



Hollywood Branch Stream Restoration

Preliminary Assessment Report_ Revised
January 2009

30% Concept Design Report
June 2009



Prepared by:

Chris Wilson
Charles P. Johnson and Associates, Inc.
910 Clopper Road, Suite 215N
Gaithersburg, MD
Phone: (301) 208-9573

Rocky Powell
Clear Creeks Consulting, LLC
1317 Knopp Road
Jarrettsville, MD 21084
Phone: (410) 692-2164

TABLE OF CONTENTS

SECTION 1: FINDINGS REPORT

PROJECT BACKGROUND

TECHNICAL REPORT

I. Study Area	2
II. Scope of Studies	2
III. Watershed Characterization	2
A. Physiography and Basin Morphometry	2
B. Climate	4
C. Geology and Soils	4
D. Land Use	5
E. Hydrology	6
F. Assessment Methods	7
1. Verifying Bankfull Channel Field Indicators	7
2. Field Reconnaissance	7
3. Level II - Morphological Description.	8
4. Level III - Assessment of Stream Condition	8
5. Level IV - Stream Stability Validation Monitoring	8
G. Findings of Field Studies	8
1. General	8
2. Reach 1 - Mainstem Hollywood Branch (Outfall of Stormwater Pond to Copley Lane)Copley Lane)	11
3. Reach 2 - Mainstem Hollywood Branch (Copley Lane to End of Mill Dam Section)	13
4. Reach 3 - Mainstem Hollywood Branch (End of Mill Dam Section to Midland Road)	16
5. Reaches 4.1 – 4.4 - Mainstem Hollywood Branch (Midland Road to Randolph Road)	17
6. Reaches 5.1 – 5.3 – Mainstem Hollywood Branch (Randolph Road to a Point 200 feet DS of Tributary 2)	22
7. Reaches 6.1 – 6.3 – Mainstem Hollywood Branch (A Point 200 feet DS of Tributary 2 to Footbridge over Mainstem)	27
8. Reach 7 - Mainstem Hollywood Branch (Footbridge over Mainstem to Cannon Road)	35
9. Tributary 1 – Upper Reach 5	41
10. Tributary 2 – Lower Reach 5	43
11. Tributary 3 – Middle Reach 6	44
H. Summary and Conclusions	51

SECTION 2: INFRASTRUCTURE REPAIRS

I. Introduction	52
II. Mainstem Reach 1	52
A. Repair 1.1	52
II. Mainstem Reach 4	52
A. Repair 4.2.1	52
IV. Mainstem Reach 5	52
A. Repair 5.1.1	52
B. Repair 5.1.2	52
C. Repair 5.1.3	53
D. Repair 5.3.1	53
E. Repair 5.3.2	53
F. Repair 6.1.1	53
G. Repair 7.1.1	53
V. Tributary 3 – Middle Reach 6	54
A. Repair Trib 3.1.1	54
B. Repair Trib. 3.3.1	54

SECTION 3: STREAM RESTORATION DESIGN

I. Introduction	64
II. Stream Restoration Projects	64
A. General Comments on Approaches to Restoration Design	64
B. Recommended Restoration Projects in the Hollywood Branch Watershed	71
III. Hollywood Branch Restoration Design	78
A. Overview	78
B. General Approach to Hollywood Branch Restoration Design	78
C. Hollywood Branch 30% Design Criteria	79
1. Design Discharges	79
2. Reference Reach Data	79
3. Channel Geometry	80
4. Channel Stabilization Techniques	80
D. Hollywood Branch 60% Design Criteria	81
1. Design Discharges	81
2. Reference Reach Data	81
3. Channel Geometry	81
4. Sediment Entrainment Analysis	82
5. Channel Stabilization Techniques	82

SECTION 4: REFERENCES

APPENDICES

- A. Drainage Area Map
- B. Geomorphic and Infrastructure Assessment Sketches
- C. Mecklenburg Spreadsheets
- D. BEHI Summary Calculations
- E. Reach Stability Rankings
- F. Reference Reach Ratios
- G. 30% Design Cost Estimate

**SECTION 1
FINDINGS REPORT**

PROJECT BACKGROUND

In September 2008, Charles P. Johnson and Associates, Inc. and Clear Creeks Consulting LLC were awarded a task order contract to assess stream stability along Hollywood Branch, between Cannon Road and the culvert inlet under Copley Lane with the end goal of, where deemed appropriate, design restoration approaches that will stabilize erosive areas, improve floodplain access, enhance riparian conditions, enhance stream conditions and improve overall aquatic resources.

Hollywood Branch is located in eastern Montgomery County, Maryland, and is a second order tributary to Paint Branch. Paint Branch is one of three major Montgomery County watersheds that drain to the Anacostia River, a tributary of the Potomac River.

Hollywood Branch is 2 ¼ miles long starting around Notley Road (north of Colesville) and travels through residential neighborhoods and parkland east of New Hampshire Ave until it enters Paint Branch near US 29. In February 2006, Montgomery County DEP completed a watershed study of the Lower Paint Branch including Hollywood Branch. The study evaluated stream conditions and looked for opportunities to improve stormwater management controls in the watershed and prioritized streams for restoration. DEP conducted two public meetings as part of the study to obtain citizen comments regarding watershed conditions and restoration projects proposed in the study. DEP has also received citizen complaints regarding stream erosion from residents on Anderson Street, Clifton Road, Rosmere Avenue, Chilton Drive and Downs Drive.

In the study Hollywood Branch was divided into 3 segments for analysis. All three segments were ranked in the top 8 stream restoration projects. The segment from Notley Road to Cannon Road, which is currently under design by DEP and which is identified in the watershed study as Reach 3, was ranked 2nd among all stream segments in Lower Paint Branch. The Maryland State Highway Administration is currently designing restoration projects for the two segments downstream of Cannon Road as mitigation for the Inter County Connector.

The Lower Paint Branch Watershed is located in a highly developed area and has undergone rapid development changes over the years. Much of the development within the watershed occurred prior to requirements to mitigate the impacts from stormwater flows.

The Countywide Stream Protection Strategy (CSPS) issued by the Montgomery County Department of Environmental Protection (DEP) in 2004 reports that the overall condition of the tributaries in the Lower Paint Branch Watershed ranges from poor to good. The goal of the CSPS is to preserve, protect, or restore watersheds and manage specific conditions of streams by evaluating county

stream resource conditions, and identifying programs for responding to problems on a subwatershed basis.

The CSPA lists priority subwatersheds based on the stream conditions assessment and the land use of the subwatershed. Hollywood Branch was identified as a priority sub-watershed within the Lower Paint Branch Watershed.

TECHNICAL REPORT

I. Study Area

The study area for the current project includes Hollywood Branch and its tributaries from the outfall of the stormwater management pond upstream of Copley Lane to the culvert on the upstream side of Cannon Road. Figure 1 shows the drainage divides to the inlet of the Cannon Road culvert. The full-size drainage area map is in Appendix A.

II. Scope of Studies

CPJ assembled existing project data, reviewed background information, and conducted preliminary investigations for stream restoration measures to evaluate the current conditions along Hollywood Branch and its tributaries throughout the watershed.

The data collected was utilized to assess the existing stream reaches and make recommendations on which stream reaches within the watershed to restore and the extent of the restoration effort required. Restoration and management recommendations and strategies were developed.

This study did not include wetland delineations, identification of significant plant or animal habitat, or other environmental studies that may be required by local, state or federal permitting agencies. These items will be provided as part of the ongoing project once individual project reaches are established.

III. Watershed Characterization

Existing information on watershed characteristics and land use was collected, compiled and reviewed. The data collected included: topography, soils, geology, and land use maps; meteorological data; hydrologic and hydraulic data; and published technical reports. The following characterization of the Hollywood Branch watershed was developed from this information.

A. Physiography and Basin Morphometry

Hollywood Branch watershed is located in Montgomery County in the southeast-central section of Maryland. This region is situated along the eastern edge of the

Piedmont physiographic province and is characterized by gently rolling to hilly topography.

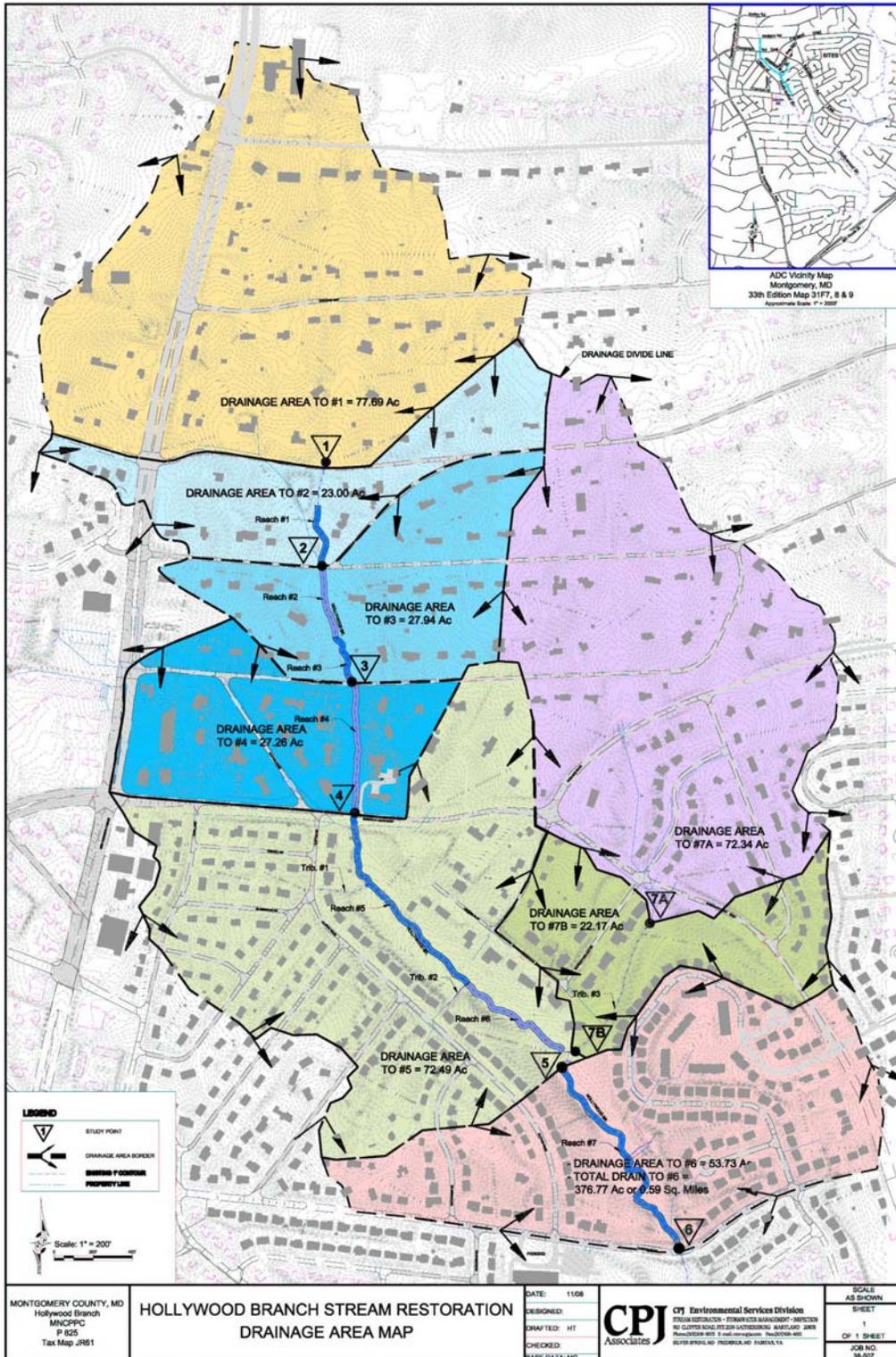


Figure 1 – Hollywood Branch Upper Watershed Drainage Divide

The total watershed area at the downstream end of the project area is 377 acres. The upper portion of the watershed is characterized by gentle to hilly topography with slopes ranging from 3% to 15%. The valley in the upper watershed is relatively narrow and the channel confined by adjacent hill slopes. The valley broadens somewhat between Copley Lane and Midland Road. Channel gradient ranges from 0.019 to 0.023 feet/foot. The valley in the middle watershed is broader in the upper reaches but narrows near Randolph Road. Channel gradient ranges from 0.014 to 0.03 feet/foot. The valley in the lower watershed is narrow in the upper reach downstream of Randolph Road, broadens in the middle reach and narrows again as the creek nears Cannon Road. Channel gradient ranges from 0.012 to 0.015 feet/foot.

B. Climate

Montgomery County experiences moderate winters and warm summers. Mean annual temperature is 55.1°F. Mean daily temperatures range from 23.5°F to 41.2°F in January and 60.8°F to 82.7°F in July.

Mean annual precipitation is 43.1 inches. Monthly precipitation varies from a low of 3.01 inches in February to a high of 4.75 inches in May. Thunderstorms may vary widely from place to place and from season to season. However, most occur in July and August. Some snow falls every winter, with mean monthly amounts ranging from 0.6 inches in November to 7.0 inches in January. Mean annual snowfall is 14.3 inches.

C. Geology and Soils

According to the Maryland Geological Survey, the entire Hollywood Branch watershed is underlain by the Lower Pelitic Schist, a medium- to coarse-grained biotite-oligoclase-muscovite-quartz schist; apparent thickness of 5,500 feet or more (MGS, 1968).

According to the mapped soils in the Soil Survey of Montgomery County (NRCS, soil map survey area Version 3, 2005 and soil survey data Version 7, 2007) the dominant upland soils are Glenelg silt loam series on the valley and sideslopes in the headwaters. The Gaila silt loam and Brinklow-Blocktown series are on the hill slopes in the middle and lower watershed. The channel and floodplain areas are dominated by Baile silt loam.

The Glenelg silt loam Series are very deep, well drained soils on uplands. They formed in Micaceous material weathered from Schist and Gneiss. These soils have a dark yellowish-brown channery loam surface layer. Moderate permeability and low erosion hazard characterize these soils. The water table is usually very deep (6 feet +). This soil is a type 'B' soil as classified by Hydrologic Soil Grouping per *Technical Release 55: Urban Hydrology for Small Watersheds*. The Gaila silt loam series are very deep and well drained. They formed in

residuum that weathered from quartz muscovite schist of the northern portion of the piedmont plateau. Included in this soils mapping unit are smaller amounts of Occoquan and Brinklow soils on slightly convex slopes and near drainage ways, and can make up as much as 15% of the soils unit. The water table rises to within 6 feet of the surface from winter to spring. Moderate permeability and moderate to low erosion hazard characterize these soils. This soil is a type 'B' soil as classified by Hydrologic Soil Grouping per *Technical Release 55: Urban Hydrology for Small Watersheds*. The Brinklow series consists of moderately deep well drained soils on uplands. They formed in residuum from Phyllite. Typically the surface layer is brown channery silt loam 10 inches thick. Available water capacity is high and shrink swell potential is moderate. This soil is not flooded and is not ponded. The water table is deeper than 6 feet. Moderately slow permeability and moderate to high erosion hazard characterize these soils. This soil is a type 'B' soil as classified by Hydrologic Soil Grouping per *Technical Release 55: Urban Hydrology for Small Watersheds*.

The dominant floodplain soils along Hollywood Branch are of the Baile silt loam series. The Baile silt loams are very deep, poorly drained soils located in upland depressions and along footslopes. They formed in local alluvium and the underlying material, weathered mainly from Micaceous Schist. The water table rises to within 6 inches of the surface from winter to spring. Permeability is low and erosion hazard is low. This soil is a type 'D' soil as classified by Hydrologic Soil Grouping per *Technical Release 55: Urban Hydrology for Small Watersheds*.

For hydrologic modeling purposes, the different soil types were grouped by their hydraulic conductivity, or the rate at which infiltration occurs. Soil maps for the Hollywood Branch watershed were obtained from the Montgomery County Division of Planning GIS Mapping and Data Services.

D. Land Use

The dominant land use in the headwaters of Hollywood Branch watershed is medium density residential off Orchard Way and Notley Road. The middle watershed includes commercial uses along New Hampshire Avenue with a mix of medium density residential off Copley Lane and Midland Road and high density residential off Randolph Road, Kara Lane and Clifton Roads. The eastern portion of the middle watershed is low and medium density residential along Anderson Street. The dominant land use in the lower Hollywood Branch watershed is medium and high density residential along Broadmore Road and Cannon Road to the east of the creek. The area to the west of the creek off Cannon Road is forested county parkland.

The stream valley in the upper watershed is mostly manicured lawn with scattered trees. With the exception of the western floodplain immediately downstream of Randolph Road, a narrow band of forest with mowed yards encroaching at various points is typical along most of the stream valley in the

middle and lower watershed. The stream valley through the county park, Cannon Road Park, is forested.

E. Hydrology

Changes in the hydrologic and sediment regimes associated with historic clearing of forests for agriculture and subsequent residential, commercial, and institutional development have caused Hollywood Branch and its tributaries to undergo significant morphological changes throughout the watershed. The Montgomery County DEP forwarded aerial photographs of the project scope to CPJ ranging from the years 1951 through 2006. In summary, these aerials show a dramatic increase in residential development from 1951 to 1970. In general, the stream corridor of the upper reach of Hollywood Branch has remained forested from 1951 until the present except for the headwaters at Notley Road and the cleared region near Broadmore Road. The region near Broadmore Road has remained deforested during this entire period, even prior to residential development and installation of a SWM pond in this area. Concerning Notley Road, a MD SHA stormwater management pond was installed in 1994 at the headwaters due to the expansion of New Hampshire Avenue from Randolph Road north to MD Rt.198; CPJ received SWM design plans of this pond from MD SHA for this report (contract no. M-529-501-371). The forest between Notley Road and Copley Lane was removed for the installation of this facility. From an overall watershed standpoint, referencing both Figure 3-2 in the Lower Paint Branch Watershed Restoration Study and a graphical presentation of the Paint Branch Impervious Area Analysis on Montgomery County's DEP website, the drainage area for the upper reaches of Hollywood Branch is currently 20% impervious, and imperviousness is projected to increase to 30 to 55% according to this analysis.

In addition to the increased residential, commercial, and institutional development from 1951 to 1970, recent direct changes in hydrology for the scope of this project, the upper reach of Hollywood Branch, can be attributed to road corridor expansions of East Randolph Road in 1990 and New Hampshire Avenue in 1994. According to the hydrologic report by HSMM (of Rockville MD) dated May 1987 (C.I.P. No. 833888), provided to CPJ by Montgomery County for this report, the weighted runoff curve number (RCN) was expected to only slightly increase from 69.2 to 69.9 due to the widening of New Hampshire Ave. and Randolph Rd. and additional development; this lack of change was attributed to the established, residential development in this region, including a majority of 1-acre wooded lots. Although only a small change in the RCN was projected, according to the signed 1990 HSMM design plans submitted to Montgomery County Dept. of Transportation for C.I.P. No. 833888, the size of the Randolph Road culvert at Hollywood Branch increased from the existing circular 72" culvert to a 192" x 62" arch culvert, with additional flow from 54" and 30" pipes at the culvert headwall. Of course the hydrologic effect of each corridor expansion was mitigated by required SWM water quality and/or quantity facilities.

A preliminary hydrologic analysis consisted of utilizing regional regressions for bankfull channel dimensions for the purpose of verifying field bankfull channel indicators; see Section F(1) below for the specific details. The results are summarized in Table 1.1 below for each of the stream reaches. The drainage area nodes are indicated in Figure 1. An in-depth hydrologic/ hydraulic analysis will be performed for the 60% design phase; see Report Main Section 3, sub-section III, for the proposed components of this analysis.

Table 1.1 Bankfull Discharges		
Stream Reach	Drainage Area (acre)	Powell (2002) Bankfull Discharge (cfs)
Main Segment 1	78	37
Main Segment 2&3	101	45
Main Segment 4	129	55
Main Segment 5&6	156	63
Main Segment 7	322	112
Tributary 3	72	34.5

F. Assessment Methods

1. Verifying Bankfull Channel Field Indicators.

Regional regressions for bankfull channel dimensions developed for use in the urban Piedmont Region of Maryland (Powell, 2002) were utilized to verify field indicators associated with the bankfull channel in conducting the geomorphic stream assessments along Hollywood Branch; see Table 1.1 above.

2. Field Reconnaissance

A field reconnaissance survey was conducted to document and assess existing conditions along Hollywood Branch and its tributaries from the outfall of the stormwater management pond upstream of Copley Lane to the culvert on the upstream side of Cannon Road. A total of 1.08 miles (5,718 linear feet) of Hollywood Branch and its tributaries were reconnoitered and mapped. To facilitate the field work and evaluation Hollywood Branch and its tributaries were divided into ten separate stream segments as shown in Appendix B.

The County's GIS topographic maps were utilized as a base for the maps used in the field reconnaissance. The field reconnaissance maps were developed at a scale of 1 inch = 50 feet to allow recording field notes and drafting of specific conditions observed in the field (e.g., eroding banks, depositional features, debris jams, etc.).

The reconnaissance survey included photographic documentation and mapping the channel and adjacent floodplain. It focused on verifying existing land use

activities and land cover, identifying and documenting unstable conditions in upland and riparian areas, characterizing stream channel morphology and condition, and identifying unstable stream reaches. A critical component of the field survey was identifying infrastructure problems and opportunities for implementing stream channel stabilization and restoration projects. See Section 2 for specific infrastructure repairs.

3. Level II - Morphological Description.

The natural stream reaches along Hollywood Branch in the project area were classified into specific categories of stream types (i.e., B4c, C4, F4, etc.) utilizing the standard field procedures recommended by Rosgen (1996). Data gathered during this portion of the assessment allowed some of the original 10 stream segments to be further subdivided into stream reaches. See Table 1.2 in Section III.G.1 below for the summary data; the raw data is available in Appendix C.

4. Level III - Assessment of Stream Condition

The reaches along Hollywood Branch were assessed for stream channel condition and influencing factors including riparian vegetation, meander pattern, depositional pattern, debris and channel blockages, sediment supply, vertical stability, and lateral stability. See Appendices D & E for summary spreadsheets.

5. Level IV - Stream Stability Validation Monitoring

In order to document channel erosion rates, develop in-field estimates of sediment loadings from in-stream sources, and monitor post construction conditions, permanent cross-sections (documented in App.C) were established along the Hollywood Branch project area in each of the stream reaches.

G. Findings of Field Studies

This section summarizes the results of the field assessment conducted in the Hollywood Branch watershed.

1. General

Changes in hydrology as well as alterations to the stream and adjacent floodplain to accommodate development and public infrastructure have contributed to unstable channel conditions. The unstable conditions include incision of the streambed, streambank erosion, widening of the channel, lateral migration, and aggradation throughout much of the watershed. These channel adjustments have contributed a significant amount of sediment to downstream stream reaches. General trends in lateral migration are visible in the aerial photographs for the lower reaches of the project scope. CPJ did not quantify the extent of the migrations due to: 1) the determination that the extensive work to quantify the

changes would not contribute significantly to this assessment report; and 2) the inability to determine exact stream locations.

Table 1.2 below summarizes the stream classification data collected for each reach along the mainstem Hollywood Branch as well as Tributary 3.

Reach ID	Width (ft)	Depth (ft)	Area (ft ²)	W/D	Entrenchment Ratio	Slope (ft/ft)	D50 (mm)	Stream Type
Mainstem								
1	14.7	0.7	10.5	21	1.4	0.019	ND	F4
	12.0	0.8	9.6	15	1.5			
2	8.6	1.2	9.9	7.4	1.9	0.023	ND	B4c
3	13.9	1.3	18.4	10.6	2.8	0.019	41	C4
	16.0	0.9	14.3	17.8	3.1			
4.1	15.0	1.0	15.6	14.3	4.7	0.03	57	C4b
4.2	12.0	1.3	15.4	9.4	1.2	0.014	57	G4
4.3	11.8	1.3	15.0	9.4	10.3	ND	ND	C4
4.4	ND	ND	ND	ND	ND	ND	ND	G4
5.1	18.9	1.0	19.3	18.6	1.4	0.015	50	F4
	27.2	1.1	31.2	23.7	1.1			
5.2	14.9	1.5	22.4	10.0	1.7			B4c
5.3	16.6	1.2	20.1	13.8	1.2			F4
6.1	20.9	1.2	25.4	17.1	2.3	0.012	55	C4
	30.4	1.1	33.4	27.6	2.2			
	15.6	1.5	24.0	10.1	4.6			
	24.0	1.1	25.8	22.2	3.5			
6.2	22.7	1.1	24.8	20.7	1.2			F4
7	20.7	1.2	25.3	16.9	2.5	0.015	55	C4
	20.9	1.2	25.6	17.0	4.6			
	20.9	1.5	31.2	14.0	5.9			
	17.2	1.6	27.6	10.6	4.3			
Tributary 3								
3.1	11.3	0.6	7.2	17.8	1.3	0.014	42	F4
	16.8	0.7	12.1	23.4	1.3			
	9.8	1.0	9.5	10.2	1.5			
3.2	7.3	1.1	7.8	6.8	2.6	0.0009	42	E4
3.3	ND	ND	ND	ND	ND	0.039	42	G4
3.4	10.2	0.8	8.3	12.5	4.0	0.02	42	C4

Table 1.2 – Summary of Stream Classification Data

2. Reach 1 - Mainstem Hollywood Branch (Outfall of Stormwater Pond to Copley Lane)

The upstream end of this segment originates at the outfall of a MD SHA stormwater management pond (contract # M-529-501-371, design plans approved in 1994) and flows 96 feet to the culvert at Copley Lane. The stormwater pond was constructed due to the expansion of Randolph Road to MD Rte.198. Historically channelized and lined with rip-rap it is characterized as a stable F4 stream channel with a moderate to high width to depth ratio, moderate slope, and low sinuosity. The pond's two-year discharge is about 8 cfs; from CPJ's field observations, the stream channel is perennial. Bank height ratio along this reach is 3.2. Trees and shrubs along the banks provide additional lateral stability for this reach.

An emergency spillway channel originates at the SWM pond and flows 225 feet before intersecting the main channel upstream of Copley Lane. The spillway channel actually joins an existing ephemeral stream channel that originates upstream as a nickpoint just north of Notley Road. This existing channel (and now spillway channel) runs parallel to the main channel along the backyards of residences that front on Saint Mary's Road Bank; erosion along the spillway channel is starting to undermine adjacent fences.



Fig. 3 – Stormwater Management Pond upstream of Reach 1



Fig. 4 – Looking downstream along Reach 1



Fig. 5 – Emergency spillway channel eroding into rear of yards

The results of the field assessment indicate that although Reach 1 is stable approximately 100 linear feet of the 225 linear feet of the spillway channel is unstable. The poor conditions along the spillway channel make it a source of sediment to downstream reaches and present a long term maintenance issue for the adjacent residences. Table 1.3 summarizes the stream conditions along Reach 1.

Table 1.3 – Summary of Stream Conditions MS Reach 1				
Stream Section	Condition	Stream Type	Length (ft)	Description
1	Stable	F4	96	Channelized and banks armored with rip-rap. Good growth of trees and shrubs on banks
Emergency Spillway	Unstable	ND	225 (100)	Localized bank erosion
		Total Length	321	
		Length Unstable	100 (31%)	

3. Reach 2 - Mainstem Hollywood Branch (Copley Lane to End of Mill Dam Section)

Reach 2 is a B4c channel with a low width to depth ratio, moderate slope, and very low sinuosity. Anecdotal information obtained from a neighbor indicates the channel was straightened by the landowner in the late 1950's. Around the same period a series of low concrete dams and water wheels were installed. Although most of the dams are still in place they are in disrepair and the water wheels are either gone or no longer functioning.

Results of the stability assessment show bank height to bankfull ratios along this reach range from 1.4 to 2.3. The dams appear to have provided some grade control. The streambanks are generally vegetated with mowed grass, ornamental shrubs, flowers, and scattered trees. Some localized bank erosion was evident. It was obvious that the landowner had attempted to stabilize the banks by placing boulders, as well as stacked concrete slabs. With the exception of the first 50 feet of channel downstream of Copley Lane the stabilization efforts have been successful. Along this 50 foot section the stacked concrete slabs have fallen into the channel and the banks are actively eroding.



Fig. 6 – Stacked concrete wall collapsing at upstream end of Reach 2



Fig. 7 – One of several small dams with waterwheel constructed along Reach 2



Fig. 8 – Remnants of small dam along Reach 2

The results of the field assessment indicate that 50 linear feet (11.8%) of the total 422 linear feet of channel along Reach 2 is unstable. The localized bank erosion along the upper section of the reach is a source of sediment to downstream reaches. Table 1.4 summarizes the stream conditions along Reach 2.

Table 1.4 – Summary of Stream Conditions MS Reach 2				
Stream Section	Condition	Stream Type	Length (ft)	Description
1	Unstable	B4c	50	Stacked concrete wall collapsing Active bank erosion
2	Stable	B4c	372	Banks stable Dams providing grade control
		Total Length	422	
		Length Unstable	50 (11.8%)	

4. Reach 3 - Mainstem Hollywood Branch (End of Mill Dam Section to Midland Road)

Reach 3 is C4 channel characterized by low to moderate width to depth ratios, moderate slope, and low sinuosity. With the exception of some localized streambank erosion this reach is relatively stable. The left bank and floodplain is wooded with a good growth of native trees and shrubs. Vegetation along the right bank includes mowed grass, scattered trees, bamboo, and multi-flora rose.

Results of the stability assessment show bank height to bankfull ratio of 1.5 throughout. BEHI ratings were very high and NBS was moderate.



Figs. 8 and 9 – Eroding banks along upstream section of Reach 3



The results of the field assessment indicate that 60 linear feet (30%) of the total 200 linear feet of channel along Reach 3 is unstable. The poor conditions along the actively eroding section of the reach are a source of sediment to downstream reaches. Table 1.5 summarizes the stream conditions along Reach 3.

Table 1.5 – Summary of Stream Conditions MS Reach 3				
Stream Section	Condition	Stream Type	Length (ft)	Description
1	Unstable	C4	60	Active bank erosion
2	Stable	C4	140	Banks stable
		Total Length	200	
		Length Unstable	60 (30%)	

5. Reaches 4.1 – 4.4 - Mainstem Hollywood Branch (Midland Road to Randolph Road)

Because stream type and conditions vary considerably along Segment 4 it was divided into four separate reaches.

Reach 4.1 is a C4b channel characterized by low to moderate width to depth ratio, steep slope, and low sinuosity. The right bank has a well defined floodplain bench vegetated with a good growth of native trees and shrubs. The left bank is vegetated with mowed grass and exhibits active erosion.

Reach 4.2 is a G4 channel characterized by low width to depth ratio, moderate slope, and low sinuosity. The right bank is vegetated with a dense stand of bamboo and the left bank is vegetated with mowed grass and scattered trees. The reach exhibits active bank erosion throughout and active headcuts at the upstream and downstream ends of the reach.

Reach 4.3 is a C4 channel characterized by low width to depth ratio, low gradient and low sinuosity. The banks are vegetated with unmowed grass and scattered trees. With the exception of minor localized bank erosion this reach is stable.

Reach 4.4 is a G4 channel characterized by low width to depth ratio, moderately steep slope, and low sinuosity. Both banks are vegetated with a dense stand of bamboo. The reach exhibits active bank erosion throughout and active headcuts at the upstream and downstream ends of the reach.

With the exception of three deep pools, the bed form along this segment is characterized by a few, shallow pools, short steep riffles, and long shallow glides. Because there is no grade control at any point along the segment it is likely that the headcuts observed in Reaches 4.2 and 4.4 will migrate upstream into the vertically stable Reaches 4.1 and 4.3 respectively.

Bank height to bankfull ratios ranged from 1.0 to 4.17 with the highest ratios along Reaches 4.2 and 4.4 and in particular at the downstream end of the segment near Randolph Road. In spite of the dense growth of bamboo there is a general lack of lateral control. Results of the stability assessment show that 455 feet (36.4%) of the banks along this segment had BEHI ratings in the high to very high range. It is likely that bank erosion and lateral migration as well as bed incision will continue to be a long-term problem along this segment.



Figs. 10 and 11 – Eroding banks at upstream end of Reach 4.2
Note: Dense stand of bamboo along right bank



Fig. 12 – Head-cut migrating upstream through Reach 4.2



Fig. 13 – Eroding bank at downstream end of Reach 4.2



Fig. 14 – Stable section at upstream end of Reach 4.3



Fig. 15 – Deeply incised channel at downstream end of Reach 4.4

The results of the field survey indicate that 475 linear feet (76%) of the total 625 linear feet of channel along Reaches 4.1 -4.4 is unstable. The poor conditions along these reaches are a source of sediment to downstream reaches. Table 1.6 summarizes the stream conditions along Reaches 4.1 -4.4.

Table 1.6 – Summary of Stream Conditions MS Reach 4				
Stream Reach	Condition	Stream Type	Length (ft)	Description
4.1	Unstable	C4b	100	Active bank erosion
4.2	Unstable	G4	163	Headcuts and active bank erosion
4.3	Stable	C4	150	Stable with minor localized bank erosion
4.4	Unstable	G4	212	Headcuts and active bank erosion
		Total Length	625	
		Length Unstable	475 (76%)	

6. Reaches 5.1 – 5.3 – Mainstem Hollywood Branch (Randolph Road to a Point 200 feet DS of Tributary 2)

Because stream type and conditions vary considerably along Segment 5 it was divided into three separate reaches.

Reach 5.1 is an F4 channel characterized by a high width to depth ratios, moderate slope, and moderate sinuosity. The upper 50 feet of the reach immediately downstream of Randolph Road is armored with rip-rap and is relatively stable. Both banks along this section are vegetated with trees and shrubs. Although the banks are vegetated with trees and shrubs, the remaining 475 linear feet of this reach is very unstable and exhibits active bank erosion, numerous debris jams, and aggradation with large lateral and mid-channel bars throughout. Scour of the bed has exposed a lateral sewer line along the second large meander bend at the upstream end of the reach.

Reach 5.2 is a B4c channel characterized by a low width to depth ratio, moderate slope, and moderate sinuosity. The middle 100 feet of the reach is armored with rip-rap and is relatively stable. Both banks are vegetated with trees and shrubs. Although landowners have attempted to stabilize their banks with bricks, broken concrete and other building debris, the remaining 200 linear feet of this reach is very unstable and exhibits active bank erosion and aggradation with large lateral bars.

Reach 5.3 is an F4 channel characterized by a moderate to high width to depth ratios, moderate slope, and moderate sinuosity. Both banks are vegetated with mowed grass and scattered trees and shrubs. The entire 300 linear feet of this reach is unstable and exhibits active bank erosion, failing banks with fallen trees, and aggradation with lateral and mid-channel bars. The sanitary sewer is threatened with damage where bank erosion has caused the channel to shift within couple feet of manholes and a failing bank caused a tree to collapse in the channel immediately adjacent to a shed at the downstream end of the reach.

Bank height to bankfull ratios ranged from 3.33 to 4.67. Results of the stability assessment show that 835 feet (37%) of the banks along this segment had BEHI ratings in the very high to extreme range. There is a high probability that bank erosion and lateral migration will continue to be a long-term problem along this segment. This instability will result in the loss of additional trees, exposure of and possible damage to public infrastructure, as well as significant sediment loading to downstream reaches.



Figs. 16 and 17 – Eroding bank at upstream end of Reach 5.1





Fig. 18 – Exposed sanitary sewer in upper Reach 5.1



Fig. 19 – Debris jam middle section of Reach 5.1



Fig. 20 – Eroding bank upstream end of Reach 5.1



Fig. 21 – Eroding bank adjacent to sanitary sewer manhole middle section of Reach 5.3



Fig. 22 – Eroding banks with trees collapsing into channel at downstream end of Reach 5.3



Fig. 23 – Failing bank and collapsed tree adjacent to shed at downstream end of Reach 5.3

The results of the field assessment indicate that 975 linear feet (87%) of the total 1125 linear feet of channel along Reach 5 is unstable. The poor conditions along this section of the reach are a source of sediment to downstream reaches. Table 1.7 summarizes the stream conditions along Reach 5.

Table 1.7 – Summary of Stream Conditions MS Reach 5				
Stream Reach	Condition	Stream Type	Length (ft)	Description
5.1	Unstable Localized stability	F4	525 (475, 50)	Deeply incised, bank erosion, debris jams and aggradation. Upper section armored with rip-rap
5.2	Unstable Localized stability	B4c	300 (200, 100)	Bank erosion, debris jams and aggradation. Middle section armored with rip-rap
5.3	Unstable	F4	300	Deeply incised, bank erosion, collapsing trees, debris jams and aggradation,
		Total Length	1125	
		Length Unstable	975 (87%)	

7. Reaches 6.1 – 6.3 – Mainstem Hollywood Branch (A Point 200 feet DS of Tributary 2 to Footbridge over Mainstem)

Because stream type and conditions vary along Segment 6 it was divided into three separate reaches.

Reach 6.1 is C4 channel characterized by moderate to high width to depth ratios, moderate slope, and moderate to moderately high sinuosity. The right bank and floodplain is wooded with a good growth of native trees and shrubs. Vegetation along the left bank includes mowed grass and scattered trees. The entire 600 linear feet of this reach is very unstable and exhibits active bank erosion, numerous debris jams, and aggradation with split channels, large point, lateral and mid-channel bars throughout. The sanitary sewer is threatened with damage where debris jams, aggradation and bank erosion has caused the channel to shift exposing a manhole. Failing banks have caused trees to collapse into the channel. In the upper section a collapsed tree fell directly onto a chain link fence. There is a significant knick-point at the downstream end of the reach. The upstream/downstream difference in bed elevation is 4 feet. A large debris jam is currently functioning as grade control. However, in the likely event that storm

flows eventually remove the debris jam the knick-point will migrate head-ward lowering the bed and raising bank heights for a considerable distance upstream.

Reach 6.2 is a short section of F4 channel characterized by a high width to depth ratio, moderate slope, and moderate sinuosity. The right bank of the reach is armored with rip-rap and is relatively stable. The left bank is vegetated with trees and shrubs and is also relatively stable. The streambed is characterized by active incision temporarily halted at the knick-point at its upstream end.

Reach 6.3 is a C4 channel characterized by a moderate to high width to depth ratios, moderate slope, and moderate sinuosity. Although both banks and the floodplain are wooded with a good growth of native trees and shrubs, a significant length of the reach is unstable and exhibits active bank erosion, failing banks with falling trees, and aggradation with lateral bars. A large debris jam has formed immediately upstream of the footbridge between Segments 6 and 7.

Bank height to bankfull ratios ranged from 2.33 to 4.0. In spite of the good growth of woody vegetation there is a lack of lateral control along a significant portion of the reaches. Results of the stability assessment show that 635 feet (27%) of the banks along this segment had BEHI ratings in the high to extreme range. There is a high probability that bank erosion and lateral migration as well as bed incision will continue to be a long-term problem along this segment. This instability will result in the loss of additional trees, exposure of and possible damage to public infrastructure, as well as significant sediment loading to downstream reaches.



Fig. 24 – Bank erosion in upper section of Reach 6.1



Fig. 25 – Split channel, large debris jam, and aggradation in upper section of Reach 6.1



Figs. 26 and 27 – Collapsed trees and damaged fences in upper section of Reach 6.1





Fig. 28 – Bank erosion along lower section of Reach 6.1



Fig. 29 – Debris jam, aggradation and exposed sanitary sewer manhole



Fig. 30 – Debris jam at knick-point at downstream end of Reach 6.1. Note aggradation upstream and significant drop in bed elevation into Reach 6.2



Fig 31 – Falling trees along upper section of Reach 6.3.



Fig 32 – Bank erosion along middle section of Reach 6.3.



Fig 33 – Bank erosion along lower section of Reach 6.3.



Fig 34 – Debris jam upstream of footbridge at downstream end of Reach 6.3.

The results of the field survey indicate that 1190 linear feet (100%) of the total 1190 linear feet of channel along Reach 6 is unstable. The poor conditions along this reach are a significant source of sediment to downstream reaches. Table 1.8 summarizes the stream conditions along Reach 6.

Table 1.8 – Summary of Stream Conditions MS Reach 6				
Stream Sections	Condition	Stream Type	Length (ft)	Description
1	Unstable	C4	600	Bank erosion, debris jams and aggradation, head-cut at downstream end
2	Unstable	F4	115	Right bank armored with rip-rap, debris jams and active bed erosion, head-cut at upstream end
3	Unstable	C4	475	Bank erosion, fallen trees, debris jams and aggradation,
		Total Length	1190	
		Length Unstable	1190 (100%)	

8. Reach 7 - Mainstem Hollywood Branch (Footbridge over Mainstem to Cannon Road)

Reach 7 is C4 channel characterized by low to moderate width to depth ratios, moderate slope, and moderate to high sinuosity. Although both banks and the floodplain are wooded with a good growth of native trees and shrubs, a significant length of the reach is unstable and exhibits active bank erosion, failing banks with severely undercut trees, and aggradation with split channels and lateral bars. In some areas lateral bars and old meander scars have evolved into permanent low, vegetated benches. The trail and approach to the footbridge at the upstream end of the reach have been damaged by storm flows overtopping the streambanks.

Bank height to bankfull ratios ranged from 2.33 to 4.67. In spite of the good growth of woody vegetation there is a lack of lateral control along a significant portion of the reaches. Results of the stability assessment show that 610 feet (41%) of the banks along this segment had BEHI ratings in the high to very high range. There is a high probability that bank erosion and lateral migration will continue to be a long-term problem along this segment. This instability will result in the loss of additional trees, exposure of and possible damage to public infrastructure, as well as significant sediment loading to downstream reaches.



Fig. 35 – Trail at footbridge by storm flow overtopping streambanks



Figs. 36 and 37 – Bank erosion along upper section of Reach 7



Fig 38 – Bank erosion, debris jam, and aggradation along upper section of Reach 7



Fig 39 – Rip-rap check dam along left side of split channel in upper section of Reach 7



Fig 40 – Floodplain bench formed by sediment deposition in old meander scar



Fig 41 – Bank erosion and debris jams along high terrace in middle section of Reach 7



Figs 42 and 43 – Severely undercut trees, debris jams and lateral bars along lower section of Reach 7



Fig 44 – Culvert under Cannon Road at downstream end of Reach 7

The results of the field assessment indicate that 650 linear feet (87%) of the total 750 linear feet of channel along Reach 7 is unstable. The poor conditions along this reach are a source of sediment to downstream reaches. Table 1.9 summarizes the stream conditions along Reach 7.

Table 1.9 – Summary of Stream Conditions MS Reach 7				
Stream Sections	Condition	Stream Type	Length (ft)	Description
1	Unstable	C4	650	Bank erosion, debris jams and aggradation,
2	Stable	C4	100	Stable banks and bed
		Total Length	750	
		Length Unstable	650 (87%)	

9. Tributary 1 – Upper Reach 5

An ephemeral stream, Tributary 1 conveys stormwater runoff from a storm drain outfall located along Clifton Road. The upper 150 feet of this Tributary is a concrete storm drain channel. The lower 250 feet is a natural F4 channel characterized by high width to depth ratios, moderate slope, and low sinuosity. Although both banks and the adjacent floodplain are wooded with a good growth of native trees and shrubs, active bank erosion was evident throughout. Immediately downstream of where the concrete channel ends a sanitary sewer manhole has been exposed by erosion.



Figs. 45 and 46 – Storm drain outfall at Clifton Road and concrete storm drain channel



Fig. 47 – Exposed sanitary sewer manhole



Fig. 48 – Confluence of Tributary 1 with Reach 5 Hollywood Branch

The results of the field survey indicate that 125 linear feet (45%) of the total 275 linear feet of channel along Tributary 1 is unstable. The poor conditions along this section of the tributary are a source of sediment to downstream reaches. Table 1.10 summarizes the stream conditions along Tributary 1.

Table 1.10 – Summary of Stream Conditions Tributary 1				
Reach	Condition	Stream Type	Length (ft)	Description
1	Stable		150	Concrete lined channel
2	Unstable	F4	125	Bank erosion exposed utilities
		Total Length	275	
		Length Unstable	125 (45%)	

10. Tributary 2 – Lower Reach 5

An ephemeral stream, Tributary 2 conveys stormwater runoff from a storm drain outfall located along Clifton Road. The entire 150 feet of Tributary 2 is a concrete storm drain channel. The channel appeared to be in good condition. Energy dissipators were installed at the downstream end of the channel to slow the water velocity and reduce scour. In addition, rip-rap was installed immediately downstream of the concrete channel.



Fig. 49 – Concrete storm drain channel

11. Tributary 3 – Middle Reach 6

A perennial stream, Tributary 3 conveys stormwater runoff from a storm drain outfall located along Randolph Road. The first 350 feet is piped and outfalls to a natural channel. Because stream type and conditions vary along Tributary 3 it was divided into four separate reaches.

Tributary Reach 3.1 is an F4 channel characterized by low to high width to depth ratios, moderate slope, and low to moderate sinuosity. Almost the entire 425 linear feet of this reach is very unstable and exhibits active bank erosion, numerous debris jams, and aggradation with split channels, large point, lateral and mid-channel bars throughout. The right bank in the upper section is at the rear of residences fronting on Burkart Bea Kay Drive. Although yards are mowed there are trees and shrubs along the bank. Some landowners have attempted to stabilize eroding banks with timber retaining walls. The walls are in disrepair. The left bank is wooded with a good growth of trees and shrubs.

Tributary Reach 3.2 is an E4 channel characterized by low width to depth ratio, low gradient, and low sinuosity. This reach exhibits minor localized bank erosion, debris jams created by dumping of yard waste, and aggradation upstream of the debris jams. The left bank in this section is at the rear of residences fronting on Broadmore Road. Yards are mowed to the top of streambank with a few scattered trees along the bank. Some landowners have attempted to stabilize eroding banks with timber retaining walls. The walls are in disrepair. The right bank is wooded with a good growth of trees and shrubs.

Tributary Reach 3.3 is a G4 channel characterized by low width to depth ratio, steep slope, and high sinuosity. There is a significant knick-point at the upstream end of the reach. The upstream/downstream difference in bed elevation is 3.5 feet. Tree roots and a debris jam are currently functioning as grade control. However, in the likely event that storm flows eventually remove the debris jam and soil around the tree roots the knick-point will migrate head-ward lowering the bed and raising bank heights for a considerable distance upstream. The right bank in this section is at the rear of residences fronting on Burkart Bea Kay Drive. Yards are mowed to the top of streambank with a few scattered trees along the bank. Some landowners, with the assistance of MC Department of Environmental Protection, have attempted to stabilize eroding banks with branch bundles. The bundles have not been effective and the banks are actively eroding. The left bank is mowed grass with scattered trees. Because this deeply incised reach is immediately adjacent to a fence and outbuilding on the right bank, the active bank erosion threatens to undermine the fence as well as the structure.

Tributary Reach 3.4 is a C4 channel characterized by low to moderate width to depth ratios, moderate slope, and moderate sinuosity. With the exception of some localized streambank erosion this reach is relatively stable. The left bank and floodplain is wooded with a good growth of native trees and shrubs. Vegetation along the right bank includes mowed grass and scattered trees. A small footbridge crosses the reach at its upstream end.

Bank height to bankfull ratios along this tributary ranged from 1.67 to 4.33. Results of the stability assessment show that 700 feet (39%) of the banks along the tributary had BEHI ratings in the high to extreme range. There is a high probability that bank erosion and lateral migration will continue to be a long-term problem along this tributary. This instability will result in the loss of additional trees, damage to private structures, as well as significant sediment loading to downstream reaches.



Fig. 50 – Storm drain outfall below Randolph Road at upstream end of Tributary 3.1



Figs. 51 and 52 – Eroding banks, failing retaining wall, mid-channel bars along upstream end of Tributary 3.1



Figs. 53 and 54 – Eroding banks, debris jams, split channel, and aggradation along middle section of Tributary 3.1



Figs. 55 and 56 – Head-cut at upstream end of Tributary 3.3
Note – debris jam and aggradation upstream of head-cut



Fig. 57 – Deeply incised channel along Tributary 3.3 with active bank erosion adjacent to structure and fence. Note - debris and rubble dumped into channel by landowner attempting to stabilize bank



Fig. 58 – Active bank erosion adjacent to structure along downstream end of Tributary 3.3.

Note – Branch bundles installed by MC DEP attempting to stabilize bank

The results of the field survey indicate that 650 linear feet (72%) of the total 900 linear feet of channel along Tributary 3 is unstable. The poor conditions along this tributary are a source of sediment to downstream reaches. Table 1.11 summarizes the stream conditions along Tributary 3.

Table 1.11 – Summary of Stream Conditions Tributary 3				
Reach	Condition	Stream Type	Length (ft)	Description
1	Unstable	F4	425	Bank erosion, debris jams and aggradation,
2	Unstable Local stability	E4	100 (50)	Debris jams and aggradation, retaining wall undermined
3	Unstable	G4	175	Deeply incised, headcuts, bed and bank erosion, debris jams
4	Stable	C4	200	Minor localized bank erosion
		Total Length	900	
		Length Unstable	650 (72%)	

H. Summary and Conclusions

The current conditions in the Hollywood Branch watershed vary considerably along the stream segments assessed. Along Mainstem Segments 1 -3 approximately 210 feet of the total 943 feet (22%) show some evidence of instability. Problems along these segments are generally minor and localized. However, approximately 3290 feet of the total 3690 feet (89%) along Mainstem Segments 4 – 7 exhibit significant stability problems. These problems include streambed erosion and channel incision, bank erosion and lateral migration, fallen trees and other channel blockages, and aggradation, damage to public infrastructure and private property. Of the three tributaries evaluated, Tributary 3 exhibits the most significant stability problems with 650 feet of the total 900 feet (72%) determined to be unstable.

The unstable conditions evident throughout a significant portion of the Upper Hollywood Branch watershed have severely degraded water quality, in-stream habitat, and supplied significant sediment loadings to downstream reaches along Hollywood Branch and Paint Branch. Public and private land, as well as public infrastructure, has been damaged. Left uncorrected, the stability problems in this watershed will continue to be long-term maintenance issues as well as a significant source of sediment.

SECTION 2
INFRASTRUCTURE REPAIRS

I. Introduction

As the Montgomery County Department of Environmental Protection, Watershed Restoration Program restores the degraded stream channel and adjacent floodplain of the upper watershed of Hollywood Branch (identified as Reach 3 in the Lower Paint Branch Watershed Restoration Study), needed infrastructure repairs will also be incorporated during this restoration effort. This section describes these needed repairs with short text descriptions of the problem; photographs identifying each needed repair follow the text. This section will be organized by proceeding upstream to downstream in the stream reach ID's as described in Section 1.

II. Mainstem Reach 1

A. Repair 1.1

Approximately twenty-five feet upstream of the Copley Lane culvert, on the left bank (as viewed downstream) and just downstream of the emergency spillway junction with the outfall channel, is a nickpoint that has the potential to affect the function and structure of the culvert and of the stream channel just upstream of the culvert. As seen in Figure 4.1, there is existing rip rap at this nickpoint, but it is apparently inadequate in preventing additional erosion.

III. Mainstem Reach 4

A. Repair 4.2.1

In Reach 4.2, at Rosgen field cross section 4.4, an exposed small pipe was field located crossing the stream channel almost perpendicular to flow; see Figure 4.2.1. According to Montgomery County G.I.S., a water pipe segment extends south from Midland Road about 600 feet towards Randolph Road, almost parallel to the stream channel. The (WSSC) sheet ID is identified as 218NE01. This pipe location is confirmed by WSSC drawing #652577 as an 8 inch water line. The exposed pipe located at cross section 4.4 and perpendicular to the stream channel is probably a connection to a residence from this 8" water line.

IV. Mainstem Reach 5

A. Repair 5.1.1

Approximately 30 feet downstream of cross section 5.1 in Reach 5.1 is an exposed 8" sewer line; see Figure 5.1.1. (This is mentioned in Section 1, page 24, second paragraph). The location of the sewer line is confirmed in Montgomery County G.I.S. and digital forms of as-built WSSC drawings provided to CPJ by Montgomery County for the purposes of this project.

B. Repair 5.1.2

Tributary 1 (located in Reach 5.1) is a storm drain outfall channel from Clifton Road located in-between the third and fourth houses south (downstream) of Randolph Road;

see Figure 5.1.2(a). The outfall channel starts as a concrete channel (see Figure 5.1.2(b)), but channel degradation is evident downstream of the concrete in the natural channel segment prior to discharge into Hollywood Branch (see Figure 5.1.2(c)). An exposed WSSC sewer manhole (contract number same as above in Repair 4.2.1) exists in this downstream section; see Figure 5.1.2(d). Tributary 1 is also described in Section III G9.; since an exposed sewer manhole exists in this tributary, it is listed as an infrastructure repair also in addition to being mentioned in the main narrative.

C. Repair 5.1.3

Just downstream of cross section 5.4 in Reach 5.1 is an erosion channel on the left bank (as viewed downstream) that discharges into Hollywood Branch. See Figure 5.1.3 (a) for an upstream view of the erosion channel at the junction with Hollywood Branch; see Figure 5.1.3(b) for an upstream view of Hollywood Branch that shows the general location of the erosion channel/ Hollywood Branch junction. The erosion channel starts behind the assisted living home on East Randolph Road and just upstream of Lot 1 on Anderson Street.

D. Repair 5.3.1

In Reach 5.3, a storm drain outfall off of Anderson Street, near the intersection of Anderson Street and Octagon Lane, is half-full of sediment; see Figure 5.3.1(a). At the earthen outfall channel junction with Hollywood Branch, the channel is eroded; see Figure 5.3.2(b). The outfall channel discharges just downstream of cross section 5.7.

E. Repair 5.3.2

A sewer manhole is almost exposed on the right bank (as viewed downstream) of Hollywood Branch just downstream of cross section 5.7 in Reach 5.3; see Figure 5.3.2. This manhole repair is also mentioned in Section 1 (see Figure 21).

F. Repair 6.1.1

As described in Section III G7, summarizing Reach 6.1, there is an exposed sewer manhole just upstream of a debris jam; see Figure 6.1.1(a). The manhole is on the right bank (as viewed downstream) adjacent from the last property on Anderson Street; this property can also be identified as being located at the intersection of Hollywood Branch and Tributary 3.

G. Repair 7.1.1

As described in Section III G8 summarizing Reach 7, the asphalt pathway to the pedestrian bridge shows evidence of damage by flows above the stream banks. Most of the apparent damage is to the asphalt pathway adjacent to the bridge footers; see Figures 7.1.1(a), (b), and (c). Assuming the right bridge footer was initially on the stream bank, the stream has scoured the right stream bank to the extent the right footer is exposed to the stream; see Figure 7.1.1(d).

V. Tributary 3 – Middle Reach 6

A. Repair Trib. 3.1.1

Tributary 3 is described in Section IIIG11. A repair to the Randolph Road storm drain outfall is also listed here as infrastructure in addition to being mentioned in Section 1. At the end of the concrete apron to the 54" storm drain CMP outfall is a plunge pool that is approximately 2.5 feet to 3 feet deep; see Figures Trib. 3.1.1(a) and Trib.3.1.1(b). CPJ is assuming these depths exceed design depths. If a plunge pool was not designed at installation, then a scour pool has developed. Adjacent to the concrete apron, on the left bank (as viewed downstream), are a couple of nickpoints that may influence the integrity of the outfall headwall, concrete apron, design plunge pool, and natural stream channel; see Figures Trib 3.1.1(c) and Trib. 3.1.1(d).

B. Repair Trib. 3.3.1

The storm drain from Burkart Bea Kay Drive in section 3 of Tributary 3 has impeding sediment in its apron; see Figure Trib 3.3.1(a). The outfall storm drain flow is causing erosion and a high grade near the junction with Hollywood Branch; see the unstable rip rap in Figure Trib. 3.3.1(b).



Figure 1.1 Nickpoint upstream of Copley Lane culvert.



Figure 4.2.1 Small pipe perpendicular to flow at cross section 4.4.



Figure 5.1.1 Exposed 8" sewer line near cross section 5.1



Figure 5.1.2(a) Clifton Road outfall.



Figure 5.1.2(b) Concrete channel outfall.



Figure 5.1.2(c) Degraded earth channel.



Figure 5.1.2(d) Exposed sewer manhole.



Figure 5.1.3(a) Erosion channel as viewed upstream.



Figure 5.1.4(b) Erosion channel junction with Hollywood Branch (upstream view).



Figure 5.3.1(a) Half-full Anderson St. storm drain outfall.



Figure 5.3.1(b) Anderson St. outfall junction with Hollywood Br. (view upstream).



Figure 5.3.2 Sewer manhole almost exposed downstream of cross section 5.7.



Figure 6.1.1 Exposed sewer manhole across from last residence on Anderson St.



Figure 7.1.1(a) Pathway on right bank/upstream



Figure 7.1.1(b) Pathway on right bank/downstream.



Figure 7.1.1(c) Pathway on left bank/downstream



7.1.1(d) Pedestrian bridge right footer exposed to stream.



Figure Trib. 3.1.1(a) Storm drain outfall from Randolph Rd.



Figure Trib. 3.1.1(b) Outfall scour pool depth.



Figure Trib. 3.1.1(c) Nickpoint near outfall apron.



Figure Trib. 3.1.1(d) 2nd nickpoint near outfall apron.



Figure Trib. 3.3.1(a) Storm drain on Burkart Bea Kay Drive.



Figure Trib. 3.3.1(b) Unstable rip rap near Hollywood Branch junction.

SECTION 3
STREAM RESTORATION STRATEGIES

I. Introduction

As presented previously, The Montgomery County Department of Environmental Protection, Watershed Restoration Program intends to restore degraded stream channel and adjacent floodplain, enhance riparian and in-stream habitat conditions, and improve aquatic resources along the uppermost reach of the Hollywood Branch stream corridor (Reach 3 as defined in the Lower Paint Branch Watershed Restoration Study).

These objectives will be accomplished by implementing an effective, long-term restoration plan for the unstable stream reaches identified during the field reconnaissance. The restoration and management strategies outlined in this report were developed to achieve these overall project objectives. These strategies focus on stabilizing unstable stream reaches along Hollywood Branch and its tributaries.

II. Stream Restoration Projects

A. General Comments on Approaches to Restoration Design

Often restoration projects are exercises in treating symptoms rather than an effective effort at finding a solution for what caused or is maintaining an unstable situation. The traditional restoration effort is project-oriented rather than system- or process-oriented. The project-oriented approach focuses on the obvious eroding stream banks or aggrading streambeds, and flood waters overtopping stream banks. It fails to recognize the natural processes that shape and maintain stream channels, the interactions between the channel and adjacent riparian areas, and how these processes and interactions are affected by channel and floodplain maintenance practices and land use in the watershed.

The traditional approach is commonly associated with engineered channels, that is, a relatively straight, wide, trapezoidal channel, with a uniform profile designed to convey all flows (baseflow, bankfull flow, and flood flow). The channel banks are often armored with rip-rap or gabions (concrete revetment in more urbanized areas) in an effort to maintain this engineered form, and grade control structures may be installed to maintain bed stability. This engineered approach invites long-term problems due to the negative feedback mechanisms inherent in all stream systems.

A geomorphic approach to restoration utilizing natural stability concepts is recommended for this project. This approach is system-oriented and works with, rather than against, the natural processes that shape and maintain stream channels. Restoration efforts are focused on: restoring a stable, self-maintaining channel form; reestablishing the critical interactions between the stream and adjacent riparian areas; restoring the natural functions of floodplains; modifying channel and floodplain maintenance practices that are inconsistent with these objectives; and minimizing the effects of land use by installing storm water controls, and adopting land use controls throughout the watershed that are based on landscape capabilities.

This approach also recognizes that natural streams are composed of three distinct channels: a thalweg or low flow channel; a bankfull channel; and a floodplain, which

conveys flows greater than bankfull. Finally, this approach emphasizes bio-engineered stream bank stabilization techniques that utilize natural materials (e.g., rootwads, logs, boulders, etc.) and live plantings.

The next few pages include examples of projects that were designed utilizing a natural channel design approach and specific techniques that are directly applicable to the stability problems identified along Hollywood Branch and its tributaries.

Natural Channel Design Projects



Figures 3.1 – a. Unstable stream reach. b. Same reach immediately after stabilization with log/boulder step-pools and toe benches. Note bank trees not disturbed during construction. c. Seven years after restoration



Figure 3.2 – a. Unstable stream reach. b. Same reach during installation of soil fabric lifts. c. Four years after restoration



Figure 3.3 – a. Unstable stream reaches. b. Same reaches six months after restoration with log/boulder step-pools

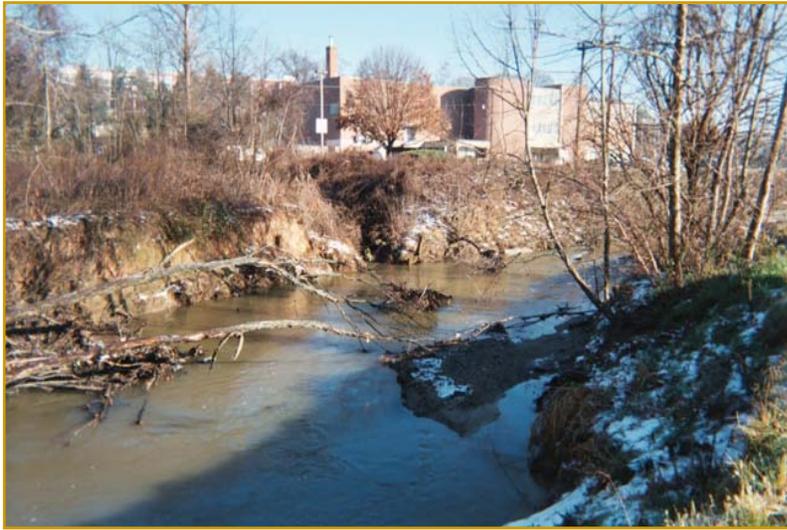


Figure 3.4 – a. Unstable reach. b. Four months after restoration with toe benches. Note channel has been narrowed significantly.



c. Three years after restoration



Figure 3.5 – a. Unstable reach.



b. Same reach six months after restoration with toe benches and soil fabric lifts.



Figure 3.6 – a. Unstable reach. b. Same reach four months after restoration with toe benches and soil fabric lifts. Note channel has been shifted away from failing slope and narrowed.



c. Three years after restoration

B. Recommended Restoration Projects in the Hollywood Branch Watershed

As noted previously, a field reconnaissance survey was conducted to assess and document existing conditions along the uppermost reach of Hollywood Branch and its three identified tributaries. The reconnaissance survey focused on identifying and documenting unstable conditions in upland and riparian areas, characterizing stream channel morphology and condition, and identifying unstable stream reaches. Based on the field reconnaissance stream reaches requiring remedial action were identified. Restoration and stabilization projects were identified for the unstable stream reaches based on their potential for correcting overall channel instability, improving in-stream habitat, and reducing sediment loadings to downstream reaches.

Those restoration and stabilization projects determined to be feasible were prioritized relative to the order in which they should be implemented. Table 3.1 describes the restoration/stabilization projects recommended for implementation in the Hollywood Branch watershed.

Table 3.1 – Hollywood Branch Stream Restoration/Stabilization Projects

Project ID	Length (feet)	Existing Problems	Proposed Solutions
UMS-1	100	Localized bank erosion along emergency spillway channel.	Grade and stabilize eroding streambanks with rip-rap
UMS-2	50	Localized bank erosion	Grade and stabilize eroding streambanks utilizing imbricated rock and plantings of native trees and shrubs.
UMS-3	60	Localized bank erosion	Shift channel toward left floodplain bench and reconstruct right banks utilizing soil fabric lifts, and live cuttings of native trees and shrubs.
UMS Total	210		
MMS-4.1	100	Active bank erosion	Grade a bankfull bench along the left bank. Stabilize streambanks utilizing erosion control matting and native trees and shrubs.
MMS-4.2	163	Headcuts and active bank erosion.	Reconstruct as a stable B4c channel. Grade a bankfull bench along both banks, install grade control structures, stabilize streambanks utilizing erosion control matting and native trees and shrubs.
MMS-4.4	212	Incised channel with headcuts and bank erosion. Headcuts in side drainages.	Reconstruct as a stable B4 channel utilizing log/boulder step-pools. Grade and stabilize eroding streambanks in lower section install grade control structures at headcuts in side drainage locations.
MMS Total	475		

Project ID	Length (feet)	Existing Problems	Proposed Solutions
LMS-5.1	475	Deeply incised, bank erosion, fallen trees, debris jams and aggradation. Upper section armored with rip-rap	Remove fallen trees and debris jams Reconstruct as a stable B4c channel. Upper section – Shift channel away from high banks, reconstruct bank with toe benches, install flow diversion structures, stabilize streambanks utilizing erosion control matting and native trees and shrubs. Middle and lower sections – Grade a bankfull bench along both banks, install flow diversion structures, stabilize streambanks utilizing erosion control matting and native trees and shrubs.
LMS-5.2	200	Bank erosion, debris jams and aggradation Middle section armored with rip-rap	Remove debris jams, Grade a bankfull bench along both banks, Install flow diversion structures, stabilize banks utilizing erosion control matting, and native trees and shrubs.
LMS-5.3	300	Deeply incised, bank erosion, collapsing trees, debris jams and aggradation,	Remove fallen trees and debris jams, Reconstruct as a stable B4c channel. Grade a bankfull bench along both banks, install flow diversion structures, stabilize streambanks utilizing erosion control matting and native trees and shrubs.
LMS-5 Total	975		

Project ID	Length (feet)	Existing Problems	Proposed Solutions
LMS-6.1	600	Bank erosion, fallen trees, debris jams, split channels, and aggradation, head-cut at down-stream end	<p>Remove fallen trees and debris jams Reconstruct as a stable C4 channel.</p> <p>Upper Section –</p> <p>Adjust meander geometry by shifting channel away from existing bank, reconstruct bank with toe bench, reconstruct single thread channel, install flow diversion structures, stabilize streambanks utilizing erosion control matting and native trees and shrubs.</p> <p>Middle Section –</p> <p>Grade a bankfull bench along left banks, install flow diversion structures, stabilize streambanks utilizing erosion control matting and native trees and shrubs</p> <p>Lower Section –</p> <p>Shift channel away from manhole, reconstruct bank with toe bench, stabilize head-cut and transition into Reach 6.2 by constructing step-pool channel</p>
LMS-6.2	115	Right bank armored with rip-rap, debris jams and active bed erosion, head-cut at upstream end	Stabilize head-cut and transition into Reach 6.1 by constructing step-pool channel

Project ID	Length (feet)	Existing Problems	Proposed Solutions
LMS-6.3	475	Bank erosion, fallen trees, debris jams and aggradation	Remove fallen trees and debris jams Reconstruct as a stable C4 channel Grade a bankfull bench along banks, install flow diversion structures, stabilize streambanks utilizing erosion control matting and native trees and shrubs.
LMS-6 Total	1190		
LMS-7	650	Bank erosion, rip-rap check dam, debris jams and aggradation, damaged trail	Remove check dam, fallen trees and debris jams Reconstruct as a stable C4 channel. Upper section – Adjust meander geometry by shifting channel away from existing banks, reconstruct bank with toe bench, reconstruct single thread channel, install flow diversion structures, stabilize streambanks utilizing erosion control matting and native trees and shrubs. Middle and lower sections – Shift channel away from high terrace, reconstruct bank with toe benches, Grade a bankfull bench along both banks, install flow diversion structures, stabilize streambanks utilizing erosion control matting and native trees and shrubs.
LMS-7 Total	650		

Project ID	Length (feet)	Existing Problems	Proposed Solutions
Tributary 1	125	Bank erosion exposed utilities	Remove debris jams Reconstruct as a stable B4c channel. Shift channel away from manhole, Grade a bankfull bench along both banks, install flow diversion structures, stabilize streambanks utilizing imbricated rock.
Tributary 3.1	425	Bank erosion, split channel, debris jams and aggradation,	Remove fallen trees and debris jams Reconstruct as a stable B4c channel. Upper section – reconstruct bank with toe bench, reconstruct single thread channel, install flow diversion structures, stabilize streambanks utilizing erosion control matting and native trees and shrubs. Middle and lower sections – Grade a bankfull bench along both banks, install flow diversion structures, stabilize streambanks utilizing erosion control matting and native trees and shrubs.
Tributary 3.2	100	Debris jams, aggradation caused by yard waste, retaining wall undermined	Remove debris jams and sediment deposition Remove retaining wall and grade banks stabilize streambanks utilizing erosion control matting and native trees and shrubs

Project ID	Length (feet)	Existing Problems	Proposed Solutions
Tributary 3.3	175	Deeply incised, headcuts, bed and bank erosion, debris jams	<p>Remove debris jams</p> <p>Upper Section –</p> <p>Reconstruct as a stable B4 channel utilizing log/boulder step-pools. Grade and stabilize eroding streambanks</p> <p>Middle and lower sections –</p> <p>Adjust meander geometry and reconstruct channel as stable B4c</p> <p>Grade a bankfull bench along both banks, install flow diversion and grade control structures, stabilize streambanks utilizing erosion control matting and native trees and shrubs</p>
Tributary 3 Total	650		
Hollywood Branch Project Total	4275		

III. Hollywood Branch Restoration Design

A. Overview

Charles P. Johnson & Associates and Clear Creeks Consulting met with Montgomery County Department of Environmental Protection on February 4, 2009 to discuss the results of the Preliminary Assessment and confirm the areas of stream restoration for the purposes of defining total project survey limits. All projects were approved downstream of Midland Road, which encompasses MMS-4.1 through MMS-7, as well as Tributaries 1 and 3.

Following the February 4th meeting, CPJA performed a topographic survey within the defined survey limits. After the survey was finished, CPJA and Clear Creeks Consulting then developed a 30% design plan view. This 30% design plan view, encompassing nine sheets, will be submitted as an accompaniment with this report. The plan view includes the Hollywood Branch stream corridor base map, the proposed solutions as outlined in Table 3.1 of this report, preliminary limits of grading, limits of disturbance, trees to be removed, staging and storage areas, proposed construction entrances and access roads, and proposed structures and their locations. CPJA and Clear Creeks Consulting also developed a preliminary, 30% cost estimate based on the 30% design plan view. The cost estimate is attached in Appendix G.

B. General Approach to Hollywood Branch Restoration Design

As pointed out in the Findings of Field Studies Section, Hollywood Branch has been affected by alterations to watershed hydrology and sediment supply associated with residential and commercial development and roads throughout the watershed. In addition, direct impacts to the channel and adjacent riparian area have occurred as a result of straightening and channelization, clearing of riparian vegetation, installation and maintenance of public utilities, as well as on-going yard maintenance practices by residential landowners.

The restoration objectives for Hollywood Branch and its tributaries include:

1. Overall channel geometry and slope will be modified to reduce near bank stress and improve sediment transport capacity. This will be accomplished by reconstructing unstable G4 and B4c reaches as stable B2 and B4c channels, respectively. Unstable C4 reaches will be reconstructed as stable C4 channels.
2. Reaches with high width/depth ratios will be reconstructed with a narrower baseflow and bankfull channel to improve habitat as well as sediment transport. This will be accomplished by grading existing banks and constructing bankfull benches along the channel margin.

3. High, vertical banks on the outside of the meander bends as well as the adjacent floodplain will be excavated and graded to establish a better angle of repose on the banks, increase floodprone area, and lower the bankfull to bank height ratio. Particular emphasis will be placed on grading those banks lacking woody vegetation and preserving those banks that are well vegetated with trees and shrubs.
4. Meander geometry will be modified to increase radii of curvature on bends where the radii of curvature are extremely low, that is smooth out the tight bends. This will reduce near bank stress caused by these tight bends and increase the overall channel gradient and sediment transport capacity.
5. Where channel reaches are currently eroding terraces and steep hill slopes, they will be relocated away from these areas and the terraces and slopes reconstructed.
6. Cross vanes, log/boulder J-hooks, and boulder step-pools will be installed at key locations along both the main stem and tributaries to reduce near-bank stress, provide grade control, dissipate energy, and create habitat.
7. Long-term bank stabilization and lateral control will be provided by planting native grasses, trees, and shrubs on the lower and upper stream banks.

C. Hollywood Branch 30% Design Criteria

1. Design Discharges

As noted in the Hydrology section of this report, preliminary bankfull discharge estimates were developed for the project reaches. This information was utilized to validate bankfull channel indicators identified in the field but was not utilized in developing the 30% plans.

2. Reference Reach Data

The morphologic stream assessment provided information on the current conditions along Hollywood Branch and its tributaries as well as the direction of adjustment toward a new stable form. Valley type, landform characteristics, and the existing Rosgen stream types were evaluated to infer the potential condition or most probable form that the unstable channel reaches would evolve toward. With the most probable stable form of the unstable reaches determined, it was possible to identify a specific “reference” or stable Rosgen stream type for the unstable reaches.

After determining the appropriate Rosgen stream types (i.e., stable form for the reaches to be restored) for Hollywood Branch, dimensionless ratios were taken

from a reference reach data base developed from stable B2, B4c and C4 streams in the Piedmont Regions of Maryland and North Carolina.

The ratios for channel plan form, cross-section and profile were compared to the geomorphic assessment data collected for the Hollywood Branch project reaches to determine the degree to which existing channel conditions differ from the stable channel form. The dimensionless ratios are presented in Appendix F in this report.

3. Channel Geometry

Since lateral erosion and aggradation are significant on-going problems along many reaches of Hollywood Branch, two major objectives of the restoration project are to reduce near bank stress and improve sediment transport.

The preliminary 30% channel plan form layout was developed during several site walks. The overall goal was to increase radii of curvature on bends where the radii of curvature are extremely low, that is smooth out the tight bends. This will reduce near bank stress and increase the overall channel gradient and sediment transport capacity. In addition, where channel reaches are currently eroding terraces and steep hill slopes, they were relocated away from these areas and the terraces and slopes were called out for reconstruction.

Although the design longitudinal profile was not developed at this stage, the preliminary location of bed features was developed based on the plan form and is shown on the 30% plans. Design cross-sectional dimensions were not developed at this stage either. However, the 30% plans reflect the overall goal of reconstructing reaches with high width/depth ratios such that the baseflow and bankfull channel are narrower. This will be accomplished by grading existing banks and constructing bankfull benches along the channel margin.

After the 60% design plan form is developed the layout of the longitudinal profile and cross-sectional dimensions will be developed for each reach to be restored.

4. Channel Stabilization Techniques

Once the 30% plan form was complete it was important to select the techniques that will be used to stabilize the streambed and banks of the restored channel. The stream channel stabilization techniques utilized should complement the restored stable channel-form with an emphasis on stability, habitat and aesthetics. The dimensions and locations of the structures shown on the 30% plans are preliminary and may be adjusted during the 60% design phase. However, they are generally consistent with the criteria developed by Rosgen for these specific types of structures.

D. Hollywood Branch 60% Design Criteria

The next phase of the design process will involve additional field work and more detailed analyses to develop the final channel plan form, cross-sectional dimensions, and longitudinal profile for each reach to be restored. Design criteria will include:

1. Design Discharges

During the 60% design phase, existing peak discharges for the 1-, 2-, 10-, 50- and 100-year storm events will be developed using hydrologic modeling, which may include utilizing TR55 and TR20 modeling, HEC-1 results from the Lower Paint Branch Watershed study (provided by Montgomery County), regional regression equations for the defined return intervals, and USGS gage analysis. Three methods will be used to develop final bankfull discharge estimates. These will include 1) regional regressions developed for use in urban watersheds (Powell, 2002), 2) hydrologic model output from the TR-55 and TR-20 hydrologic models, and 3) Manning's equation and field data. The bankfull discharge estimate determined to be the most reliable, as well as the peak discharge estimates for the 1-, 2-, 10-, 50-, and 100-year storm events will provide input for the HEC-RAS hydraulic model.

2. Reference Reach Data

The natural channel design approach is based on the concept that dimensionless ratios can be developed from the morphological data collected from the stable reference reach and utilized to establish design criteria for the cross-sectional geometry, meander pattern, profile, and other morphologic features of an unstable stream reach. During the 60% design phase, dimensionless ratios will be taken from the reference reach data base developed from stable B2, B4c and C4 streams in the Piedmont Regions of Maryland and North Carolina and utilized to develop channel geometry for the reaches to be restored.

3. Channel Geometry

The 60% plan form will be adjusted to accommodate natural (mature trees) and man-made (public utilities, sheds, etc.) constraints. After the 60% channel plan form is completed, channel dimensions will be developed utilizing the hydraulic geometry regional regressions for urban watersheds (Powell, 2002) to determine channel cross-sectional area (A) based on the drainage area to a given reach. The calculated A and W/D ratios from the reference reach database will be used to determine bankfull width $W_{bf} = \sqrt{(W_{bkf} / dbkf)} (Abkf)$ and bankfull mean depth $Dbf = W_{bkf} / (W_{bkf} / dbkf)$.

The proposed slope, bankfull cross-sectional area, width, depth and width/depth ratios will be adjusted for each reach using an iterative process that includes multiple sediment entrainment analyses. After each adjustment the latest

channel dimensions and profile will be checked against ratios from the reference reach database.

4. Sediment Entrainment Analysis

In restoration design, entrainment analysis is utilized to verify that the proposed channel generates the shear stress needed to entrain and transport the sediment expected to be moving through the project reach under bankfull flow conditions. A number of bulk sediment samples will be collected along Hollywood Branch during the 60% design phase of the project. This effort will include the collection of riffle pavement and subpavement samples, as well as point bar samples. Sediment data gathered from riffle pavement/subpavement and point bar samples will be utilized in the entrainment analysis to verify that the project channel dimensions and profile are appropriate to maintain the competency of the restored reaches.

- Existing Conditions

The critical shear stress values developed in these analyses will be compared to the critical shear stress values calculated for riffle cross-sections along the existing channels. This comparison will provide verification of field observations regarding existing streambed stability and channel competency.

- Proposed Conditions

During the design phase of the project, the critical shear stress developed in these analyses will be utilized to verify that the project channel dimensions and profile are appropriate to maintain the competency of the restored reaches.

5. Channel Stabilization Techniques

Once the 60% channel plan form is complete, the dimensions and locations of the grade control and flow diverting structures will be adjusted to be consistent with the criteria developed by Rosgen for these specific types of structures.

SECTION 4 REFERENCES

References

Hammer, T.R., 1972. Stream Channel Enlargement Due to Urbanization. In D. R. Coates (ed). Environmental Geomorphology and Landscape Conservation, Volume II: Urban Areas. 1974. Dowden, Hutchinson and Rose, Inc. Stroudsburg, PA.

Maryland Geological Survey, 1968. Montgomery County, MD.

Maryland State Highway Administration, April 2007, Introduction to GISHydro2000 Training Manual (www.gishydro.umd.edu), Fixed Region Regression Equations for the Piedmont Region (urban equations, p.108); authored by Dr. Glenn E. Moglen, University of Maryland, Associate Professor, Dept. of Civil and Environmental Engineering.

Montgomery County Department of Environmental Protection, 2006. Lower Paint Branch Watershed Restoration Study. Prepared by URS, Gaithersburg, Maryland.

Montgomery County Department of Environmental Protection, 2004. Countywide Stream Protection Strategy.

National Oceanographic and Atmospheric Administration – National Climate Data Website, 2002. Annual Climatological Summary – Temperature and Precipitation Records 1871 – 2001 for Baltimore, Maryland

Powell, R., Regional Regressions for Use in Geomorphologic Assessments of Streams in Urban Watersheds in the Piedmont and Western Coastal Plain Regions of Maryland and Delaware.

Robinson, A. M., 1976. Effects of Urbanization on Stream Channel Morphology. National Symposium on Urban Hydrology, Hydraulics and Sediment Control.

Rosgen, D. L., 1996. Applied River Morphology . Wildland Hydrology. Pagosa Springs, Colorado.

US Department of Agriculture, Natural Resources Conservation Service, Version 3, 2005. Soil Survey of Montgomery County, MD.