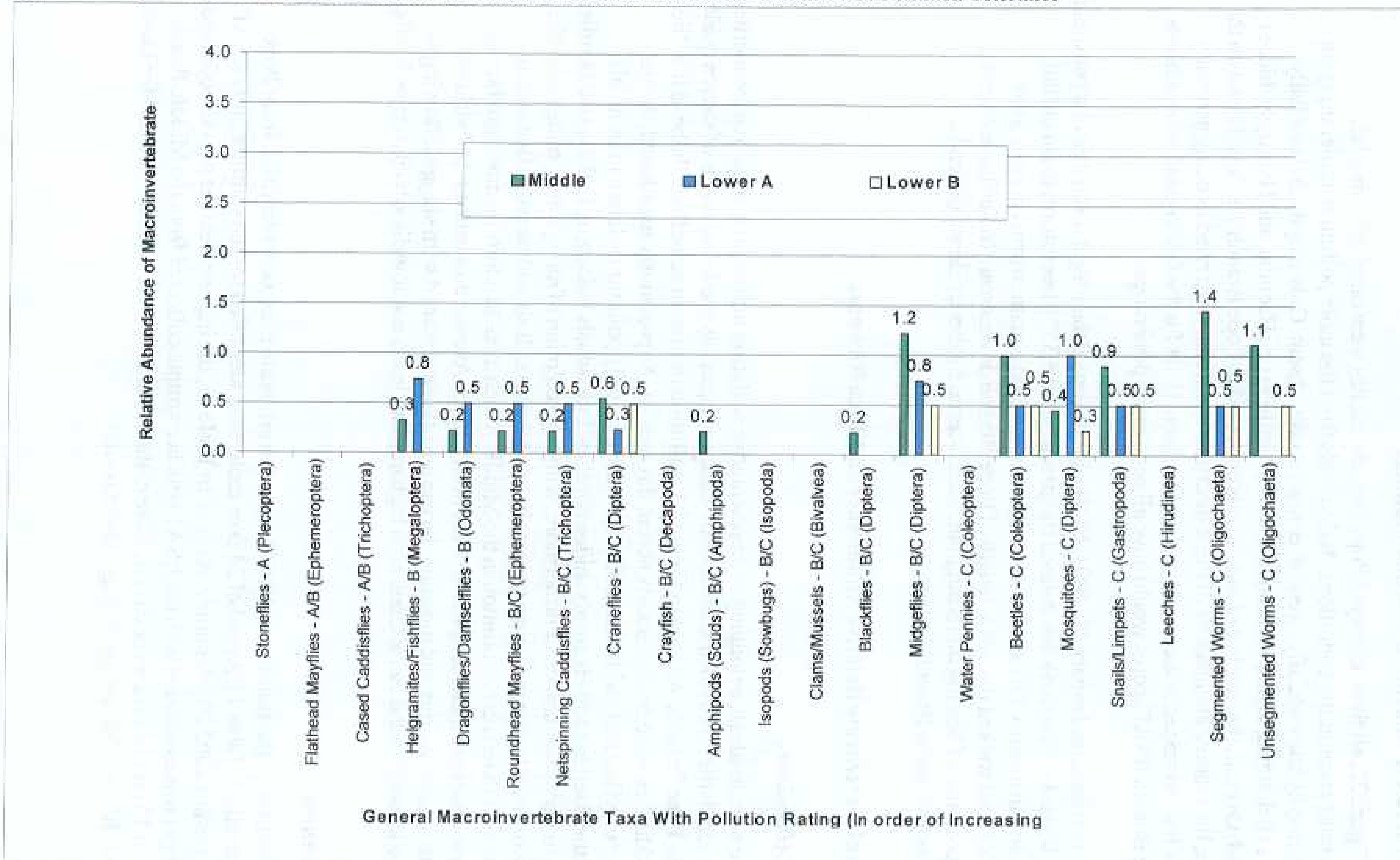
Relative Abundance

The absence of individuals belonging to representative pollution intolerant groups (e.g., stoneflies, mayflies and caddisflies) provided additional evidence of generally moderate levels of stream quality impairment in Pope Branch. As seen in Figure 23, pollution intolerant stoneflies, flathead mayflies and cased caddisflies were conspicuously absent throughout. As previously mentioned, the only representative mayflies and caddisflies collected were generally pollution tolerant individuals belonging to the Baetidae and Hydropsychidae families. Individuals belonging to these two families were present in very low numbers. Furthermore, with the exception of mosquitoes, midges, beetles and aquatic worms, all other taxa were present in low numbers. It should be noted that aquatic worms were found to be scarce/common in the Middle Reach area. In addition, mosquito larvae, *Culex sp.*, were observed increasing in numbers from Branch Avenue downstream to Fairlawn Avenue. Both aquatic worms and mosquito larvae are often associated with sluggish flowing to stagnant aquatic habitats and can tolerate both high nutrient loads and low dissolved oxygen levels.

Taxa Richness

During the course of the study, a total of 37 macroinvertebrate taxa were identified from Pope Branch (Appendix 5; Table 1). A total of 24 taxa each, were identified for the summer 2002 RSAT voucher and the fall 2002 20 jab sample. As seen in Table 11, the highest number of taxa collected (21, good range) was associated with the RSAT voucher sample collected from the Middle Reach area. A total of 13 and 16 taxa respectively, were collected in the RSAT voucher samples for Lower Reach 'A' and 'B' (i.e., fair and good range, respectively).

Figure 23 - Pope Branch - Relative Abundance of Observed Macroinvertebrates[1] and General Pollution Tolerance[2]



[1] Relative abundance scores were averaged for each mainstem reach. Relative abundance interpretation: 0.1-0.9 = Scarce, 1.0-2.0 = Scarce/Common, 2.1-3.0 = Common, 3.1-4.0 = Common/Abundant, > 4.1- 5.0 = Abundant.
[2] Pollution Tolerance Rating: A = Intolerant, B = Moderately Tolerant, C = Tolerant

Table 11 - Summary: Pope Branch Macroinvertebrate Taxa Richness, Spring and Fall 2002

RSAT Stream Segment	Sampling Date			Stream Order[1]	Number of Taxa Collected			Verbal Rating[2]		
	20 Jabs	RSAT Voucher[3]	20Jabs		20 Jabs	RSAT Voucher[3]	20 Jabs	20 Jabs	RSAT Voucher[3]	20 Jabs
	Spring	Summer	Fall		Spring	Summer	Fall	Spring	Summer	Fall
Upper Reach 'A' and 'B'	Not Surveyed									
Middle Reach	March 2002	July 2002	November 2002	1	8	21	13	Fair	Good	Fair
Lower Reach 'A'	March 2002	July 2002	November 2002	2	9	13	12	Fair	Fair	Poor
Lower Reach 'B'	March 2002	July 2002	November 2002	2	11	16	13	Fair	Good	Fair
Total	-----	-----	-----	-----	19	24	24	-----	-----	-----

3.5.4 2m^2 Sample Metrics and MBSS IBI Scores

As previously stated, the 20-jab macroinvertebrate sampling includes a more quantitative interpretative approach, featuring the employment of seven individual MBSS Coastal Plain stream metrics. Individual metric calculations were performed and used in developing the overall IBI score for each surveyed stream reach. Results are presented in Table 12. It should be noted that Fort Dupont Tributary fall 2002 20 jab sampling results were intentionally included in Table 12, so as to provide additional insight on the effects of the drought on the Pope Branch macroinvertebrate community.

As seen in Table 12, both spring and fall overall MBSS IBI scores for all three stream reaches were verbally rated as being very poor (i.e., IBI scores < 2.0). In addition, the associated verbal ratings for the individual metrics fell into either the poor or fair categories. According to Stribling et al. (1998), the general response for all seven metrics to increasing perturbation is a decrease in number, percent or score. A narrative description of stream biological integrity associated with the four IBI categories is provided in Table 13.

While, the severity of the drought greatly reduced Pope Branch baseflow, aquatic habitats such as riffle, run and pools remained (although at markedly shallower depths). Therefore, the negative impacts on the Pope Branch macroinvertebrate community were surprisingly far less severe than those observed in the neighboring Fort Dupont tributary following the summer 1999 drought (i.e., fall densities in Fort Dupont Tributary were on the order of six to seven times lower than spring samples). As seen in Table 12, fall 2002 Branch 20-jab macroinvertebrate densities were, compared to spring samples, markedly lower for both the Middle and Lower Reach 'A' areas, where the number of organisms collected decreased to 42 and 101 individuals, respectively. In contrast, densities at Lower Reach 'B' increased slightly. It should be noted that the Pope Branch macroinvertebrate

[1] Stream order based on 200-foot scale topographic map interpretation.
[2] General RSAT voucher interpretation for the number of taxa: >=25 = Excellent, 16-24 = Good, 8-15 = Fair, 0-7 = Poor.
[3] RSAT voucher protocol surveys an area of 3 m^2/mi versus 1-2 m^2/mi surveyed with the 1m^2 sample.

Table 12 - Summary: Pope Branch and Fort Dupont Tributary - Spring and Fall 2002 20-Jab Macroinvertebrate Sample Metrics and MBSS Coastal Plain IBI Scores

Site	Sampling Date	No. of Organisms/m²	Taxa Richness[1]	Total No. of EPT Taxa[2]	Percent Ephemeroptera[3] (%)	Percent Tantarsini[4] (%)	Beck's Biotic Index[5]	No. of Scraper Taxa[6]	Percent Clingers[7] (%)	MBSS IBI Score[8]	MBSS IBI Verbal Ranking
Pope Branch Spring											
Upper	3/22/2002	140	8	0	0	0	2	0	0.0	0.8	Very Poor
Middle	3/22/2002	214	9	1	0	0	4	0	9.8	1.0	Very Poor
Lower	3/22/2002	90	11	1	0	0	4	0	10.0	1.2	Very Poor
Pope Branch Fall											
Upper	11/8/2002	98	13	0	0	0	6	0	0.0	1.2	Very Poor
Middle	11/21/2002	113	12	2	0	0	7	0	16.8	1.2	Very Poor
Lower	11/8/2002	119	13	1	0	0	4	0	9.2	1.2	Very Poor
Fort Dupont Spring											
Upper	4/14/1999	40	10	1	0	0	1	0	2.5	1.0	Very Poor
Middle	4/14/1999	66	9	1	0	0	4	0	6.1	1.3	Very Poor
Lower	4/14/1999	123	10	1	0	0	2	1	0.8	1.3	Very Poor
Tributary No. 2	4/14/1999	806	12	2	0	0	5	0	1.6	1.6	Very Poor
Fort Dupont Fall											
Upper	11/22/1999	32	8	0	0	0	3	0	3.1	1.0	Very Poor
Middle	12/13/2002	84	8	0	0	0	4	0	6.0	1.0	Very Poor
Lower	11/22/1999	49	7	0	0	0	1	0	0.0	1.0	Very Poor
Tributary No. 2	12/13/2002	229	13	1	0	0	8	0	2.2	1.2	Very Poor

[1] Taxa richness represents the total number of taxa collected and is interpreted by MBSS as follows: ≥25 = Good, 11-24 = Fair, <11 = Poor.

[2] Counts the distinct taxa considered pollution intolerant within the groups of Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies). EPT taxa metrics are interpreted as follows: >6 = Good, 3 - 6 = Fair, and <3 = Poor.

[3] Measures the abundance of generally pollution intolerant Ephemeroptera (mayflies) relative to other often more tolerant individuals and is interpreted as follows: >11.4% = Good, 2.0 – 11.4% = Fair and < 2.0% = Poor.

[4] Measures the abundance of generally pollution intolerant Tanytarsini (midgeflies) relative to other more tolerant Chironomidae and is interpreted as follows: >13.0% = Good, 0.0 – 13.0% = Fair and < 0.0% = Poor.

[5] The Beck's Biotic Index is a weighed enumeration of two Class of organic pollution tolerant taxa, the most tolerant and the second most tolerant groups. The index is interpreted as follows: >12 = Good, 4.0-12.0 = Fair and <4.0 = Poor.

[6] The number of herbivorous scrapers is a metric used to reflect available food resources like periphyton and microfauna which may themselves be more abundant under conditions of minimal perturbation. This value is interpreted as follows: >4 = Good, 1-4 = Fair, <1 = Poor.

[7] Measure the organisms that are behaviorally and morphologically adapted to clinging to surfaces in fast moving riffles. Percent ratios are interpreted as follows: ≥ 62.1% = Good, 38.7 – 62.1% = Fair and <38.7% = Poor.

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

Table 13 - General IBI Score Interpretation (Stribling et al. 1998)

Verbal Ranking	IBI Score Range	General Description
Good	4.0 - 5.0	Comparable to reference streams considered to be minimally impacted. Fall within the upper 50% of reference site conditions.
Fair	3.0 - 3.9	Comparable to reference conditions, but some aspects of biological integrity may not resemble the qualities of these minimally impacted streams. Fall within the lower portion of the range of reference sites (10th to 50th percentiles).
Poor	2.0 - 2.9	Significant deviation from reference conditions, with many aspects of biological integrity not resembling the qualities of these minimally impacted streams, indicating some degradation.
Very Poor	1.0 - 2.9	Strong deviation from reference conditions, with most aspects of biological integrity not resembling the qualities of these minimally impacted streams, indicating severe degradation.

community is comprised of organisms (e.g., aquatic beetles and worms, mosquitoes, midgeflies, dragonflies, damselflies, etc.,) that can tolerate the reduced flow, elevated water temperatures and lower dissolved oxygen levels, which often accompany severe drought conditions.

The preceding MBSS metric and IBI scores generally support RSAT voucher collection findings that the overall Pope Branch macroinvertebrate community is, at a minimum, moderately impaired. It should be noted that poor water quality may be a major limiting factor. However, other factors such as streambed instability, altered water temperature regime, the discharge of toxic products, etc., are also limiting Pope Branch's aquatic community.

3.6 RSAT Summary Stream Quality Ratings

A summary breakdown of the six RSAT evaluation categories employed for evaluating overall stream quality in the Pope Branch is included as Table 14. As previously stated, due to the stream channel being dry, only a partial RSAT survey was conducted for the Upper Reach. Therefore, the

Table 14 - Pope Branch Study Summary[1]: Upper, Middle and Lower Pope Branch RSAT Ratings[2]

RSAT Stream Segment	Channel Stability	Channel Scouring/ Sediment Deposition	Physical Instream Habitat	Water Quality	Riparian Habitat Conditions	Biologica lIndicators	Overall RSAT Stream Quality Rating [3]
Upper							
Reach 'A'	Excellent (11)	NS	NS	NS	Good (5)	NS	NS
Reach 'B'	Poor (2)	NS	NS	NS	Excellent (6)	NS	NS
Middle							
Reach	Good (7)	Fair (4)	Fair (4)	Fair (3)	Good (5)	Fair (4)	Fair (27)
Lower							
Reach 'A'	Good (6)	Fair (3)	Fair (3)	Poor (2)	Fair (3)	Fair (4)	Fair (21)
Reach 'B'	Good (6)	Fair (4)	Fair (3)	Poor (2)	Fair (3)	Fair (3)	Fair (21)

[1] RSAT survey not conducted for Upper Reach A and B (as indicated by NS) due to dry riffle areas observed during study period.
[2] Actual point values are shown in parentheses.
[3] Total RSAT score interpretation: 42-50 = Excellent, 30-41 = Good, 16-29 = Poor.

following RSAT Evaluation Summary categories were not completed for this area: Channel Scouring/Deposition, Physical Instream Habitat, Water Quality, and Biological Indicators. As seen in Table 14, the Middle and Lower Reaches received fair overall stream quality ratings.

3.7 Pope Branch One-Pass Electrofishing Survey

As already noted, the planned summer 2002 mainstem electrofishing survey was not performed. During many site visits, COG staff observed no fish in the Upper or Middle reaches, and captured only one small (approximately 8 inches-long) American eel, *Anguilla rostrata*, elver in Lower Reach 'B' (Figure 24). The only other vertebrates collected from Pope Branch were larvae of the northern two-lined salamander, *Eurycea bislineata*, which were relatively scarce. The preceding results confirmed that: 1) the Pope Branch system is currently not supporting a resident fish community and 2) the 1,385 foot long pipe section from Fairlawn Avenue down to the Anacostia River is a complete fish blockage which precludes normal exchange with and repopulation from Anacostia River fish stock.

Figure 24 - Lower Reach 'B' - American Eel Elver Captured

3.8 Stream Chemistry

As part of the additional non-RSAT water quality grab sampling performed for the study, COG staff collected both baseflow and stormflow samples for water chemistry analysis by CT&E Environmental Services, Incorporated. Due to budgetary constraints, this analysis was performed for three baseflow and six stormflow samples collected from the Middle Reach (X-26 area) between August and October 2002, only. In addition, limited insitu grab sampling with hand-held meters was conducted for the period May through December 2002 at the four following locations: 1) Middle Reach (X-14), 2) Lower Reach 'A' (X-26) and 3) Lower Reach 'B' (X-29). Results are summarized in Figures 25 -27, Table 15 and Appendix 6.

3.8.1 Baseflow DO

During the study period, violations of the District of Columbia's Department of Health (DC-DOH) 5.0 mg/l dissolved oxygen (DO) water quality standard were recorded in both the Middle and Lower Reach 'A' sections. In fact, eleven DO measurements (40 percent) out a total of 27 taken were below the minimum 5.0 mg/L criterion recommended for the support of a healthy aquatic community. A further breakdown of the DO violations are as follows: Middle Reach (X-14) seven out nine (77 percent), and Lower Reach 'A' (X-26) four out of 10 (40 percent). No minimum DO violations were recorded for Lower Reach 'B'. As seen in Figure 25, DO levels increased along with increasing streamflow in a downstream direction. The median DO levels for Lower Reach 'A' and

'B' were 5.48 and 5.68 mg/L, respectively. On average, these values were 1.5-2.0 mg/l higher than those recorded for the Middle Reach.

3.8.2 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), decreased in Pope Branch in downstream fashion.[13] As seen in Figure 25, median baseflow conductivity concentrations for the three stream sites ranged from a low of 338 mS/cm in Lower Reach 'A' to a high of 354 mS/cm in the Middle Reach.

Limited water quality surveys of relatively undisturbed Coastal Plain streams in Maryland and other mid-Atlantic states strongly suggest that Pope 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 elevated conductivity readings suggest a variety of possible anthropogenic-related influences including treated water from leaking water or sewer lines, road salting, leaching from recently disturbed soils, application of fertilizers, etc.

3.8.3 Baseflow pH

pH, which is used to indicate the acidity or alkalinity of water, increased in downstream fashion in Pope Branch. As seen in Figure 25, median pH levels ranged from a low of 5.66 (slightly acidic) for the Middle Reach to a high of 6.55 (near neutral) for Lower Reach 'B'. In general, unimpaired fresh water streams in the Washington metropolitan area have a pH range on the order of 6.5 to 8.0. This is the pH range favorable for the support of most aquatic organisms. It should be noted that because of treatment-related changes, the pH of tap water is generally higher than background water supply levels. The pH of treated water in District of Columbia is generally around 8.0 (DCWASA, 2003).

3.8.4 Baseflow Fluoride

Median fluoride (F-) concentrations in Pope Branch also increased heading downstream. Instantaneous measurements ranged from a low of 0.07 mg/l in the Middle Reach to an extremely high 0.69 mg/l in Lower Reach 'B'. The median F- concentration in Lower Reach 'A' was 0.30 mg/l, which is on the order of 0.10 mg/l higher than the values reported for either the Middle or Lower Reach 'B' areas. As seen in Table 15, the median F- concentration for Pope Branch is 0.1 mg/l higher than that recorded for the neighboring Fort Dupont Tributary. It should be noted that local naturally occurring fluoride concentrations generally range from 0.1 to 0.2 mg/l and that District of Columbia treated water F- concentrations are typically 0.4 mg/l (DCWASA, 2001).

3.8.5 Middle Reach Baseflow NO_3, TP, Fe, Cu, TOC and BOD

Limited baseflow laboratory water chemistry analysis summary results (Figure 26; Appendix 6: Table 1) for Pope Branch Lower Reach 'A' (X-26) revealed that: 1) nitrate (NO_3-) concentrations

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[13] Conductivity levels often increase in response to a variety of anthropogenic activities and related pollution such as sewage from sanitary sewer line/septic field leakage, road salting, leaching from recently disturbed soils, application of fertilizers, etc.

Figure 25 - Pope Branch Middle, and Lower 'A' and 'B' Reach Baseflow DO, Conductivity, pH and Fluoride (July - November 2002)

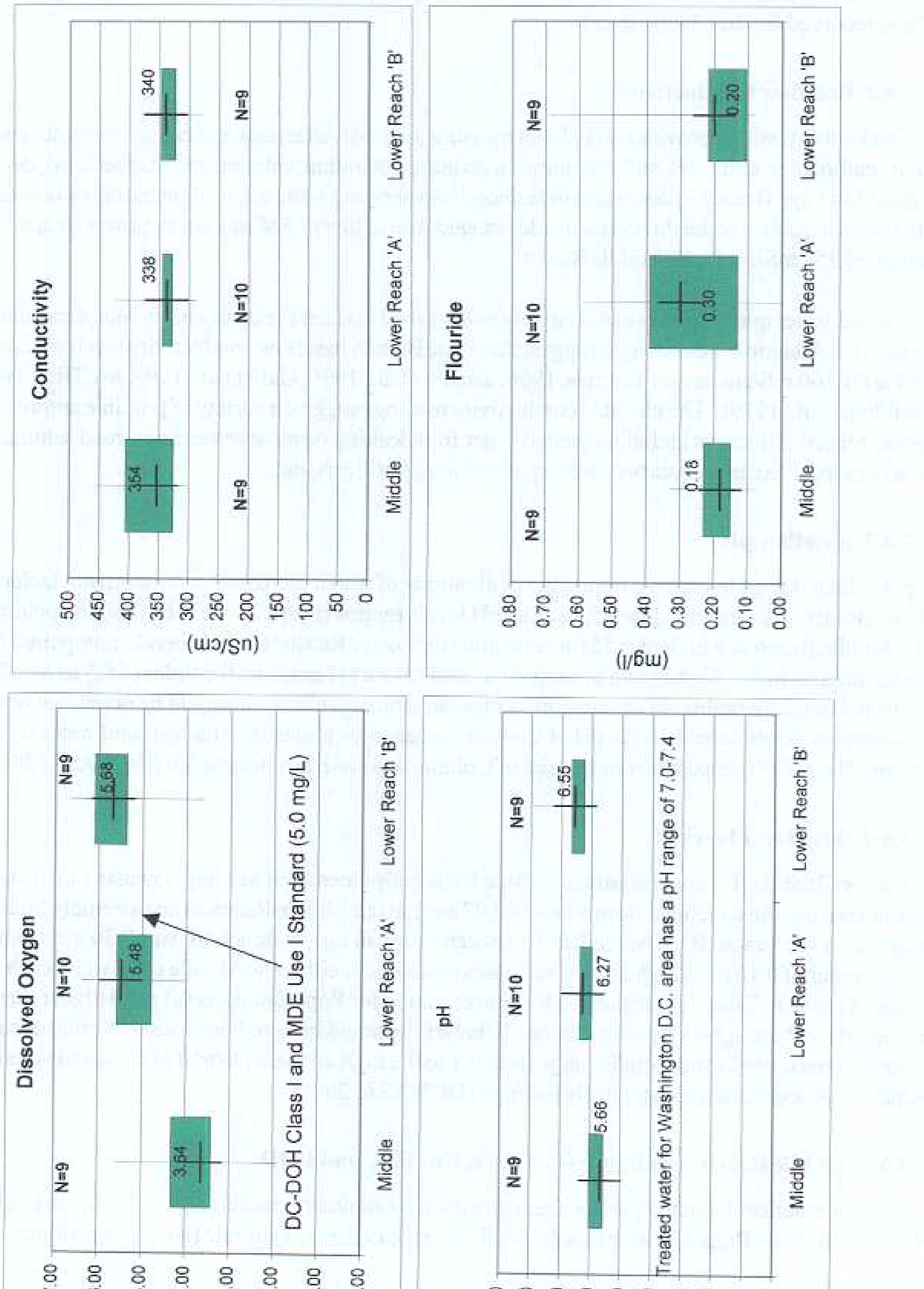
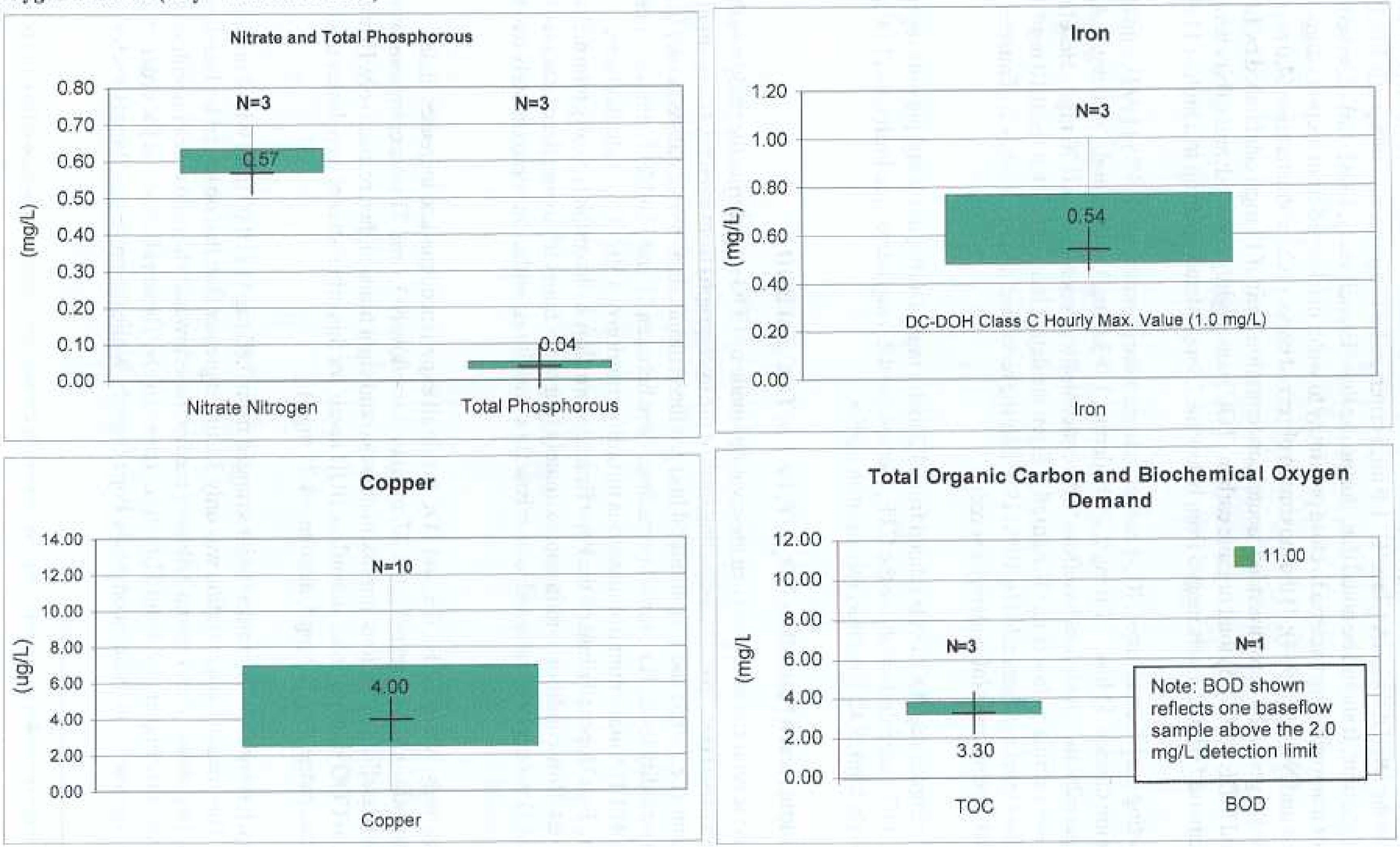


Figure 26 - Pope Branch Lower Reach 'A' (Transect X-26) Baseflow Nitrate, Total Phosphorus, Copper, Iron, Total Organic Carbon, and Biochemical Oxygen Demand (July – November 2002)



were in the moderate range; 2) total phosphorus (TP) concentrations were low; 3) iron (Fe) levels were below the DC-DOH/EHA Class 'C' 1.0 mg/l criterion for the protection of aquatic life 100 percent of the time. It should be noted that, during the Pope Branch study, COG staff observed the presence of iron-oxidizing bacteria in close proximity to water discharged from seeps as suggested by Robbins and Norden (1994); 4) the maximum observed copper (Cu) concentration (4.0 mg/l) was well below the generally recommended 'acute' concentration limit of 13 mg/l established by EPA (2002); and MDE (2003); 5) total organic carbon (TOC) was slightly elevated; and 6) biochemical oxygen demand[14] (BOD) levels ranged from below the 2.0mg/l detection limit to a high of 11.0mg/l.

For reporting purposes, nitrate (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. As seen in Figure 26, the maximum baseflow NO_3- concentration recorded was 0.70 mg/l. Baseflow TP levels were similarly low (i.e., <0.10 mg/l). From the data 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 infrequently exceeded.

As seen in Figure 26, TOC levels ranged from 3.2 to 4.4 mg/l. During the study, the only reported baseflow BOD concentration above the CTE, Incorporated 2.0 mg/l detection limit was 11.00 mg/l. This relatively high BOD level may represent an outlier.

3.8.6 Middle Reach Stormflow NO_3-, TP, Fe, Cu, TOC and BOD

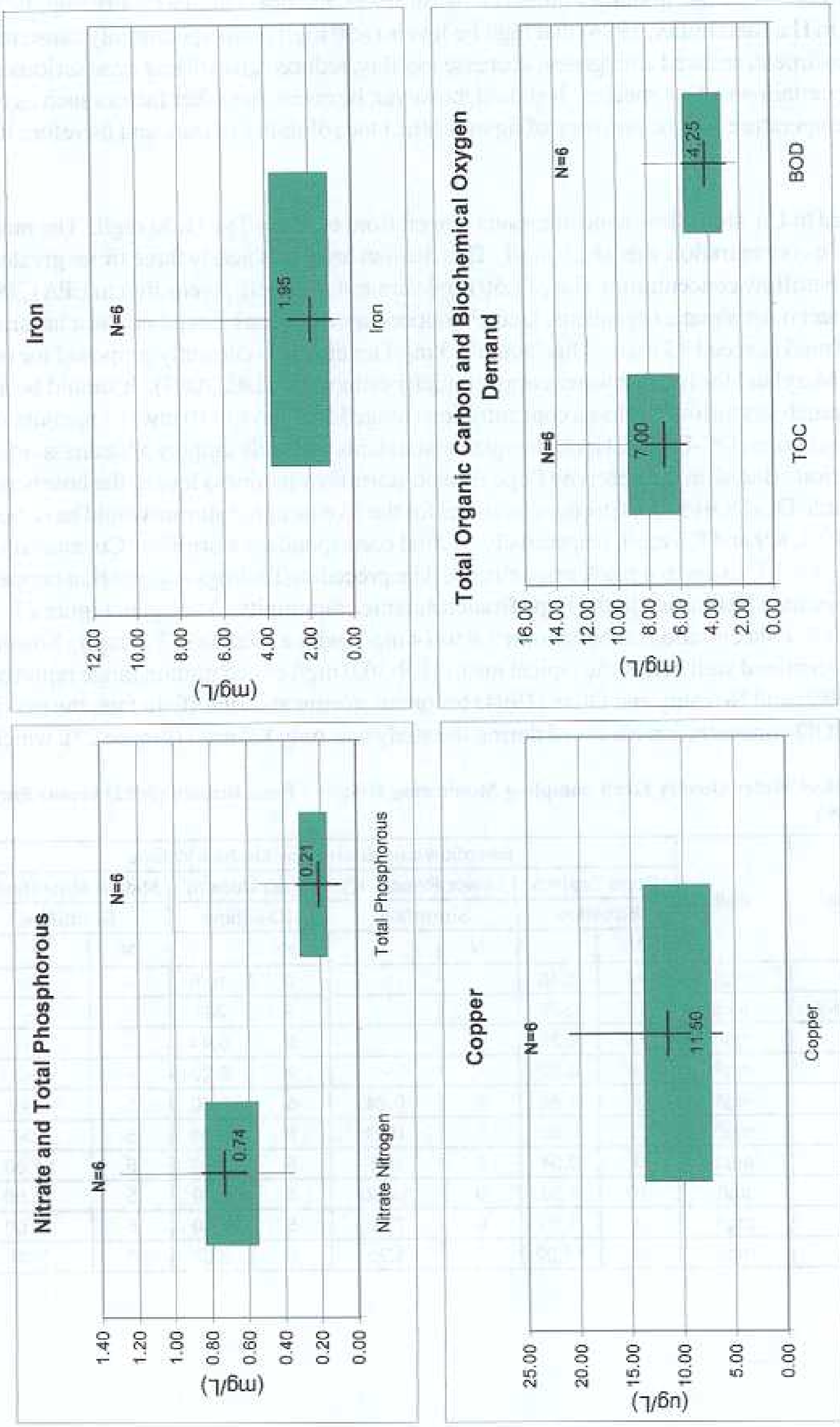
Among the several stormflow-related observations made by COG staff during the study was that: 1) first flush runoff (i.e., from the ascending limb of the hydrograph) from even relatively small rainfall events (i.e., <0.35 inches rainfall/24 hrs) produced turbid, dark-brown colored water in Pope Branch, 2) turbidity levels (i.e., turbidity readings were between 11 and 150 NTU) did not violate the DC-DOH/EHA maximum instantaneous turbidity criterion of 150 NTU, 3) similar to the neighboring Fort Dupont Tributary, the Pope Branch stormflow hydrograph typically returned to its pre-storm baseflow condition within approximately four to six hours following the cessation of rainfall, and 4) water clarity returned to near baseflow conditions within an approximately two to three hour period.

Not surprisingly, NO_3-, TP, Fe, Cu, and TOC levels all experienced marked increases under stormflow conditions. As seen in Figure 27, median stormflow NO_3- and TP concentrations were, compared to baseflow conditions, approximately two and eight times higher, respectively. However, somewhat to COG staff surprise, stormflow BOD levels for this urban stream were lower than expected (i.e., range 2.2 – 8.2 mg/l, median = 4.25 mg/l).

Pope Branch stormflow Fe concentrations ranged from 0.86 mg/l to 10.00 mg/l with a median of 1.95 mg/l. This median concentration was only 3.6 times greater than that observed for baseflow conditions. In contrast, Fort Dupont Tributary median baseflow and stormflow Fe concentrations (Table 15) were far higher at 2.4 and 51.0 mg/L, respectively. These values are on the order of four and 25 times greater than those recorded for Pope Branch. While the preceding Pope Branch Fe

[14] BOD level reflects one baseflow sample, only BOD levels less than the 2.0 mg/L detection limit were not reported by CTE laboratory.

Figure 27 - Pope Branch Lower Reach 'A' (Transect X-26) Stormflow Nitrate, Total Phosphorus, Copper, Iron, Total Organic Carbon, and Biochemical Oxygen Demand (July - November 2002)



concentrations and exposure periods may not in themselves be toxic, it has been shown in macroinvertebrate and fish toxicity studies (Gerhardt, 1992, Skyora et al., 1972; Ebeling, 1931; Roback, S. in Hart and Fuller, 1974) that high Fe levels (>50 mg/l) could potentially cause reproductive impairment, reduced emergence, decrease motility, reduced growth and even serious injury or death for certain sensitive species. It should, however, be noted that other factors such as pH, hardness, temperature and the presence of ligands affect the solubility of iron, and therefore its toxicity.

With regard to Cu, stormflow concentrations ranged from 6.30 mg/l to 21.00 mg/l. The median stormflow Cu concentration was 11.50 mg/l. This median level was nearly three times greater than the median baseflow concentration (i.e., 11.50 mg/l versus 4.00 mg/l). According to EPA (2002), in order to protect most aquatic organisms, 'acute' copper concentrations should not (at a hardness level of 100 mg/l) exceed 13 mg/l. This 'acute' 13 mg/l level is also currently proposed for use by the State of Maryland for its freshwater copper toxicity criterion (MDE, 2003). It should be noted that Pope Branch stormflow hardness concentrations ranged from 66 to 110 mg/l (Appendix 6: Table 2). In addition, DC-DOH/EHA water quality standards currently employ a hardness-adjusted copper criterion. Based on the observed Pope Branch stormflow hardness levels, the hourly maximum allowable DC-DOH/EHA Cu concentrations for the five sampled storms would have been 8.7, 10.8, 12.8, 10.4, 8.9 and 8.3 mg/l, respectively. Actual corresponding stormflow Cu concentrations were 21, 6.3, 14, 10, 13 and 6.4 mg/l, respectively. The preceding findings suggest that copper concentrations may be limiting to the Pope Branch aquatic community. As seen in Figure 27, stormflow TOC concentrations ranged from 5.8 to 14 mg/l, with a median of 7.0 mg/l. Stormflow BOD levels remained well below the typical mean 11.9-30.0 mg/l concentration range reported by Schueler (1987) and Novotny and Olem (1994) for urban stormwater runoff. In fact, the maximum stormflow BOD concentration observed during the study was only 8.2 mg/l (Figure 27), which is

Table 15 - Select Water Quality Grab Sampling Monitoring Results - Pope Branch (2002) versus Fort Dupont (1999)

Parameter	unit	Baseflow and Stormflow Median Values							
		Pope Branch (Lower Reach 'A')				Fort Dupont (Middle Mainstem)			
		Baseflow		Stormflow		Baseflow		Stormflow	
		N		N		N		N	
1. DO	mg/l	10	5.48	-	-	9	10.6	-	-
2. Conductivity	(µs/cm)	10	338	-	-	9	207	-	-
3. pH	mg/l	10	6.27	-	-	9	6.44	-	-
4. Fl-	mg/l	10	0.30	-	-	9	0.20	-	-
5. NO3	mg/l	3	1.80	6	0.74	5	0.20	5	0.40
6. TP	mg/l	3	0.05	6	0.21	5	0.01	5	0.36
7. Fe	mg/l	3	0.54	6	1.95	5	2.40	5	51.00
8. Cu	µg/l	10	4.00	6	11.50	5	4.00	5	14.00
9. TOC	mg/l	3	3.30	6	7.00	5	6.40	5	18.00
10. BOD	mg/l	3	11.00	6	4.25	5	2.00	5	5.00

approximately 3.0 mg/l less than the single baseflow BOD level recorded. Finally, it should be noted that stormflow fecal coliform concentrations ranged from a low of 160 to a high of 49,000 MPN; reflecting low to moderate input levels of animal and/or human waste.

3.9 Sediment Chemistry

Results from the Pope Branch sediment grab sample testing are presented in Table 16. As seen in Table 16, none of the major hydrocarbon analytes tested for as part of the EPA priority pollutant scan were present within the detection limits of the analysis. In addition, representative metals (e.g., copper, chromium, lead and zinc) typically present in urban runoff were detected at relatively low levels, and were comparable to the levels observed in the neighboring Fort Dupont Tributary. It should be noted that interpretation of the sediment chemistry data is, because of the current lack of EPA sediment pore water quality criteria and incomplete understanding of the bioavailability of these pollutants, still difficult at this time. However, based on the EPA priority pollutant scan results it does not appear that the pollutants detected pose serious environmental toxic risks to the biological community of Pope Branch.

Table 16 - Pope Branch - Select Mainstem Sediment Chemistry Results (December 2002)

EPA Method Number	Analyte (mg/kg)	Detection Limit (Fort Dupont) (mg/kg)	Detection Limit (Pope Branch) (mg/kg)	Test Value[1] (Pope Branch)	Test Value [1] (Fort Dupont)
	Hydrocarbons				
625	Benzo(a) anthracene	1	0.40	ND	ND
625	Benzoflouranthenes[2]	1	0.40	ND	ND
625	Benzo(a)pyrene	1	0.40	ND	ND
625	Benzo(g,h,i)perylene	1	0.82	ND	ND
625	Bis(2-ehtylhexyl)phthalate	10	0.40	ND	ND
625	Chrysene	1	0.40	ND	ND
625	Fluoranthene	1	0.40	ND	ND
625	Indeno-(1,2,3,-cd)-pyrene	10	0.40	ND	ND
625	Phenanthrene	1	0.40	ND	ND
625	Pyrene	1	0.40	ND	ND
625	Di-N-butyl phthalate	1	0.40	ND	ND
	Metals				
200.7	Arsenic	50	0.92	1.2	<50
200.7	Beryllium	1	0.18	0.26	<1
200.7	Chromium	1	0.92	7.2	5.9
200.7	Copper	1	0.92	4.0	4.7
200.7	Lead	10	0.92	3.8	<10
200.7	Nickel	2	0.92	4.9	5.7
200.7	Phenol	10	0.40	ND	ND
200.7	Zinc	1	3.70	19.0	21.0

[1] ND indicates not detected.

[2] Detected and reported as the sum of Benzo(b)flouranthene and Benzo(k)flouranthenes.

4.0 Physical/Hydrological

4.1 Rosgen Level I and II Stream Channel Morphology

Based on both Rosgen Level I and II stream channel morphology results (Table 17), the Pope Branch stream channel network may be generally classified as belonging to the following stream types: Upper Reach 'B' - F_{4b}, Middle Reach - B_4, Lower Reach 'A' - C_{4b}, and Lower Reach 'B' - C_{4b}. As seen in Table 17, the degree of channel entrenchment decreased in a downstream fashion. The entrenchment ratio ratings for Pope Branch are as follows; Upper Reach 'A' - entrenched (i.e., <1.4), Middle Reach - moderately entrenched (i.e., 1.4 – 2.2), and Lower Reach 'A' and 'B' - slightly entrenched (i.e., >2.2). For additional Rosgen Level II analysis results, the reader is referred to Table 17 and Appendix 7.

4.2 2002 Stream Temperature Monitoring

Results from the 5/24/02 to 9/12/02 (111 days)[15] continuous stream temperature monitoring portion of the study are presented in Figures 28 and 29. In addition to the 32.2 °C (90 °F) DC-DOH/EHA Class 'C' temperature standard for the stream, COG staff included both the MDE 24 °C Use IV (recreational trout) and 20 °C (68 °C) Use III (natural trout waters) criteria for further comparison. It should be noted that the HOBO® temperature probe located in Lower Reach 'A' malfunctioned and did not record temperatures from August 1 through September 12, 2002. Consequently, only 69 days of continuous stream temperature data was recorded for this site.

As seen in Figure 28, with the exception of one single reading, stream temperatures in the three surveyed Pope Branch reaches (i.e., Middle Reach and Lower Reach 'A' and 'B') were well below the DC-DOH/EHA Class 'C' standard. Furthermore, for the period of May 24th through August 1st, the Middle Reach, with its wide riparian buffer zones and excellent canopy coverage was the coolest of the three stream areas.

Unlike Lower Reach 'B', which exhibited sharp water temperature 'spikes' in response to stormflow inputs and high air temperatures, diurnal stream temperature fluctuations, in both the Middle and Lower Reach 'A' areas were markedly lower. Additional results from the monitoring period are as follows: 1) all three stream areas had maximum summer daily temperatures that exceeded the 20 °C MDE Use III temperature criterion; 2) through August 1st, Lower Reach 'A' did not exceed the 24 °C MDE Use IV temperature criterion, whereas the Middle and Lower Reach 'B' exceeded this criterion on a total of one and twenty days, respectively, 3) the maximum daily water temperature recorded during the study (32.8 °C) was measured in the Middle Reach on September 9, 2002 and coincided with a water hydrant release event that lasted for approximately six hours ; 4) the thermal regime of Lower Reach 'B' was far more strongly influenced by prevailing air temperatures than those of either the Middle or Lower Reach 'A' areas; and 5) Lower Reach 'B' also experienced a thermal "spike"' where the maximum stream temperature reached 28.3 °C, coincident with another water hydrant release event that lasted for approximately five hours. Additional analysis

[15] Temperature monitoring for the Lower Reach 'A' totaled 69 days due to equipment failure.

Table 17 - Pope Branch - Rosgen Level I and II - Summary Results

RSAT Stream Segment	Drainage Area (ac)[1]	Stream Length		Stream Type Classification		Stream Order	Entrench-- ment Ratio[2]	Width/ Depth Ratio[3]	Sinuosity [4]	Channel Slope (%)[5]	Channel Material (D50)[6] Size (mm)
		Feet	Miles	Level I	Level II						
Upper											
Reach 'A'	54.3	1,129.5	0.21	-	-	1					
Reach 'B'	54.1	1,557.9	0.30	F	-	1	-	-	-	-	-
Subtotal	108.4	2,687.4	0.51	-	F4b	-	1.3	9.3	1.6	4.8	27.0
Middle					-		-	-	-	-	-
	78.8	2,330.3	0.44	B		1					
Lower					B4		1.6	8.3	1.5	3.0	28.0
Reach 'A'	35.9	922.0	0.17	C		1					
Reach 'B'	25.4	880.4	0.17	C	C4b	1	2.6	7.4	1.5	2.9	21.5
Subtotal	61.3	1,802.4	0.34	-	C4b	-	9.5	16.4	1.3	2.9	16.5
Total	248.5	6,820.1	1.29	-	-	-	-	-	-	-	-

[1] Drainage acreage reflects area draining down to Fairlawn Avenue. Drainage area estimates below Fairlawn Avenue total an additional 17.0 acres.

[2] Entrenched = <1.4; Moderately Entrenched = 1.4 – 2.2; Slightly Entrenched = > 2.2

[3] Width /Depth Ratio Interpretation: Very Low to Low = < 12; Moderate to High => 12; Very High = > 40

[4] Sinuosity Interpretation: Low = < 1.2; Moderate to High => 1.2; Very High = > 1.5

[5] Channel slope calculated from reach riffle-to-riffle measurements (Rosgen, 1996).

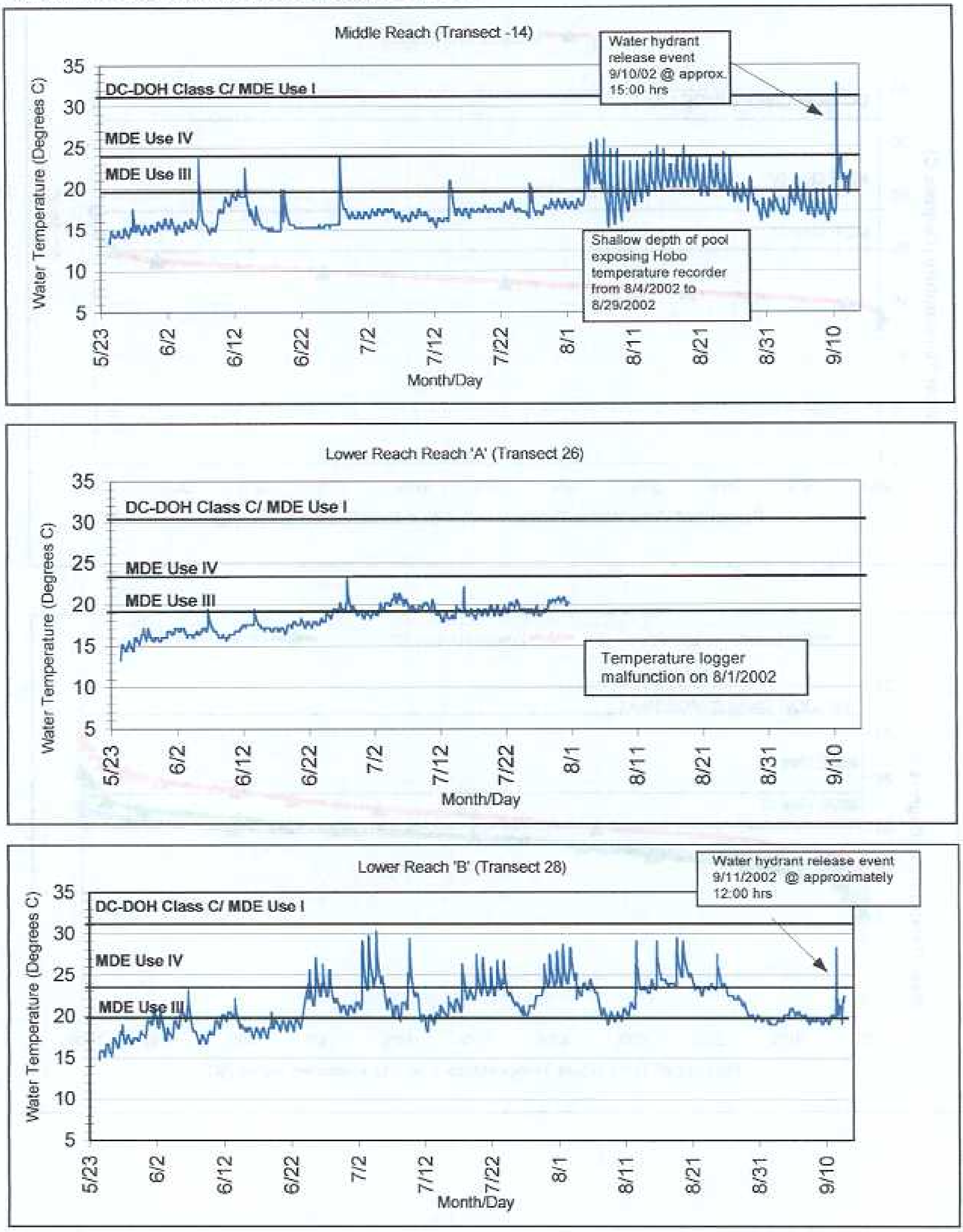
[6]

Substrate Class (AGI, 1982)	Very Fine Sand	Coarse Sand	Very Coarse Sand	Very Fine Gravel	Medium Gravel	Coarse Gravel	Very Coarse Gravel	Small Cobble	Large Cobble	Boulder	Bedrock
Size Range (mm)	0.06 – 0.13	1.00 – 1.31	1.01– 1.99	2.00 – 7.99	8.00 – 15.99	16.00 – 31.99	32.00 – 63.99	64.00 – 127.99	128.00 – 255.99	256.00 – 4095.99	>= 4096.00

(Figure 29) revealed that Middle Reach water temperatures were at or below 20°C 93 percent of the time. In contrast, Lower Reach 'A' and 'B' temperatures were below 20°C 80, and 35 percent of the time, respectively.

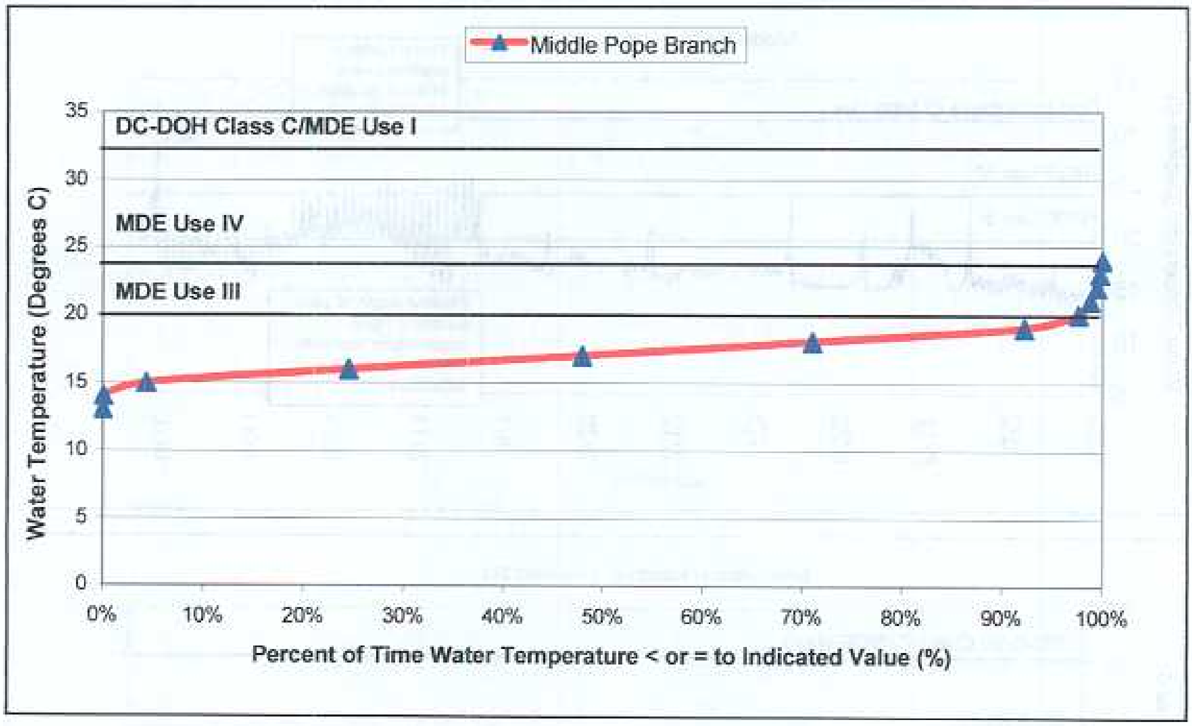
Based on the preceding water temperature monitoring results the Pope Branch water temperature regime can be generally categorized, per Galli (1990), as being that of a coolwater stream system. Summer temperatures at all three stations regularly exceeded temperature levels considered optimal (i.e., less than 17 to 20 °C) for many 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.

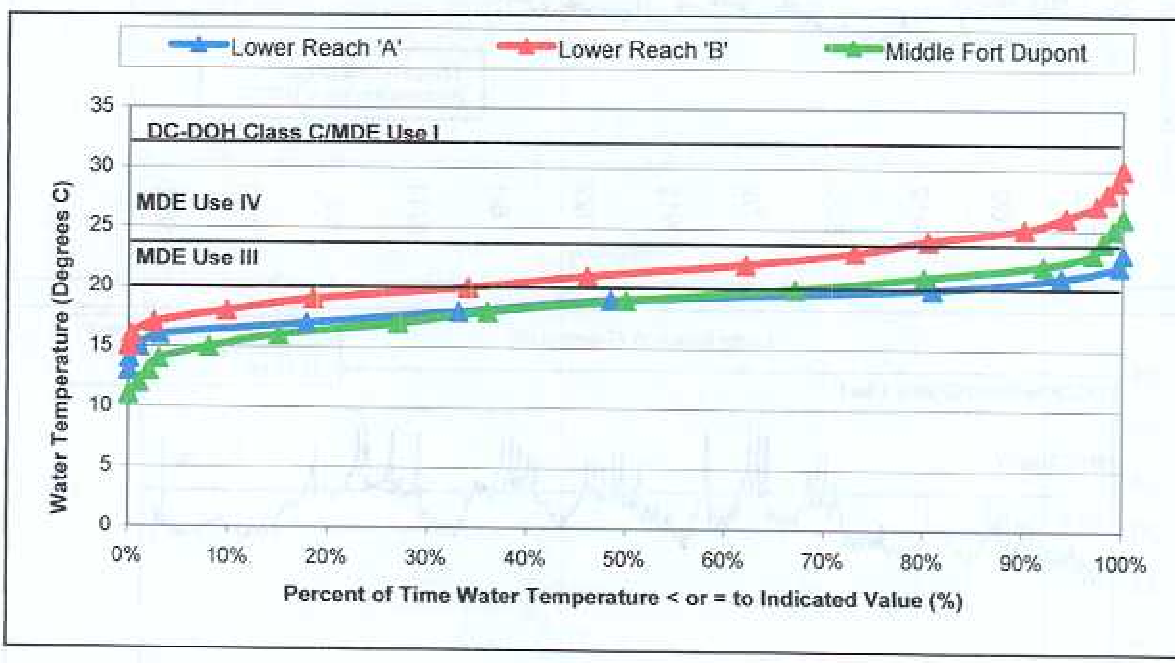
Figure 28 - Pope Branch - Middle, Lower Reach 'A', and Lower Reach 'B' Twenty-Minute Water Temperature Readings[1] (May 24-September 12, 2002)



[1] DC-DOH Maximum Water Temperature Standards: Class-Protection and propagation of fish, shellfish and wildlife = 32.2°C. MDE Maximum Water Temperature Standards: Use I (water contact recreation, aquatic life and water supply) = 32°C; Use III (natural trout waters) = 20°C; Use IV (recreational trout waters) = 24°C.

Figure 29 - Pope Branch Water Temperature Distribution: Middle Pope Branch; Lower Reach 'A', Lower Reach 'B', and Middle Fort Dupont Tributary.

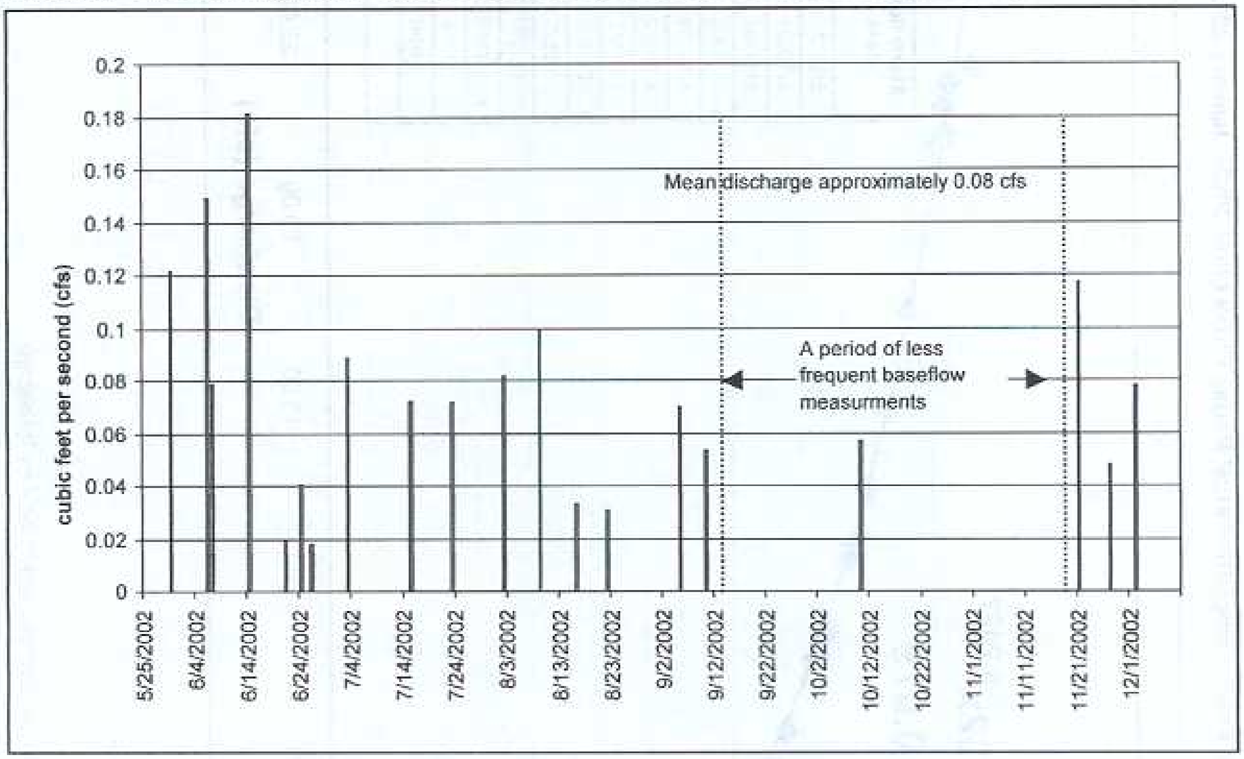




4.3 Baseflow Discharge

As previously indicated, between May 25th and December 3rd, 2002 COG staff took a total of 20 measurements at the Lower Reach 'A' (X-26) baseflow monitoring station. Baseflow discharge results are summarized in Figure 30. As seen in Figure 30, Pope Branch maintained baseflow throughout the study period in both the Middle Reach and Lower Reach "A' and 'B' areas. Not surprisingly, baseflow between mid-June through mid-October was markedly reduced by the drought. Although mean Pope Branch baseflow during the study period was 0.08 cfs, in all likelihood this discharge (based on total "water year", October through September, precipitation levels) was approximately 10-15 percent below the expected 'normal' average. During the 2002 water year, monthly precipitation was well below normal in 10 out of the 12 months. It should be noted that dry channel conditions were observed during mid-June through mid-October in both Upper Reach 'A' and 'B'. In addition, it appears that Pope Branch baseflow is partially augmented by an inflow of treated municipal water above Branch Avenue.

Figure 30 - Baseflow Discharge - Lower Reach 'A' (Transect X-26 - at Minnesota Avenue)

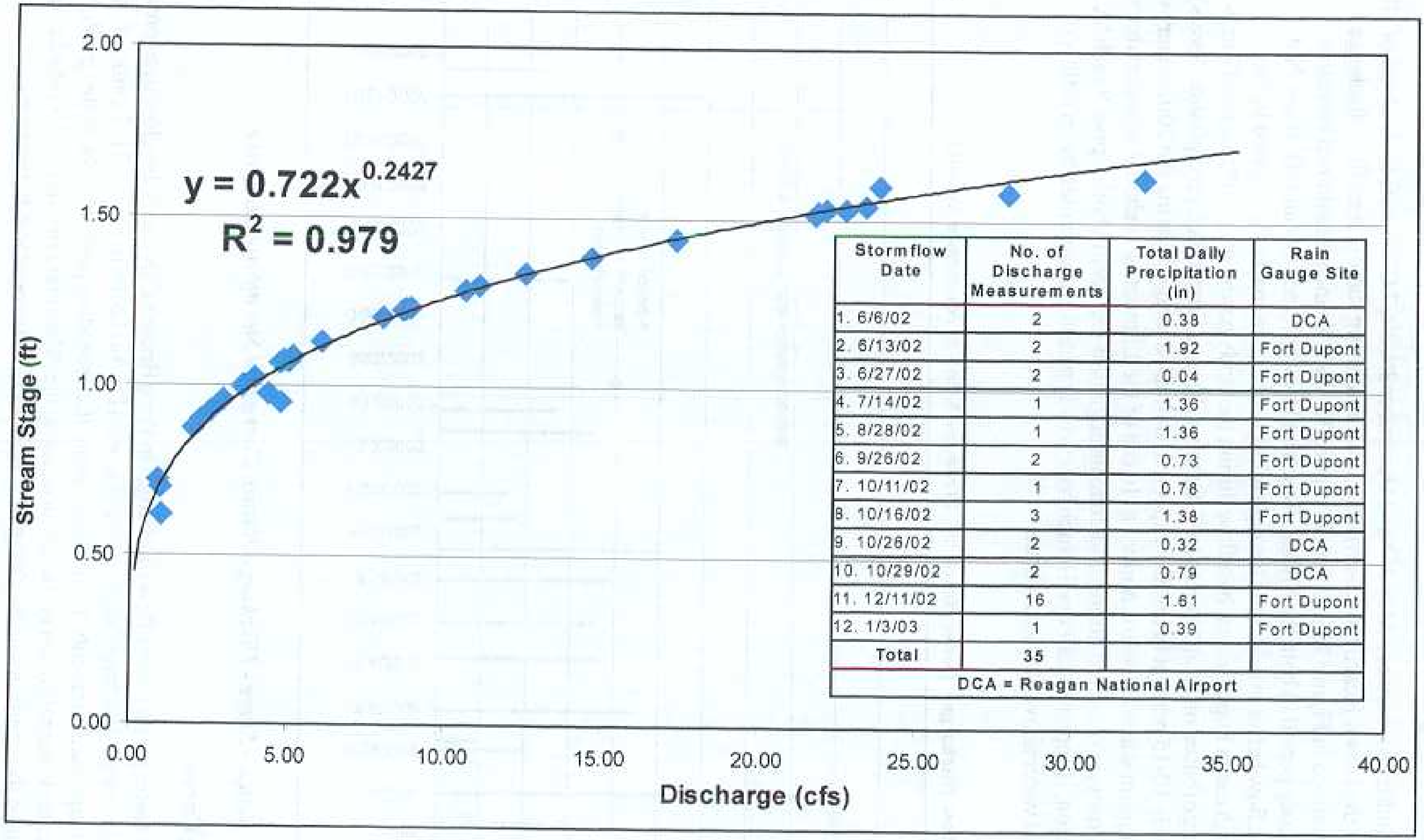


4.4 Middle Reach - Stage - Discharge Rating Curve and Stormflow Response

4.4.1 Rating Curve

In an effort to better predict stormflow discharges in Pope Branch COG staff developed, as previously described, a stage-discharge rating curve (Figure 31). As shown in Figure 31, 12 stormfall events (35 discharge measurements, total, taken during the ascending portion of the hydrograph) were used to generate the rating curve. In addition, using the "Rational Formula", COG staff conservatively calculated the approximate discharge levels for the following storm frequencies:

Figure 31 - Pope Branch - Lower Reach - Stage-Discharge[1] Rating Curve (June 2002 - January 2003)[1]



Stormflow Date	No. of Discharge Measurements	Total Daily Precipitation (in)	Rain Gauge Site
1. 6/6/02	2	0.38	DCA
2. 6/13/02	2	1.92	Fort Dupont
3. 6/27/02	2	0.04	Fort Dupont
4. 7/14/02	1	1.36	Fort Dupont
5. 8/28/02	1	1.36	Fort Dupont
6. 9/26/02	2	0.73	Fort Dupont
7. 10/11/02	1	0.78	Fort Dupont
8. 10/16/02	3	1.38	Fort Dupont
9. 10/26/02	2	0.32	DCA
10. 10/29/02	2	0.79	DCA
11. 12/11/02	16	1.61	Fort Dupont
12. 1/3/03	1	0.39	Fort Dupont
Total	35		

DCA = Reagan National Airport

[1] Discharge measurements were taken during the ascending limb of the storm hydrograph

- weekly (0.25" rainfall/24 hours)= ~17.4 cfs;
- six month (1.65" rainfall/24 hours)= ~114.8cfs;
- 1-year (2.60" rainfall/24 hours)= ~180.9 cfs;
- 2-year (3.20" rainfall/24 hours)= ~222.7 cfs; and
- 5-year (4.20" rainfall/24 hours)= ~292.2 cfs.

The preceding results should be of interest for future detailed Pope Branch hydraulic geometry, sediment transport, stormwater management, and storm drainage and/or stream restoration evaluations.

4.4.2 Stormflow Response

As is the case with most small urban streams, flows in the Pope Branch responded quickly and often unpredictably to small rainfall events. For example, the relatively steady 0.38-inch rainfall on December 8, 2002 resulted in a 0.13-foot increase in stage and a discharge of approximately 0.72 cfs (Figure 30). In contrast, runoff associated with the shorter, more intense 0.38-inch storm on June 6, 2002 produced both a 0.77-foot increase in stage and a discharge of approximately 10 cfs (which, is approximately 125 times higher than the mean baseflow discharge).

During the study, COG staff also observed that stormwater runoff associated with even small, 0.25 inch rainfall events was sufficient to move the gravel-sized materials in the Pope Branch streambed materials in the. It was additionally noted that runoff from approximately 1.0 inch storms displaced cobble-sized materials.

5.0 Discussion

The results of this study generally support the findings from previous investigations (Johnson, 1989; Banta, 1993) that the Pope Branch biological community is moderately impaired. Not surprisingly, decades of uncontrolled stormwater runoff in combination with periodically leaking sewer lines, episodic discharges of toxic materials such as petroleum products, and major channel alterations have: 1) created a characteristically 'flashy', urban stream flow regime; 2) modified channel morphology and increased levels of stream channel erosion, particularly in Upper Reach 'B'; 3) exposed a total of seven sewer line areas; 4) increased stormflow levels of Cu and various other pollutants; 5) reduced both streambed stability and physical aquatic habitat quality; 6) resulted in the enclosure of 1,700 linear feet of the stream system and the creation of 14 major fish blockages; and 7) with the exception of the American eel, *Anguilla rostrata*, eliminated all resident fishes from the stream.

Despite the severity of the drought and the aforementioned problems, the Pope Branch macroinvertebrate community still continues to support 37 taxa. Not surprisingly, pollution intolerant stoneflies, flathead maylflies and cased caddisflies have long since been eliminated from the stream. In fact, only relatively low numbers of pollution tolerant mayflies and caddisflies currently remain.

Regarding Pope Branch restoration potential, several key limiting factors must be kept in perspective. First, unlike the neighboring Fort Dupont Tributary which has several smaller feeder tributaries and hence, potential refugia areas for aquatic life, Pope Branch consists of one single stream channel. Consequently, Pope Branch's aquatic community is at far greater risk from toxic spills, leaking sewer lines and other anthropogenic-related mishaps and insults. Second, imperviousness levels and related uncontrolled volumes of stormwater runoff in the Pope Branch subwatershed are both relatively high. The stormwater runoff problem is exacerbated by the presence of a network of piped storm drains, which convey runoff directly to the stream. Typical of a very urban subwatershed, all five Pope Branch stream reaches include the presence of one or more storm drain outfalls. Third, the relatively low baseflow (i.e., mean 0.08 cfs) coupled with the low number of deep, high quality pools and presence of 14 fish blockages (including a 1,385 feet long piped lower stream section), greatly restricts fish restoration potential.

In addition, as graphically illustrated by Figure 32, the structural deterioration of the 3,600 feet long nearly 70-year-old sewer line section which parallels and traverses both the Upper Reach 'B' and Middle Reach Appendix 8) areas poses an imminent threat to the stream and its biota. Correcting this problem in an expeditious manner would help improve existing water quality, as well as benefit any future restoration project aimed at restoring physical and aquatic community conditions in Pope Branch.

Figure 32 - Pope Branch - Upper Reach 'B' - Undercut Sewer Manhole

Among the priority stormwater runoff/storm drainage problem areas to consider for both future stormwater management and storm drain outfall retrofitting are the 'O' Street, Texas Avenue, 35th Street, and Branch Avenue sub-catchments. These drainage areas contribute significant volumes of uncontrolled runoff and pollutants to Pope Branch. While the stream should respond well to the installation of both effective stormwater management and velocity dissipation techniques (e.g., Figure 33), widespread implementation will be extremely challenging. Therefore, a comprehensive stream restoration approach which also includes major reconstruction of Pope Branch's stream channel morphology so as to better meet its altered urban stream flow and sediment transport regimes will also be required.

Figure 33 - Fort Davis Drive Storm Drain System - Flow Regulating Weir

Regarding the potential re-establishment of a Pope Branch fish community, the number and magnitude of existing fish blockages makes fish reintroduction with native species the most cost-effective and viable option. While in COG staff's opinion the perennial portion of the stream is presently capable of supporting pollution tolerant pioneer fish species such as blacknose dace, Rhynicthys atratulus, and northern creek chub, Semotilus atromaculatus, it would be premature to reintroduce these species given the existing sewer system-related problems. Based on its stream size and direct connection with the tidal Anacostia River, it is estimated that Pope Branch may have historically supported 6 to 10 resident fish species. Although no historical fisheries data specific to the Pope Branch are known to exist, the list of fishes collected in neighboring Oxon run in 1920 (Table 18) provides both valuable historical insight, as well as potential candidate species for future reintroduction.

6.0 Recommendations

In an effort to comprehensively address both existing problems and restoration opportunities for Pope Branch, COG staff developed the following suite of recommendations, which are keyed both to Figure 34 (map) and Figures 35 – 42 (photographs). Importantly, it is understood that the comprehensive restoration of Pope Branch is dependent upon DC-DOH/EHA, the U.S. Army Corps of Engineers, DCWASA, NPS, District of Columbia Department of Public Works (DC-DPW), District of Columbia Office of Planning (DC-OP) and the District of Columbia Department of Parks and Recreation (DC-DPR) working together to pursue a variety of stormwater management, storm drainage, sewer system upgrade and stream restoration options which will significantly reduce erosive stormflows, improve water quality and enhance aquatic and terrestrial habitat conditions throughout the subwatershed. Therefore, COG staff suggest that those agencies responsible for current and/or planned future Pope Branch restoration-related activities, carefully review the more specific recommendations which follow:

Table 18 - Potential Candidate Fish Species for Pope Branch Reintroduction

	Fishes Collected in Oxon Run, 1920 [1]	Origin	Trophic Level	Suitable Volume Flow (cfs) [2]	Adult Habitat	Spawning Strategy	Pollution Tolerance
1.	American Brook Lamprey	Native	Herbivore	No preferred flow	All	Open Substratum	Intolerant
2.	Blacknose Dace	Native	Generalist	0.1 - 5.97	All	Open Substratum	Tolerant
3.	Northern Creek Chub	Native	Generalist	0.1 - 7.89	Pool/Run	Nest Builder	Tolerant
4.	Fallfish	Native	Generalist	1.61 - 21.07	Pool/Run	Nest Builder	Tolerant
5.	White sucker	Native	Omnivore	1.84 - 68.0	Pool/Run	Open Substratum	Tolerant
6.	Northern Hogsucker	Native	Insectivore	1.99 - 39.8	Riffle/Run	Open Substratum	Intolerant
7.	Creek Chubsucker	Native	Invertivore	Larger streams	Pool	Open Substratum	------
8.	Bluntnose Minnow	Native	Omnivore	0.4 - 39.8	Pool/Run	Nest Builder - Guarded	Tolerant
9.	Rosyside Dace	Native	Insectivore	0.1 - 4.96	Pool	Open Substratum	Intolerant
10.	Swallowtail Shiner	Native	Omnivore	0.299 - 68.0	Pool/Run	Crevice Spawner	Tolerant
11.	Satinfin Shiner	Native	Omnivore	0.299 - 40.0	Pool/Run	Open Substratum	Tolerant
12.	Common Shiner	Native	Omnivore	2.58 - 40.79	Pool/Run	Open Substratum	Intermediate
13.	Steelcolor Shiner	Native	Insectivore	Larger streams	Run/Pool	Crevice Spawner	------
14.	Golden Shiner	Native	Omnivore	No preferred flow	Pool	Open Substratum	Tolerant
15.	Eastern Silvery Minnow	Native	Herbivore	Larger streams	Pool/Run	Open Substratum	Tolerant
16.	Silverjaw Minnow	Native	Insectivore	0.7 - 50.7	Pool/Run	Open Substratum	Intermediate
17.	Cutlips Minnow	Native	Omnivore	0.1 - 68.0	Pool/Run	Nest Builder	Intermediate
18.	American Eel	Native	Piscivore	10.04 - 68.0	Pool/Run	Ocean Spawner	Intermediate
19.	Banded Killifish	Native	Invertivore	>= 3.6	Pool/Run	Open Substratum	Tolerant
20.	Redbreast Sunfish	Native	Invertivore	No preferred flow	Pool	Nest Builder - Guarded	Tolerant
21.	Pumpkinseed Sunfish	Native	Invertivore	No preferred flow	Pool	Nest Builder - Guarded	Tolerant
22.	Largemouth Bass	Introduced	Piscivore	No preferred flow	Pool	Nest Builder - Guarded	Tolerant
23.	Tesselated Darter	Native	Insectivore	0.1 - 68.0	Pool/Run	Nest Builder - Guarded	Tolerant

[1] Breder, C.M. and D.R. Crawford, 1922. The Food of Certain Minnows. Zoologica (2): 287-327.
[2] Tsai, C. and M.L. Wiley, 1983. Instream Flow Requirements for Fish and Fisheries in Maryland. Maryland Water Resources Research Center, College Park, MD. 90pp.

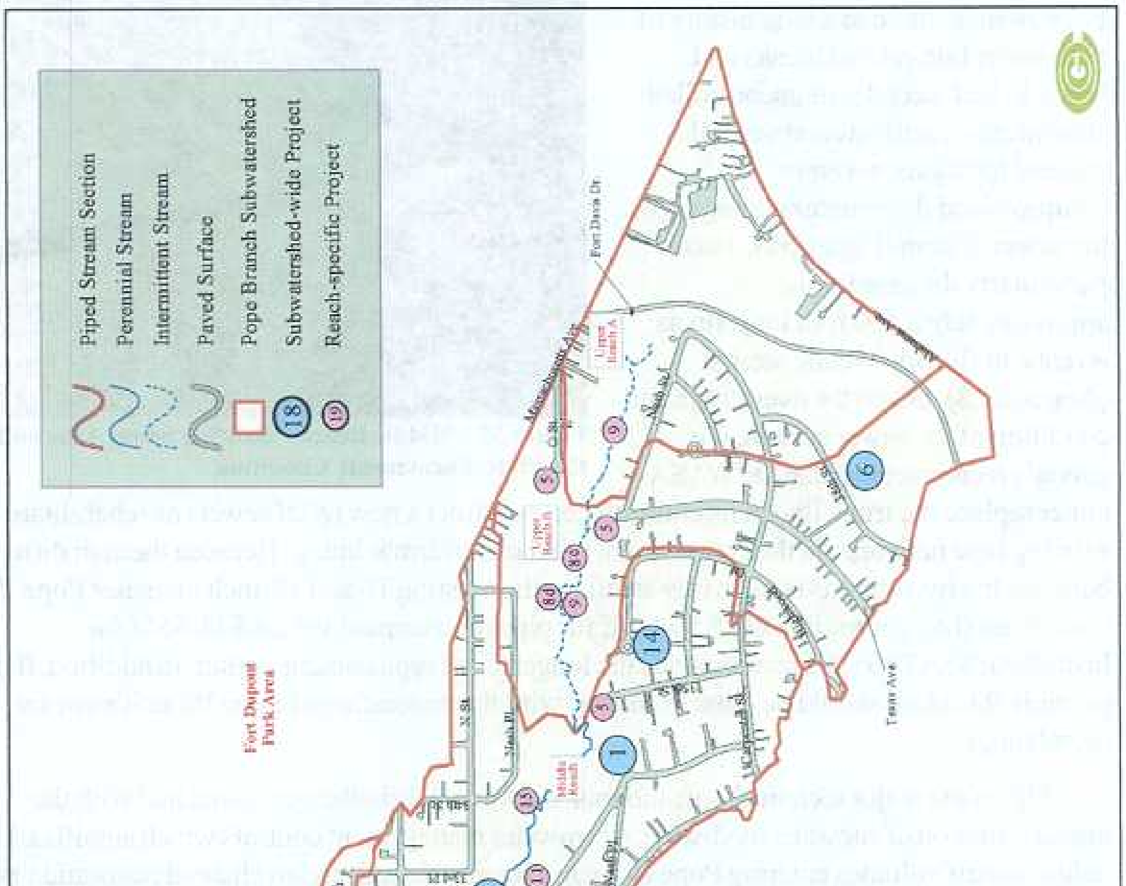


Figure 34 - Pope Branch - Project Recommendation Sites

Figure 35 - Middle Reach - Existing Sewer Line and Concrete Encasement Condition

1. The aging, main trunk sanitary sewer line which dates from the late 1930's and which parallels much of Pope Branch, has had a long history of both sewer line-related breaks and leaks. In fact, decades of uncontrolled stormwater runoff have, at several channel locations, severely compromised the structural integrity of the sewer system (Figure 35). This is particularly the case for the approximately 3,600 foot long Texas Avenue to Branch Avenue section (Appendix 8). Given the overall age and condition of the sewer system, it is strongly recommended that DCWASA either replace the trunk line in its entirety (i.e., construct a new relief sewer) or rehabilitate the existing pipe network via the employment of an Insituform® lining. Because the cost differential between the two options is relatively small for the existing 10 and 12-inch diameter Pope Branch trunk lines (i.e., approximately $ 50-60/lf for pipe replacement versus $45-55/lf for Insituform®), COG staff recommends the longer-lived replacement option. In addition, if at all possible this work should be done in concert with the restoration of Pope Branch's stream morphology.

2. Given the major technical, institutional and financial challenges associated with the implementation of subwatershed-wide, stormwater management controls which significantly reduce runoff volumes entering Pope Branch, a Rosgen-based stream channel restoration project for the entire length of open channel (i.e., approximately 1.3 miles) is recommended. As part of this work, it is recommended that: a) the large sand bar and meander which has formed immediately upstream of Branch Avenue be removed and b) the stream be realigned at this location with the culvert entrance, so as to reduce both existing sediment deposition and lateral stream channel erosion conditions.

Figure 36 - Lower Reach 'B' - Complete Fish Barrier - Branch Avenue Culvert Endwall

3. The inadvertent collapse of the endwall section of the 8'x 8' Branch Avenue concrete arch culvert (Figure 36) is providing defacto stormwater management quantity control for both Lower Reach 'A' and 'B' (i.e., the original cross-sectional area has been effectively reduced to an approximately 2'x 8' opening). While this collapsed section should be repaired it is recommended that, as part of the repair project, DC-DOH/EHA and DC-DPWT

investigate the possibility of constructing a formal, flow -reducing weir on the upstream side of the culvert.

4. As the lowermost piped portion of Pope Branch may ultimately provide the best opportunity for supporting a permanent resident fish community, the "daylighting" of this 1,385 feet long piped section (i.e., from Fairlawn Avenue downstream to the Anacostia River) should be a top priority. Not surprisingly, this work will have to be coordinated closely with the Fort Dupont stream restoration project, as well as with the planned or potential use of this portion of Anacostia River Park by both the NPS and the Anacostia Waterfront Restoration Initative.

Figure 37 - Upper Reach 'B' - Texas Avenue Storm Drain Outfall

5. The six (see Appendix 9 for approximate storm drain outfall locations) following storm drain system outfall locations are either in need of major repair) and/or the installation of more effective velocity dissipation features: 'O' Street, Texas Avenue (Figure 37), 35th Street, 33rd Place, 34th Street and Branch Avenue.

6. To the greatest practical extent, the employment of various stormwater management water quality control techniques (such as but not limited to Low Impact Development (LID), DC-DOH/EHA approved water quality inserts and inlets, sand filters, porous pavement, green roofs, etc.) are needed throughout the Pope Branch subwatershed. This is especially true for major roadways and commercial areas, which typically generate higher pollutant loads.

7. Lower Reach 'B'- reforest the right hand bank (looking downstream) from Minnesota Avenue to Fairlawn Avenue with native plant materials, so as to create a minimum 50-foot wide, continuous forested buffer (Figure 38).

8. Fish passage-remove or modify the following culverts and /or obstructions, which are either partial or complete barriers:

a. Lower Reach 'B'- Minnesota Avenue culvert, 1.5' drop, complete blockage (employ riffle grade control structure);

Figure 38 - Lower Reach 'B' - Recommended Reforestation Area

b. Middle Reach- perched concrete sewer line crossing in the vicinity of X-19 (Figure 39), 2.0' drop, complete blockage (employ riffle grade control structure);

c. Middle Reach-nick point in the vicinity of X-16, 0.5' drop, partial blockage (employ rock vanes or equivalent);

d. Upper Reach 'B'- perched concrete sewer line crossing, in the vicinity of X-6, 1.5' drop, complete blockage (employ riffle grade control structure); and

Figure 39 - Middle Reach - Complete Fish Blockage (X-19)

e. Upper Reach 'B'- perched concrete sewer line crossing in the vicinity of X-5, 1.7' drop, complete blockage (employ riffle grade control structure).

9. Create vernal pools for amphibian habitat in one or more of the following general areas: Upper Reach 'A' and 'B' (as part of larger proposed stream restoration project, cut off portions of one or more stream meanders and convert into vernal pools); Middle Reach (X-15 and X-19 areas)-excavate vernal pools along right hand bank; and Lower Reach 'B' (X-29 area)-excavate vernal pool along right hand bank. Note: several of these vernal pool sites can be excavated by hand using Earth Conservation Corps or other local volunteer labor. Also, in all likelihood the reintroduction of native amphibians such as spotted salamanders (*Ambystoma maculatum*), wood frogs (*Rana sylvatica*) and spring peepers (*Hyla crucifer*) will require the physical transplantation of eggs and/or larvae from other Anacostia sites.

10. Create an approximately 0.15 acre, off-line excavated wetland along the right hand bank portion of Lower Reach 'B' immediately upstream of Fairlawn Avenue (Figure 40). Potential water supply for the wetland includes interception of the water table and/or diversion of stormwater runoff from nearby 'M' Place.

Figure 40 - Lower Reach 'B' - Recommended Off-Line Excavated Wetland Site

11. The boulder/rubble fill slope located along the left hand bank in the Middle Reach X-14 to X-18 area is exhibiting signs of localized slope failure Figure 41. In COG staff's opinion, a geotechnical study should be undertaken of this area to determine its potential long-term stability.

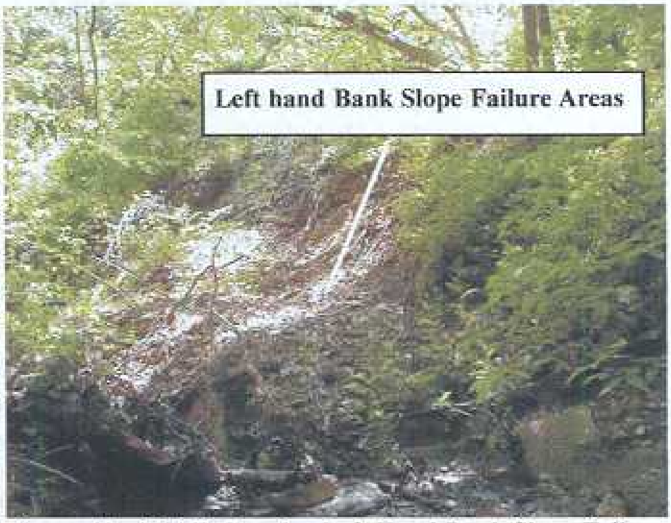


Figure 41 - Middle Reach - Left Hand Bank Slope Failure Area

12. A community-based clean up of trash and debris from the entire Pope Branch stream valley park system is needed (Figure 42). Major trash/dump sites include Upper Reach 'A' (left hand bank, X-2 and X-3 areas) and Lower Reach 'A' (left hand bank, X-25 and Minnesota Avenue areas).

13. At a minimum, appropriate stream signage and no dumping signs should be installed at major stream crossings such as Branch and Minnesota Avenues. In addition, the stenciling of all storm drain inlets in the Pope Branch subwatershed with a "No Dumping-Drains to Pope Branch" message should be made a high priority.

14. A volunteer-based exotic/invasive plant management initiative modeled after Montgomery County's "Weed Warrior" program should be seriously considered for the Pope Branch stream valley park system.

15. Based on recent success in the neighboring Fort Dupont Tributary, reintroduce native fishes (after the main trunk sewer line problems have been addressed) into the Middle and Lower Reach portions of Pope Branch. The recommended species and approach are described below:

Figure 42 - Lower Reach 'A' - Dump Site Upstream of Minnesota Avenue (X-25)

• Using COG's previous stream restoration experience in the Anacostia's Sligo Creek subwatershed and Table 17 as reference, the following six pollution tolerant species should be considered for reintroduction: blacknose dace (*Rhinichthys atratulus*), northern creek *chub (Semotilus atromaculatus*), white sucker (*Catostomus commersoni*), tessellated darter (*Etheostoma olmstedi*), swallowtail shiner (*Notropis procne*) and satinfin shiner (*Notropis analostanus*). The preceding species may be easily collected in good numbers from various Anacostia streams, including the Northeast and Northwest Branches, Lower Beaverdam Creek, Watts Branch, etc.

• Stocking should be phased, with the hardiest pioneer species, such as the blacknose dace and northern creek chub, being introduced first. As a rough stocking density guide, COG staff recommend that approximately 10-12 blacknose dace and two to four northern creek chub individuals be stocked per high quality pool (i.e., approximately 120-150 blacknose dace and 25-35 northern creek chubs, total). If the two preceding species survive as expected, then the four remaining recommended species should be reintroduced; with white suckers being introduced last and only after overall post restoration physical aquatic habitat conditions have markedly improved. Additional future stockings beyond the recommended six target species should only occur after both stream restoration and stormwater retrofitting work have been completed and monitoring results indicate a recovering stream system.

16. Continue physical, chemical and biological monitoring of Pope branch so as to evaluate stream recovery from both the recent drought and restoration projects.

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Appendix 1

Table 1 - Pope Branch - Corresponding Latitude and Longitude Coordinates for RSAT Transects

Transect Number	Latitude	Longitude
Pope Branch Upper Mainstem – Reach 'A'		
1	38.872190	-76.950114
2	38.872410	-76.950844
3	38.872580	-76.951461
4	38.872800	-76.952094
Pope Branch Upper Mainstem – Reach 'B'		
5	38.872890	-76.952743
6	38.872940	-76.953440
7	38.873230	-76.953789
8	38.873320	-76.954047
9	38.873320	-76.954395
10	38.873350	-76.955114
11	38.873460	-76.955602
12	38.873040	-76.955833
Pope Branch Middle Mainstem		
13	38.872800	-76.956477
14	38.873030	-76.957083
15	38.873310	-76.957356
16	38.873510	-76.957609
17	38.873710	-76.958065
18	38.873820	-76.958676
19	38.874260	-76.959207
20	38.874680	-76.959658
21	38.874880	-76.960264
22	**38.875120**	-76.960559
Pope Branch Lower Mainstem – Reach 'A'		
23	38.875810	-76.962490
24	38.876040	-76.963059
25	38.876330	-76.963447
26	38.876600	-76.963906
Pope Branch Lower Mainstem – Reach 'B'		
27	38.876970	-76.964470
28	38.877070	-76.965194
29	38.877340	-76.965419
30	38.877390	-76.966186

Appendix 2

Table 1 – Summary - Reference Stream – Spring and Fall Macroinvertebrate Sample Metrics and MBSS Coastal Plain IBI Scores

Site	Sampling Date	No. of Organisms/m[2]	Taxa Richness[1]	Total No. of EPT Taxa[2]	Percent Ephemeroptera[3] (%)	Percent Tanytarsini[4] (%)	Beck's Biotic Index[5]	No. of Scraper Taxa[6]	Percent Clingers[7] (%)	MBSS IBI Score[8]	MBSS IBI Verbal Ranking
					Spring						
Upper Beaverdam Creek	4/12/1999	639	24	7	3	0.00	11	5	53.6	**3.3**	Fair
Silverwood Tributary	4/27/1999	1028	14	6	3	0.47	8	3	73.1	**3.6**	Fair
					Fall						
Upper Beaverdam Creek	11/22/1999	194	12	5	2	0.00	3		71.1	**3.0**	Fair
Silverwood Tributary	11/22/1999	312	20	11	4	0.00	14	3	23.1	**3.0**	Fair
Fort Dupont					**Spring**						
Upper	04/14/1999	40	10	1	0	0	1	0	2.5	**1.0**	Very Poor
Middle	04/14/1999	66	9	1	0	0	4	0	6.1	**1.3**	Very Poor
Lower	04/14/1999	123	10	1	0	0	2	1	0.8	**1.3**	Very Poor
Tributary Number 2	04/14/1999	806	12	2	0	0	5	0	1.6	**1.6**	Very Poor
Fort Dupont					**Fall**						
Upper	11/22/1999	32	8	0	0	0	3	0	3.1	**1.0**	Very Poor
Middle	12/13/2002	84	8	0	0	0	4	0	6.0	**1.0**	Very Poor
Lower	11/22/1999	49	7	0	0	0	1	0	0.0	**1.0**	Very Poor
Tributary Number 2	12/13/2002	229	13	1	0	0	8	0	2.2	**1.2**	Very Poor

1 Taxa richness represents the total number of taxa collected and is interpreted by MBSS as follows: ≥25 = Good, 11-24 = Fair, <11 = Poor.

2 Counts the distinct taxa considered pollution intolerant within the groups of Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies). EPT taxa metrics are interpreted as follows: >6 = Good, 3 - 6 = Fair, and <3 = Poor.

3 Measures the abundance of generally pollution intolerant Ephemeroptera (mayflies) relative to other often more tolerant individuals and is interpreted as follows: >11.4% = Good, 2.0 – 11.4% = Fair and < 2.0% = Poor.

4 Measures the abundance of generally pollution intolerant Tanytarsini (midgeflies) relative to other more tolerant Chironomidae and is interpreted as follows: >13.0% = Good, 0.0 – 13.0% = Fair and < 0.0% = Poor.

5 The Beck's Biotic Index is a weighed enumeration of two Class of organic pollution tolerant taxa, the most tolerant and the second most tolerant groups. The index is interpreted as follows: >12 = Good, 4.0-12.0 = Fair and <4.0 = Poor.

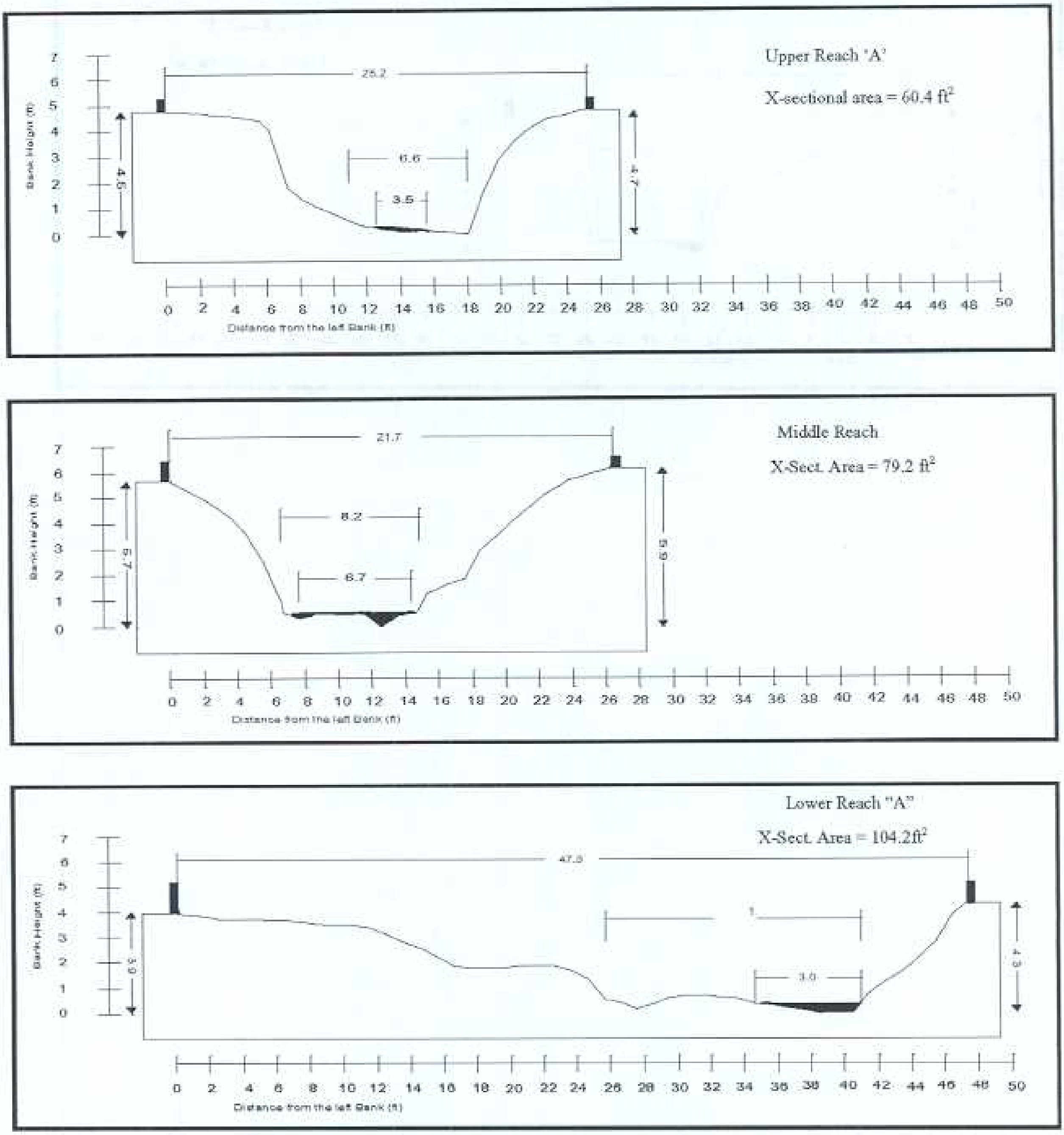
6 The number of herbivorous scrapers is a metric used to reflect available food resources like periphyton and microfauna which may themselves be more abundant under conditions of minimal perturbation. This value is interpreted as follows: >4 = Good, 1-4 = Fair, <1 = Poor.

7 Measure the organisms that are behaviorally and morphologically adapted to clinging to surfaces in fast moving riffles. Percent ratios are interpreted as follows: ≥62.1% = Good, 38.7 – 62.1% = Fair and <38.7% = Poor.

8 Index of Biological Integrity developed by Maryland Department of Natural Resources, Maryland Biological Stream Survey (MBSS). MBSS IBI Score interpretation 4.0-5.0 = Good, 3.0-3.9 = Fair, 2.0-2.9 = Poor, <1.9 = Very Poor.

Appendix 3

Figure 1 - Pope Branch - Permanent Channel Cross-Sections[1]



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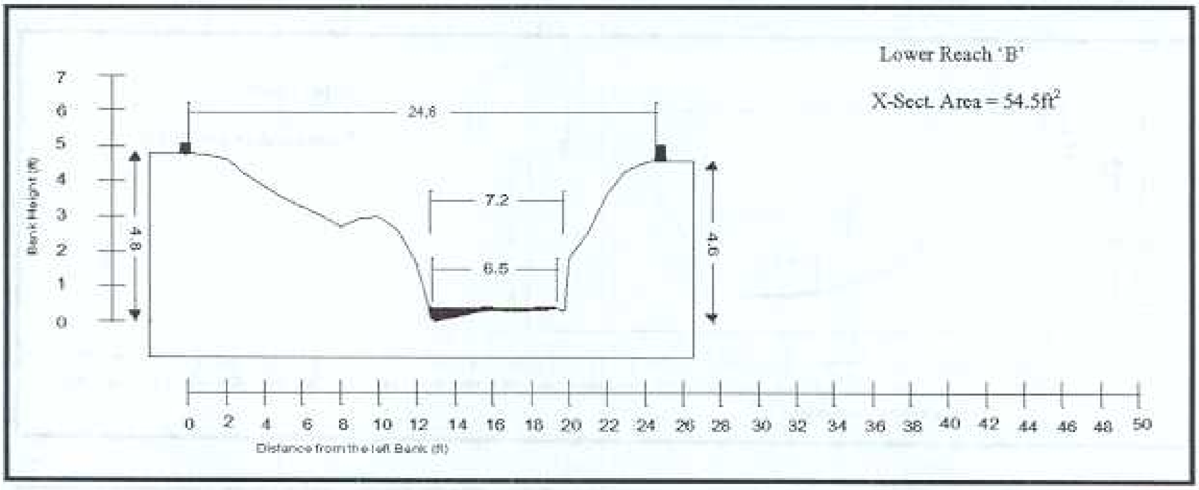
[1] Top Channel width, bottom channel width, and wetted perimeter area (heavy black line) depicted.

Figure 1: Continued[1]



[1] Top Channel width, bottom channel width, and wetted perimeter area (heavy black line) depicted.

Appendix 4

Table 1 - Pope Branch - RSAT Field Data

Stream: Upper Reach 'A' — Topo Map(s): 6268 — RSAT Score:

Reach: Fort Davis to Texas Avenue — Survey Date: 01/16/03

Transect Number	Top Channel Width	Bottom Channel Width	Wetted Perimeter	Mean Riffle Depth	Mean Bank Height R	Mean Bank Height L	Mean Bank Stability R & L	Bank Material Type	Bank Material Type	Substrate Material Comp.	Mean Riffle Embedd-edness	Mean Substrate Fouling Level	Riparian Veg. Type	Riparian Veg. Type	Buffer Width	Buffer Width	Max. Pool Depth	Pool Habitat Quality	Time	TDS	Turb.	pH	DO	Temp Air	Temp Water	Nitrate -Nitrogen (mg/L)	Fl	Phos-phate (mg/L)
	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(%)	R	L		(%)	(%)	R	L	R	L	(ft)		(hr)	(mg/L)	(NTU)		(mg/L)	(C)	(C)		(mg/L)	
X-1	6.28	4.14	-	-	2.16	2.36	95	L/S	SL/L	-	-	-	F	F	200	80	-	-										
X-2	5.78	3.63	-	-	.88	.88	95	SL/L	SL/L	-	-	-	F	F	200	43	-	-	Dry Channel									
X-3	6.24	3.34	-	-	2.04	1.13	93	SL/S	SL/S	-	-	-	F	F	200	48.1	-	-										
X-4	8.6	3.06	-	-	1.76	3.14	93	SL/S	SL/S	-	-	-	F	F	200	92.5	-	-										
Average	6.7	3.5	-	-	1.7	1.9	94	-	-	-	-	-	-	-	>200	>66	-	-										

Stream: Upper Reach 'B' — Topo Map(s): 6268-6168 — RSAT Score:

Reach: Texas Avenue to 35th Street — Survey Date: 01/16/03

Transect Number	Top Channel Width	Bottom Channel Width	Wetted Perimeter	Mean Riffle Depth	Mean Bank Height R	Mean Bank Height L	Mean Bank Stability R & L	Bank Material Type	Bank Material Type	Substrate Material Comp.	Mean Riffle Embedd-edness	Mean Substrate Fouling Level	Riparian Veg. Type	Riparian Veg. Type	Buffer Width	Buffer Width	Max. Pool Depth	Pool Habitat Quality	Time	TDS	Turb.	pH	DO	Temp Air	Temp Water	Nitrate -Nitrogen (mg/L)	Fl	Phos-phate (mg/L)
	(ft)	(ft)	(ft)	(ft)	ft)	(ft)	(%)	R	L		(%)	(%)	R	L	R	L	(ft)		(hr)	(mg/L)	(NTU)		(mg/L)	(C)	(C)		(mg/L)	
X-5	16.5	13.3	-	-	4.0	4.5	66	SL	SL	-	-	-	F	F	>200	>200	-	-										
X-6	14.65	8.47	-	-	3.0	3.6	55	S	CL/S	-	-	-	F	F	>200	120	-	-										
X-7	15.3	7.2	-	-	3.1	3.8	45	S	CL/S	-	-	-	F	F	>200	200	-	-										
X-8	16.38	5.05	-	-	2.12	3.6	61.5	S	CL/S	-	-	-	F	F	>200	>200	-	-										
X-9	18.23	0.62	-	-	5.05	4.72	57.5	S/CL	S	-	-	-	F	F	>200	>200	-	-	Dry Channel									
X-10	16.4	4.57	-	-	3.6	4.7	62.5	S	S/SL	-	-	-	F	F	>200	>200	-	-										
X-11	12.85	7.54	-	-	2.8	2.7	55	S/CL	Concrete	-	-	-	F	F	>200	>200	-	-										
X-12	15.78	10.8	-	-	2.3	3.1	52.5	SL	SL	-	-	-	F	F	>200	130	-	-										
Average	15.8	9.1	-	-	3.2	3.8	56.9	-	-	-	-	-	-	-	>200	>200	-	-										

Table 1 - Pope Branch - RSAT Field Data (continued)

Stream: Middle Reach
Reach: 35th Street to Branch Avenue

Topo Map(s): 6188
Survey Date: 7/11/02

RSAT Score: 27

Transect Number	Top Channel Width	Bottom Channel Width	Wetted Perimeter	Mean Riffle Depth	Mean Bank Height R	Mean Bank Height L	Mean Bank Stability R & L	Bank Material Type	Bank Material Type	Substrate Material Comp.	Mean Riffle Embedd-edness	Mean Substrate Fouling Level	Riparian Veg. Type	Riparian Veg. Type	Buffer Width	Buffer Width	Max. Pool Depth	Pool Habitat Quality	Time	TDS	Turb.	pH	DO	Temp Air	Temp Water	Nitrate-Nitrogen (mg/L)	Fl	Phos-phate (mg/L)
	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(%)	R	L		(%)	(%)	R	L	R	L	(ft)		(hr)	(mg/L)	(NTU)		(mg/L)	(C)	(C)		(mg/L)	
X-13	22.4	7.5	2.5	.10	5.5	4.1	95	SL/S	SL/S	G,C,R,S,B	60	30	F	F	>200	150	2.7	Excellent	10:30	200	0	5.23	2.80	22.0	16.3	2.2	0.2	0.03
X-14	15.3	9.4	6.8	.14	3.9	2.9	92.5	S/SL	SL/S	G,S,C,R,B	80	40	F	F	>200	175	0.9	Good										
X-15	14.5	9.8	3.1	.18	3.4	3.4	87.5	S/SL	S/SL	G,C,S,R	40	50	F	F	>200	130	1.4	Excellent										
X-16	14.5	9.1	3.4	.10	3.8	3.0	80	S/SL	S/SL	G,C,S,R	40	60	F	F	>200	125	1.1	v. Good										
X-17	15.7	5.7	3.2	.10	3.7	3.7	72.5	S/SL	SL/S	G,C,S,R,B	50	25	F	F	>200	125	1.9	Fair										
X-18	11.0	7.2	3.3	.10	3.2	3.9	85	S/SL	SL/S	G,S,R	75	25	F	F	>200	125	0.9	Good										
X-19	18.5	12.0	3.5	.09	3.5	3.8	80	SL/S	S/SL	G,S,C,R	40	10	F	F	>200	100	1.8	Fair										
X-20	21.0	9.5	2.7	.09	3.1	2.7	77.5	C/S	SL/S	G,S,C,R	30	15	F	F	100	100	0.8	Fair										
X-21	14.0	8.2	3.4	.10	2.5	2.9	82.5	SL/S	SL/S	G,S,C	50	10	F	F	150	150	0.8	Good										
X-22	17.0	13.8	4.8	.08	2.3	2.5	95	SL/S	S/SL	G,S,C,R	75	10	F	F	200	200	2.0	Excellent	10:50	180	0	5.59	4.9	21.0	19.0	1.7	0.2	0.56
Average	**16.4**	**9.2**	**3.7**	**0.11**	**3.5**	**3.3**	**84.8**				**54**	**27.5**					**1.4**			**190**	**0**	**5.41**	**3.85**	**21.5**	**17.65**	**1.95**	**0.2**	**0.29**

Stream: Lower Reach 'A'
Reach: Branch Avenue to Minnesota Avenue

Topo Map(s): 6168
Survey Date: 7/15/02

RSAT Score: 22

Transect Number	Top Channel Width	Bottom Channel Width	Wetted Perimeter	Mean Riffle Depth	Mean Bank Height R	Mean Bank Height L	Mean Bank Stability R & L	Bank Material Type	Bank Material Type	Substrate Material Comp.	Mean Riffle Embedd-edness	Mean Substrate Fouling Level	Riparian Veg. Type	Riparian Veg. Type	Buffer Width	Buffer Width	Max. Pool Depth	Pool Habitat Quality	Time	TDS	Turb.	pH	DO	Temp Air	Temp Water	Nitrate-Nitrogen (mg/L)	Fl	Phos-phate (mg/L)
	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(%)	R	L		(%)	(%)	R	L	R	L	(ft)		(hr)	(mg/L)	(NTU)		(mg/L)	(C)	(C)		(mg/L)	
X-23	23.3	11.5	6.0	0.08	3.7	3.4	78	S1/S	CL/L	G,S,C,R,C L	73	28	F	F	120	90	1.1	Fair										
X-24	18.5	10.8	6.5	0.06	3.4	2.9	87	S/L	S1/S	G,S,C,R	80	30	F	F	120	90	2.0	Good										
X-25	13.4	8.5	3.5	0.09	2.3	1.6	59	S1/S	S	G,S,C,R,C L	43	10	F	F	120	50	1.0	Good										
X-26	14.5	6.5	3.5	0.08	4.0	3.2	91	S1/S	S1/S	G,S,C	90	15	F	F	200	132	0.9	Poor	10:00	170	0	5.63	5.63	21.55	18.8	2.3	0.3	1.77
Average	**17.4**	**9.3**	**4.8**	**0.08**	**3.4**	**2.8**	**78.9**				**71.5**	**20.7**			**140**	**98.5**	**1.3**			**170**	**0**	**5.63**	**5.63**	**21.55**	**18.8**	**2.3**	**0.3**	**1.77**

Table 1 - Pope Branch - RSAT Field Data (continued)

Stream: Lower Reach 'B'
Reach: Minnesota Avenue to Fairlawn Avenue

Topo Map(s): 6169
Survey Date: 7/16/02

RSAT Score: 21

Transect Number	Top Channel Width	Bottom Channel Width	Wetted Perimeter	Mean Riffle Depth	Mean Bank Height R	Mean Bank Height L	Mean Bank Stability R & L	Bank Material Type	Bank Material Type	Substrate Material Comp.	Mean Riffle Embedd-edness	Mean Substrate Fouling Level	Riparian Veg. Type	Riparian Veg. Type	Buffer Width	Buffer Width	Max. Pool Depth	Pool Habitat Quality	Time	TDS	Turb.	pH	DO	Temp Air	Temp Water	Nitrate-Nitrogen (mg/L)	Fl	Phos-phate (mg/L)
	(ft)	(ft)	(ft)	(ft)	ft)	(ft)	(%)	R	L		(%)	(%)	R	L	R	L	(ft)		(hr)	(mg/L)	(NTU)		(mg/L)	(C)	(C)		(mg/L)	
X-27	24.7	13.0	3.2	0.1	2.3	2.6	73	Sl/S	S/Sl	G,S,C	49	35	F/Gr	F	150	50	3.5	Excellent	09:00	230	1	6.52	5.93	-	20.8	-	-	-
X-28	18.3	12.0	4.7	0.08	2.0	1.1	93	S/Sl	Sl/S	G,S,C	70	15	F/Gr	F	186	60	1.9	V. Good										
X-29	14.5	11.3	6.6	0.07	2.4	3.3	57.3	Sl/S	Sl/S	G,S,C,R	70	25	F/Gr	F	100	150	1.1	Good										
X-30	11.5	5.6	4.5	0.09	4.6	3.1	70	Sl/S	Sl/S	G,S,C,R	72	20	Sh/Gr	F	180	60	1.0	Good	09:50	180	0	5.55	7.00	21.2	18.5	1.5	0.4	.10
Average	17.2	10.5	4.7	0.09	2.8	2.5	73.3				65.3	23.8			154	80	1.9			205	0.5	6.0	6.5	21.2	19.7	1.5	0.4	0.1

Appendix 5

Table 1. Pope Branch – Macroinvertebrate 20 Jabs (~2m^2) Feeding Functional Group and Pollution Tolerance Values

Order	Taxa	Common Name	Pollution Tolerance[1]	Functional Feeding Group[2]
Ephemeroptera	1. Baetis sp.	Mayfly	6	Collector
Trichoptera	2. Cheumatopsyche sp.	Caddisfly	5	Filterer
	3. Hydropsyche sp.	Caddisfly	6	Filterer
Anisoptera	4. Boyeria sp.	Dragonfly	2	Predator
	5. Libellula sp.	Dragonfly	9	Predator
Zygoptera	6. Calopteryx sp.	Damselfly	6	Predator
	7. Lestes sp.	Dragonfly	6	Predator
Coleoptera	8. Agabus sp.	Beetle	5	Predator
	9. Celina sp.	Beetle	5	Predator
	10. Cybister sp.	Beetle	5	Predator
	11. Dytiscus sp.	Beetle	5	Predator
	12. Hydroporus sp.	Beetle	5	Predator
	13. Sperchopsis sp.	Beetle	5	Collector
	14. Stenelmis sp.	Beetle	5	Collector
	15. Uvarus sp.	Beetle	5	Predator
Diptera	16. Anopheles sp.	Mosquito	9	Collector
	17. Bittacomorpha sp.	False Cranefly	5	Collector
	18. Chironomini	Midge	6	Collector
	19. Culex sp.	Mosquito	10	Filterer
	20. Limnophila sp.	Cranefly	4	Predator
	21. Orthocladiinae	Midge	5	Collector
	22. Psychoda sp.	Mothfly	5	Collector
	23. Pyralidae	Aquatic Butterfly	6	Shredder
	24. Simulium sp.	Blackfly	7	Filterer
	25. Tanypodinae	Midge	6	Predator
	26. Tipula sp.	Cranefly	4	Shredder
	27. Tipulidae	Cranefly	5	Shredder
Gastropoda	28. Gyraulus parrus	Snail	8	Scraper
	29. Physella sp.	Snail	8	Scraper
Hemiptera	30. Notonecta sp.	Backswimmer	10	Filterer
Decapoda	31. Cambaridae	Crayfish	6	Shredder
Isopoda	32. Asellus sp.	Sowbug	8	Collector
Amphipoda	33. Gammarus sp.	Scud	6	Shredder
Collembola	34. Collembola	Water Flea	5	Collector
Lepidoptera	35. Pyralidae	Aquatic Butterfly	6	Shredder
Nematomorpha	36. Nematomorpha	Horse Hair	10	Collector
Oligochaeta	37. Oligochaeta	Aquatic Worm	10	Collector

[1] A number assigned to an individual or its group describing the degree to which that individual or group tolerates organic pollution.
[2] Feeding adaptations that classify the nutritional processing method performed by different aquatic insects (Merritt and Cummins, 1984).

Table 2. Pope Branch - Macroinvertebrate RSAT Voucher Collection – Relative Abundance[1]

Taxa	Tolerance Value[2]	Middle Reach	Lower Reach 'A'	Lower Reach 'B'
Ephemeroptera (Mayflies)	A/B			
1. Baetis sp.	B	1	1	
Trichoptera (Caddisflies)	A/B			
2. Hydropsyche sp.	B	1	1	
3. Cheumatopsyche sp.	B		1	
Anispotera (Dragonflies)	B			
4. Boyeria sp.	A/B	1		1
Zygoptera (Damselflies)	B			
5. Lestes sp.	B	1	1	1
Coleoptera (Beetles)	B			
6. Cybister sp.	B	2		
7. Stemelmis sp.	B	1		
8. Uvarus sp.	B		1	1
9. Dytiscus sp.	B	1	1	1
Diptera (True Flies)	B/C			
10. Bittacomorpha sp.	B	1	1	1
11. Chironomini (Midgeflies)	B	2	1	1
12. Limnophila sp. (Craneflies)	B	1		1
13. Orthocladiinae (Midgeflies)	B	1		
14. Tanypodinae (Midgeflies)	B	1	1	1
15. Tipula sp. (Craneflies)	B	1	1	1
16. Simulium sp. (Blackflies)	B/C	1		1
17. Anopheles sp. (Mosquitoes)	C	1		2
18. Culex sp. (Mosquitoes)	C	2	2	2
Lepidoptera (Aquatic Buttferlies)	B/C			
19. Pyralidae	B	1		1
Amphipoda	B/C			
20. Gammarus sp. (Scuds)	B	1		
Gastropoda	B/C			
21. Physa sp. (Snails)	B	1		1
22. Gyraulus parrus	B/C	1		
Isopoda	B/C			
23. Asellus sp. (Sowbugs)	B/C		1	1
Oligochaeta (Aquatic Worms)				
24. Oligochaeta (Aquatic Worms)	C	2	1	1
Total Taxa		21	13	16

[1] Relative abundance scores were averaged for each mainstem reach. Relative abundance interpretation: 0.1-0.9 = Scarce, 1.0-2.0 = Scarce/Common, 2.1-3.0 = Common, 3.1-4.0 = Common/Abundant, 4.1-5.0 = Abundant.

[2] Pollution Tolerance Rating: A = Intolerant, B = Moderately Tolerant, C = Tolerant

Table 3. Pope Branch and Fort Dupont - Number of Individuals Macroinvertebrate 20 Jabs (~$2m^2$)

			Pope Branch						Fort Dupont	
			Middle Reach	Lower Reach A	Lower Reach B	Middle Reach	Lower Reach A	Lower Reach B	Middle	Trib. # 2
Taxa	Tolerance Value[1]	Common Name	S 02	S 02	S 02	F 02	F 02	F 02	F 02	F 02
Ephemeroptera (Mayflies)	A/B									
1. Baetis sp.	B	Mayfly				1				
Trichoptera (Caddisflies)	A/B									
2. Cheumatopsyche sp.	B	Caddisfly					2			
3. Hydropsyche sp.	B	Caddisfly		2	1		16	9		
4. Ptilostomus sp.	B	Caddisfly								1
Megaloptera (Fishflies and Alderflies)	B									
5. Sialis sp.	B	Fishfly								5
Anispotera (Dragonflies)	B									
6. Boyeria sp.	A/B	Dragonfly	1			7				
7. Calopteryx sp.	B	Damselfly					8	44		
8. Libellula sp.	C	Dragonfly	1							
Coleoptera (Beetles)	B									
9. Cybister sp.	B	Beetle	1			9				
10. Dytiscus sp.	B	Beetle			4					
11. Hydrobius sp.	B	Beetle							1	
12. Hydroporus sp.	B	Beetle		1		8	3	10		6
13. Sperchopsis sp.	B	Beetle						1		
14. Collembola	B	Beetle						1		
15. Agabus sp.	B	Beetle		7				2	1	2
16. Celina sp.	B	Beetle				1				
Diptera (True Flies)	B/C									
17. Bittacomorpha sp.	B	False Cranefly				1	2			
18. Chironomini	B	Midge		69	12		6	10	1	4
19. Culex sp.	C	Mosquito				3				
20. Orthocladiinae	B	Midge		21	23	1	7	2	48	60
21. Psychoda sp.	B	Mothfly	64			1				
22. Tanypodinae	B	Midge	7	30	20	5	17	7		7
23. Tanytarsini	B	Midge								1
24. Tipulidae	B	Cranefly	57							
25. Ormosia sp.	B	Cranefly							1	2
26. Tipula sp.	B	Cranefly		7	16	10	16	27	24	102
Lepidoptera (Aquatic Buttferlies)	B									
27. Pyralidae	B	Aquatic Butterfly			1					
Amphipoda	B/C									
28. Gammarus sp.	B	Scud				17				8
Gastropoda	B/C									
29. Physa sp.	B	Snail		19	8		10	1		
Hemiptera										
30. Notonecta sp.	C	Backswimmer					1			
Decapoda	B/C									
31. Cambaridae	B	Crayfish	1		1			1		1
Oligochaeta										
32. Oligochaeta	C	Aquatic Worm	8	58	3	34	25	4	8	30
Nematomorpha										
33. Nematomorpha	C	Horse Hair			1					
		Total	140	214	90	98	113	119	84	229

[1] Pollution Tolerance Rating: A = Intolerant, B = Moderately Tolerant, C = Tolerant
Note: A blank cell indicates the macroinvertebrate group was not found during 20 jab sampling.

Appendix 6

Table 1. Pope Branch Baseflow Grab Sampling Results (July-September 2002[1])

	Unit	Detection Limit	07/23	08/08	09/09
1. Alkalinity, Total (as Ca Co3)	mg/L	2	50	58	64
2. Hardness (total)	mg/L	5	140	130	120
3. pH			6.84	6.77	6.24
4. Specific Conductance	mmhos/cm	1	360	400	420
5. Dissolved Solids	mg/L	1	240	240	210
6. Total Suspended Solids	mg/L	5	ND	ND	6
7. Turbidity	NTU	0.5	2.5	2	5.3
8. Nitrate Nitrogen	mg/L	0.05	0.57	0.57	0.7
9. Ortho Phosphate	mg/L	0.020	0.02	ND	0.026
10. Total Phosphorous	mg/L	0.02	0.024	0.038	0.066
11. Total Organic Carbon	mg/L	1	3.2	4.4	3.3
12. Biochemical Oxygen Demand – 5 Day	mg/L	5	ND	ND	11
13. Cadmium	ug/L	1	ND	1.7	ND
14. Copper	ug/L	5	ND	ND	ND
15. Iron	mg/L	0.05	0.54	0.42	1
16. Total Petroleum Hydrocarbons	mg/L	1	ND	ND	ND
17. Surfactants (MBAS)	mg/L	0.03	4.2	ND	0.056
18. Fecal Coliform	MPN	2	-	500	790
19. Total Coliform	MPN	2	22000	-	>16000

[1] Chemical analysis performed by CT&E Environmental Services Inc.
Note: ND indicates no data reported.

Table 2. Pope Branch Stormflow Grab Sampling Results (August-October 2002[1])

	Unit	Detection Limit	08/28	09/26	10/10	10/11	10/16	10/30
Rainfall (in.)			1.36	0.73	0.58	0.78	1.38	0.35
1. Alkalinity, Total (as Ca Co3)	mg/L	2	32	42	47	30	31	26
2. Hardness (total)	mg/L	5	70	90	110	86	72	66
3. PH			7.20	6.86	6.49	7.55	7.08	7.78
4. Specific Conductance	mmhos/cm	1	220	280	240	100	150	110
5. Dissolved Solids	mg/L	1	260	210	ND	ND	ND	260
6. Total Suspended Solids	mg/L	5	190	55	ND	96	120	82
7. Turbidity	NTU	0.5	150	48	11	100	50	49
8. Nitrate Nitrogen	mg/L	0.05	1.3	0.80	0.85	0.35	0.51	0.67
9. Ortho Phosphate	mg/L	0.02	ND	0.08	0.04	ND	0.15	0.16
10. Total Phosphorous	mg/L	0.02	ND	0.24	ND	0.18	0.54	0.11
11. Total Organic Carbon	mg/L	5	14	9.8	7.9	6	6.1	5.8
12. Biochemical Oxygen Demand – 5 Day	mg/L	2	8.2	5.8	2.2	3.6	4.9	3.0
13. Cadmium	ug/L	1	ND	ND	ND	ND	4.2	ND
14. Copper	ug/L	5	21	6.3	14	10	13	6.4
15. Iron	mg/L	0.05	10	2.2	0.56	4.3	1.7	0.86
16. Total Petroleum Hydrocarbons	mg/L	1	1.1	ND	ND	1.5	2.3	1.1
17. Surfactants (MBAS)	mg/L	0.03	0.18	0.10	0.086	0.086	0.063	0.049
18. Fecal Coliform	MPN	2.0	-	23,000	160	-	33,000	49,000
19. Total Coliform	MPN	2.0	-	33,000	-	-	33,000	490,000

[1] Chemical analysis performed by CT&E Environmental Services Inc.
Note: ND indicates not detected.

Table 3. Summary: Pope Branch – Instantaneous Baseflow Water Chemistry (May-December 2002)

Sample Site	Date	Air Temp C	Water Temp C	DO (mg/L)	pH	TDS (mg/L)	Cond. (uS/cm)	Turb. (NTU)	Nitrate (mg/L)	Flouride (mg/L)	Ortho Phosphate (mg/L)	Copper (mg/L	Iron (mg/L)
Middle	7/15/2002	21.9	71.4	2.36	5.28	290	455	0	-	-	-	-	-
Middle	7/23/2002	27.5	81.5	1.93	6.03	270	402	0	-	0.33	0.04	-	-
Middle	8/02/2002	30.9	87.7	3.64	6.25	230	347	1	-	0.26	0.21	-	-
Middle	8/09/2002	22.1	71.8	5.25	6.22	200	354	1	-	0.15	0.31	-	-
Middle	8/22/2002	28.2	82.8	4.32	5.82	210	326	1	-	0.15	0.2	-	-
Middle	9/05/2002	28.4	83.2	5.58	5.32	200	305	1	-	0.17	0.11	-	-
Middle	9/10/2002	26.3	79.4	3.48	5.66	270	406	1	-	0.19	0.10	-	-
Middle	11/08/2002	11.7	53.1	3.41	5.6	240	320	1	-	0.22	0.34	-	-
Middle	11/27/2002	10	50	4.28	5.56	350	420	0	-	0.07	0.22	-	-
Lower													
Reach A	5/30/2002	24.1	75.3	6.36	6.16	215	290	0	0.9	0.00	0.06	0.02	0.34
Reach A	6/21/2002	27.5	81.5	4.89	6.42	240	336	0	1.8	0.30	0.13	0.03	0.24
Reach A	7/15/2002	29.3	84.8	5.70	6.6	260	337	0	-		-	-	-
Reach A	7/23/2002	20.3	68.5	5.51	6.29	240	348	1	1.5	0.40	0.17	0.06	0.62
Reach A	8/2/2002	27.6	81.6	4.76	6.3	270	345	0	1.2	0.59	0.17	0.08	0.74
Reach A	8/9/2002	27.7	81.8	5.51	5.9	260	339	1	2.6	0.44	0.05	0.12	0.71
Reach A	8/16/2002	24.7	76.4	5.61	5.83	210	326	0	1.2	0.38	0.09	0.02	0.37
Reach A	8/22/2002	24.8	76.7	4.21	5.69	210	317	1	1.8	0.22	0.16	0.04	0.39
Reach A	9/5/2002	10.2	50.4	4.03	6.24	260	345	0	3.4	0.30	0.17	0.05	0.39
Reach A	9/10/2002	6.6	43.9	5.45	6.38	250	424	1	2.3	0.32	0.17	0.04	0.25
Reach A	11/8/2002								2.7	0.10	0.06	0	0.36
Reach A	11/27/2002	24.2	75.6	5.12	6.25	210	279	0	0.5	0.16	0.25	0.12	0.38
Reach B	7/15/2002	26.8	80.2	5.37	7.94	270	352	1	-	-	-	-	-
Reach B	7/23/2002	21	69.8	6.10	6.7	240	369	1	-	0.20	0.16	-	-
Reach B	8/2/2002	24.3	75.7	5.54	6.55	240	340	0	-	0.11	0.31	-	-
Reach B	8/9/2002	24.1	75.3	5.86	5.98	240	323	0	-	0.09	0.11	-	-
Reach B	8/22/2002	27.1	80.8	6.30	6.63	210	324	3	-	0.69	0.16	-	-
Reach B	9/5/2002	9.3	48.7	6.66	6.36	260	340	0	-	0.08	0.24	-	-
Reach B	9/10/2002	11.3	52.3	5.68	6.25	300	409	0	-	0.24	0.12	-	-
Reach B	11/8/2002	21.9	71.4	2.36	5.28	290	455	0	-	0.20	0.11	-	-
Reach B	11/27/2002	27.5	81.5	1.93	6.03	270	402	0	-	0.21	0.03	-	-

Appendix 7

Figure 1 - Pope Branch - Rosgen Stream Classification- Morphological Description - Level II (Rosgen, 1996)

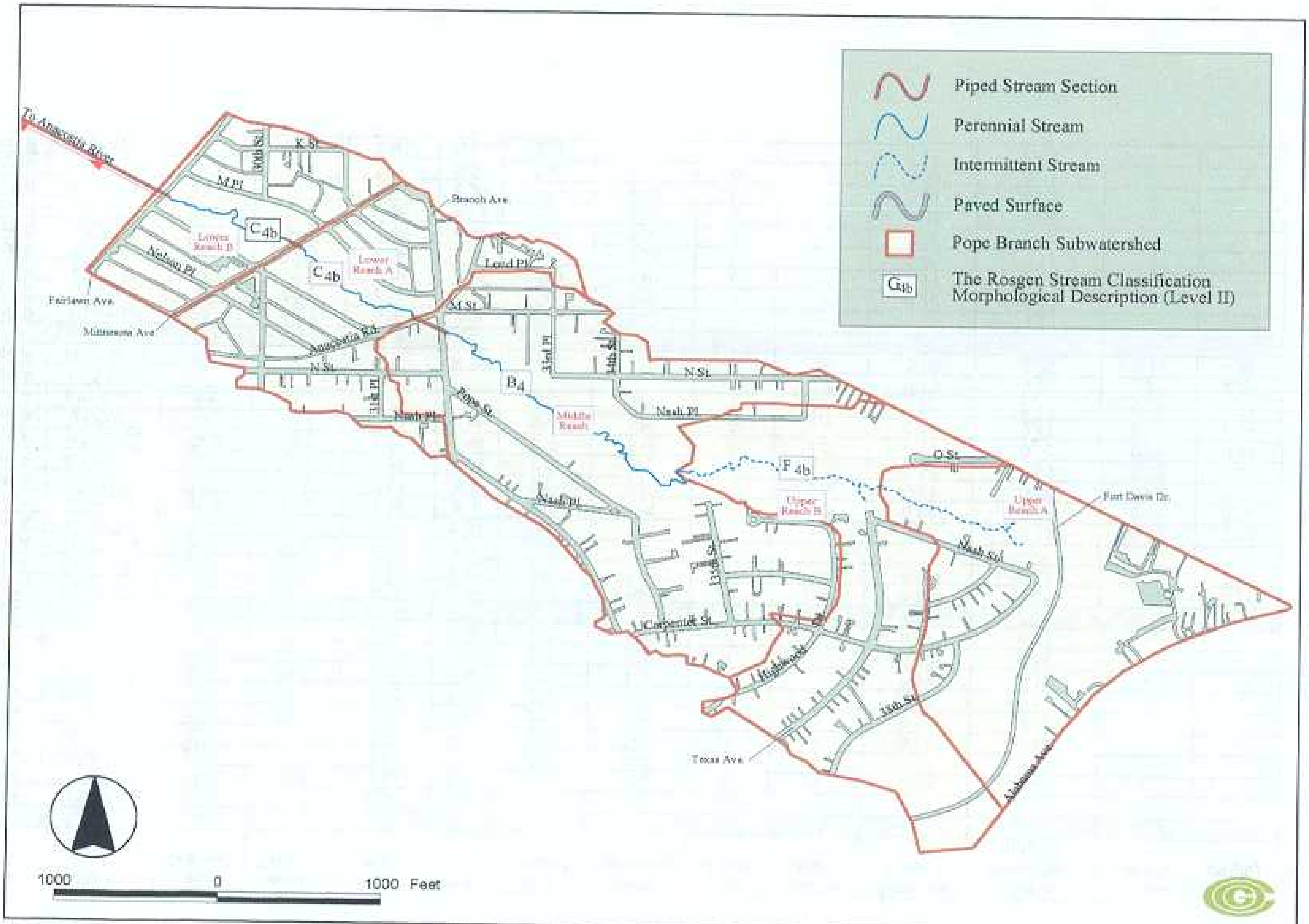


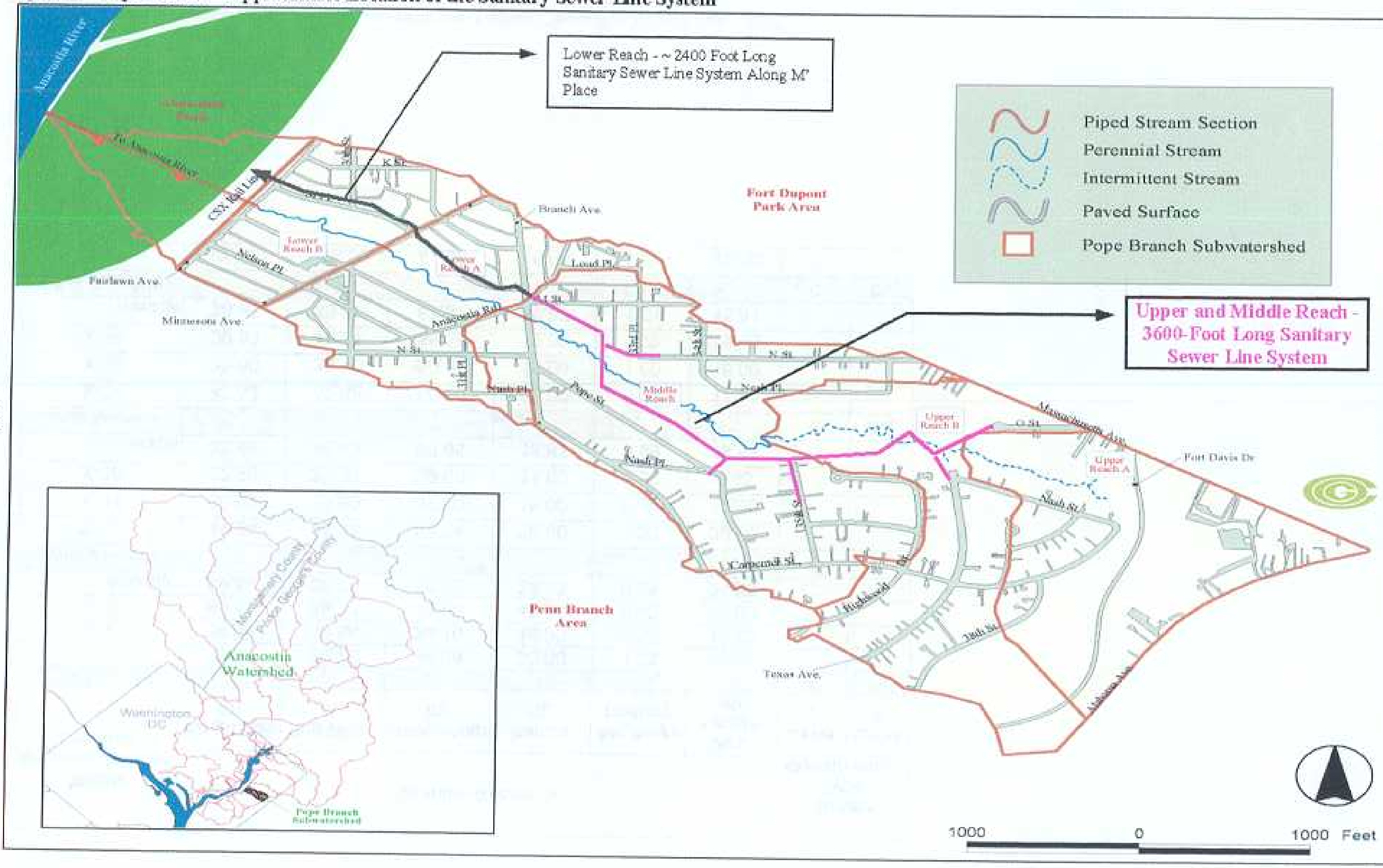
Table 1 - Pope Branch Upper Reach 'B', Middle Reach and Lower Reach 'A' and 'B'– Summary - Rosgen Stream Classification (Level II) – Meander Geometry[1]

Stream Segment/Transect Location	Meander Geometry						Stream Type Classification	
	Amplitude (ft)	Belt Width (ft)	Wavelength (ft)	Radius (ft)	Arc Angle (radian)	Arc Length (ft)	Level I	Level II
Upper Reach 'B'							F	F_{4b}
X-6	62.96	72.76	99.06	30.00	1.23	36.90		
X-7	34.68	39.68	39.10	15.00	0.86	12.90		
X-12	80.86	86.76	41.00	40.00	0.40	16.00		
Average	**59.50**	**66.40**	**59.72**	**28.33**	**0.83**	**21.93**		
Middle Reach							B	B_4
X-13	44.24	48.08	83.34	30.00	1.20	36.00		
X-14	30.93	35.50	57.80	15.00	0.86	12.90		
X-15	22.90	32.31	39.00	11.00	0.63	6.93		
Average	**32.69**	**38.63**	**60.05**	**18.67**	**0.90**	**18.61**		
Lower Reach 'A'							C	C_{4b}
X-24	47.32	52.68	56.10	23.00	0.75	17.25		
X-24	33.69	38.10	50.50	15.00	1.00	15.00		
X-25	29.83	46.81	65.35	12.00	1.29	15.48		
Average	**36.95**	**45.86**	**57.32**	**16.67**	**1.01**	**15.91**		
Lower Reach 'B'							C	C_{4b}
X-29	107.50	110.50	41.50	15.00	1.20	18.00		

[1] Descriptions of the meander geometry can be found in chapter five of *Applied Channel Morphology* (Rosgen ,1996)

Appendix 1

Figure 1 – Pope Branch – Approximate Location of the Sanitary Sewer Line System



Appendix 9

Figure 1 - Storm Drain Outfalls Discharging Directly into Pope Branch