Appendix B. Plan Formulation and Environmental Benefits Model Appendix

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Anacostia Watershed Assessment Plan Formulation and Environmental Benefits Model Appendix

August 2017

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INTRODUCTION

This appendix provides details specific to the plan formulation of the study to support the information provided in the main report. Information contained in this appendix includes:

1. Details on sites considered and the final sites selected for analysis in the study,
2. The procedures used to quantify environmental benefits,
3. Field data sheets for habitat assessments, and
4. Results of model runs to quantify environmental benefits.

In fall 2013, Baltimore District, U.S. Army Corps of Engineers (USACE) began documenting biological benefit models for approval by USACE Headquarters. The proposed models utilize existing methods of the Maryland Biological Stream Survey (MBSS data) and are applicable within the Anacostia Watershed in Prince George's County. These methods characterize changes in aquatic habitat conditions that could be produced by stream geomorphic restoration projects. MBSS has published habitat and biological condition assessment procedures, and has collected data in the study area since the 1990s using these methods. The methodology and metrics in MBSS are based on USEPA rapid bioassessment methodology (Barbour et al. 1999).

MBSS developed its Physical Habitat Index (PHI) for three geographic regions in Maryland: Piedmont, Coastal Plain, and Highlands. For this study, Piedmont and Coastal Plain models are utilized and are applicable within the Anacostia Watershed (in appropriate geomorphic areas) in Prince George's County. PHI will be utilized in Prince George's County because MBSS protocols and metrics are also utilized by Prince Georges County in their biological monitoring programs. Furthermore, statewide MBSS datasets include Prince George's Counties, but the data network is less dense than county datasets.

SITE SELECTION

Table 1 provides a summary of the reaches considered and identifies those eliminated from further consideration for this study. Section 3 of the main report details the specific site selection criteria used for consideration or elimination of the sites. These criteria included degraded aquatic habitat, potential for restoration, opportunity to connect with other restored reaches, location on public land, and location relative to features that might affect restoration actions. Table 2 includes initial field and office notes on general habitat condition and potential restoration opportunities at the study sites selected for further consideration. Following selection of the tentatively selected plan, additional field visits were performed for development of feasibility level designs. This information was used to evaluate environmental impacts and is included in Section 5 of the main report.

Table 1. Summary of Sites Considered and Selection

Map No.	Reach	Subwatershed	Current Status	Length (ft)	Notes
1	Indian Creek – I-95	Indian Creek	Selected	6,958	Multiple opportunities for stream and wetland restorations between I-95 and Beltsville. Restoration potential may be impacted by regional stormwater facility. This entry only includes "selected" portion of reach.
1	Indian Creek Upstream of –I-95	Indian Creek	Eliminated	6,911	Upstream of I-95 eliminated due to disconnection from rest of stream by large culverts; downstream section eliminated due to large concrete channels.
2	Lower Beaverdam Creek – Cabin Branch	Lower Beaverdam Creek	Eliminated	26,689	Upper half of reach is very constrained with real estate and fish movement is constrained by lower half of reach which is compromised by legacy pollutants and land use. Issues identified by field team.
3	Northwest Branch – Hyattsville	Northwest Branch	Selected	7,644	Partial fish blockage identified by MWCOG. Influences confluence of Sligo Creek. Large restoration project directly upstream in design by Prince George's Count. Multiple small projects completed in reach; opportunity to tie projects together. Small AWS project in reach may be incorporated into design.
4	Northwest Branch – Upstream of University Blvd	Northwest Branch	Eliminated	10,114	Habitat/geomorphic conditions are very good in reach and potential restoration actions would likely have little impact.
5	Paint Branch	Paint Branch	Selected	5,879	Immediately downstream of Paint Branch CAP Section 206 project. Long identified as priority by MNCPPC, MWCOG, and Prince George's County. Connects restoration activities from confluence with Little Paint Branch to confluence with Indian Creek.
6	Dueling Creek/Colmar Manor Wetlands	Tidal	Eliminated	N/A	Tidal wetland restoration with small restoration potential.
7	Paint Branch – I-95 Interchange	Paint Branch	Selected	5,935	Eroded stream banks. Opportunity to decrease erosion and instability where not bedrock controlled. Entirely under highway bridges. Difficult access.
8	Cross Creek	Little Paint Branch	Eliminated	8,553	Crosses many private parcels and is through a golf course. Immediately downstream of ICC detention basins.
9	Sligo Creek	Sligo Creek	Selected	2,330	Fish passage blockage, restoration potential.
10	Chillum Road Tributary	Northwest Branch	Selected	2,226	Provides opportunity for comprehensive restoration with Northwest Branch main stem. Evident channel incision and erosion. MWCOG suggested site.

Map No.	Reach	Subwatershed	Current Status	Length (ft)	Notes
11	Indian Creek – College Park	Indian Creek	Selected	9,843	Opportunity to increase stream habitat heterogeneity (mix of pools, riffles, runs) where degraded by channelization.
12	Little Paint Branch	Little Paint Branch	Selected	4,389	Directly upstream of ICC mitigation project at Paint Branch/Little Paint Branch confluence. Opportunity to increase stream habitat heterogeneity (mix of pools, riffles, runs) where degraded by channelization. Channel incision and erosion evident. Good access.
13	Northwest Branch: East-West Highway to Fordham Road	Northwest Branch	Selected	2,953	Already partially designed by Prince George's County. Proposed Purple Line may run on road above project site. Cultural resources surveys already performed and clear for this area. Project designed for reach at Fordham Road into Northwest Branch.
14	William Wirt Middle School	Briers Mill Run	Eliminated	2,797	Sewage evident in water. Extremely unstable. Good opportunity for restoration, but unrealistic given needs to address sewage issues. AWS stormwater project at Middle School. This segment is a side tributary to the Northeast Branch.
15	Northeast Branch: Calvert Road Disc Golf Park	Northeast Branch	Selected	5,323 (includes approx. length for side tributary up to UMD property)	On public land. Would provide connectivity with other restoration already targeted in Paint Branch #5 (1.1 mi) and Indian Creek #11 (1.86 mi) segments. The addition of this segment will link up with approximately 5.3 miles of Paint Branch either already designed for or planned under the ARP for targeted stream restoration. This 0.7 miles is a critical junction along the main stem of the Northeast Branch downstream at the confluence of Indian Creek and Paint Branch.
16	Dueling Creek	Tidal	Eliminated	8,641	Highly urbanized, entrenched, incised, and eroded. Upstream reach underground, tidal area is stable. Limited restoration potential given stream crossings/culvert/paving and real estate issues. Abundant trash. Too many issues for restoration success.
17	Quincy Manor	Northeast Branch	Eliminated	3,096	Previously studied and designed by Prince George's County. Issues with real estate/access.
18	Indian Creek: Calvert Road Disc Golf	Indian Creek	Eliminated	2,335	Habitat/geomorphic conditions are good in reach and potential restoration actions would likely have little impact.

Table 2. Prince George's County Selected Stream Segments General Habitat Condition Description and Implications for Assessment. All segments are situated in the Coastal Plain unless otherwise noted.

USACE Segment	General Location (up to down)	General Habit Condition Segment Scale [Review of Google Earth Photos, linear measurements in Google Earth (i.e., not following thalweg) plus previous site visit]	Wetlands Along Candidate Segment (NWI Map Review)	Habitat Restoration Opportunities and Needs	Habitat Assessment and Restoration Project Issues/Uncertainties
1	Indian Creek I95 (I95 to Caroline/Quimby Aves)	Lowermost 0.3 mi reach is mature riparian forest. Stream apparently had braided condition previously based on aerial photos and site visits, unclear whether braided condition occurred over historical or geologic time. Small ponds near Caroline Avenue neighborhood on W side of stream with levee system. Middle reach downstream of Ammendale Rd by 0.1 to 0.3 mi passes through FRM/SWM basin and outfall structures. Some downcutting downstream of outfall. Substantial physical alteration. Channelized downstream of FRM feature, very altered within feature. Uppermost 0.6 mi (Rt 95 – Ammendale Rd) entirely wooded. In photos appears to also have multiple braided/anastomosing stream segments present historically or over geologic time (similar to lowermost reach). Stream ditched /straightened on E side of wetland. No erosion observed in wetland, ideal stream floodplain interaction.	Uppermost segment above Ammendale Rd is mapped as PFO/PSS wetland parcel up to about ½ way to 95. On site visit (6/27/2017), observed large wetland area with water level controlled by beaver pond just upstream of Ammendale Rd. PEM wetland mapped along stream midway between Ammendale and Quimby	In uppermost reach above Ammendale Rd could increase sinuosity of stream in wetland to restore instream habitat and increase stream/wetland interaction, but would need to maintain water supply to wetland from creek Below FRM/SWM feature, increase habitat complexity in ditched stream down to point where stream meandering again occurs.	(Did not visit uppermost reach immediately below route 95, however presumably woods as per lower end of segment above Ammendale Rd) Eliminate consideration of portion within uppermost FRM/SWM feature because of mission limits? Would be worried about environmental trade-offs of stream restoration project in lowermost reach (mature forest impacts). Uppermost reach would have wetlands impacts, however could be net positive for wetland. Possible private property concerns in uppermost reach.

3	Northwest Branch Hyattsville (Ager Rd to Queens Chapel Rd (Rt 500)	Majority of segment channelized historically. Uppermost reach above 410 channelized but no stabilization. Remains in earthen channel. Fill placed along channel though did include concrete rubble which now has mature trees growing out of it. Habitat simplified in channelized reach, but naturally developing multistage channel in bottom. However, large dewatered channel area (bars) lacking vegetation presumably because of frequent scour. Also, presumably pools would be deeper if channel narrower. Below this but still above 410, stream not channelized (or if it was, they left meanders in). Severe erosion on cut banks there with occasional deep pools at woody debris jams but also braided sections at sediment jams. Then stabilized in vicinity of 410. Then below 410, not channelized (or if it was, they kept meanders) nor stabilized. As with reach above 410 not channelized, severe erosion on cut banks, with large woody debris jams and braided sections. Based on field observations, stream is then downstream stabilized with boulders but not channelized, forming deep pools. Locally severe erosion where not stabilized. Downstream channelized with mix of gabion baskets and boulders, again forming deep pools, but not eroding.	No wetlands mapped (11/14/14)	Increase stream habitat heterogeneity (mix of riffles, runs, pools, velocities, and depths). Habitat degraded (homogenized) by channelization. Decrease locally severe erosion/instability	

USACE Segment	General Location (up to down)	General Habit Condition Segment Scale [Review of Google Earth Photos, linear measurements in Google Earth (i.e., not following thalweg) plus previous site visit]	Wetlands Along Candidate Segment (NWI Map Review)	Habitat Restoration Opportunities and Needs	Habitat Assessment and Restoration Project Issues/Uncertainties
		Downstream, stream channelized and stabilized but stabilization partially buried by channel parallel deposits.			
5	Paint Branch (Rt 1 to Indian Creek confluence)	Historically channelized. Spoil placed parallel to channel along much of stream based on presence of channel-parallel levees. Stream remains primarily in earthen channel with minimal stabilization. Boulder stabilization occurs in vicinity of sewer infrastructure and bridges. Latter include Route 1, two pedestrian trails, and dual railroad tracks. Riffle grade control boulder stabilization features occur immediately downstream of lower pedestrian bridge. Bank heights vary along channel, presumably as function of natural topography and extent of overbank spoil placement. Stream habitat simplified by historic channelization. Long reaches with homogeneous conditions occur where earthen channel occurs. Drastically different conditions occur in vicinity of woody debris jams where heterogeneous but unstable conditions occur. In vicinity of boulder stabilization works, stream is typically wider and has greater depth. Invasive bamboo patch at upper end, south bank.	Majority of stream riparian corridor mapped as PFO wetlands. Large PFO parcel to N of stream S of RR tracks. PFO on both sides of stream in large parcel between Route 1 and RR tracks.	Increase stream habitat heterogeneity (riffles, runs, pools mix, velocities, depths), habitat degraded (homogenized) by channelization. Possibly rewater wetlands drained by channelization by raising stream water surface elevation to raise groundwater level and increase frequency of overbank flooding. Eradicate bamboo patch if can be done in conjunction with upstream bamboo eradication. Consider possibly restoring stream to historic channel which is still present along much of S bank downstream of Route 1.	Need to determine where wetland vs upland mature trees occur to determine whether wetland rewatering acceptable. (Not acceptable if impacting substantial number of upland mature trees).

USACE Segment	General Location (up to down)	General Habit Condition Segment Scale [Review of Google Earth Photos, linear measurements in Google Earth (i.e., not following thalweg) plus previous site visit]	Wetlands Along Candidate Segment (NWI Map Review)	Habitat Restoration Opportunities and Needs	Habitat Assessment and Restoration Project Issues/Uncertainties
7	Paint Branch I95 Interchange (Powder Mill Rd to I95)	Lowermost 0.4 miles historically channelized. Substantial portion of segment (channelized and unchannelized) is underneath 95/495 Interchange. The stream is bedrock-controlled Piedmont for a stretch immediately south of Powder Mill Road, then becomes alluvial Piedmont, then intermittently again becomes bedrock-controlled Piedmont locally under Route 95 to just above the power lines. From the power lines downstream, the stream is then again alluvial Piedmont but becomes increasingly coastal plain in character.	PFO wetland mapped in large parcel on both sides of stream segment between Powder Mill Rd and 95. No wetlands mapped occurring S of 95 along stream segment	Decrease erosion/instability in Piedmont section where not bedrock controlled. Possibly rewater wetlands drained by stream incision in Piedmont sections by raising stream grade to raise groundwater level and increase overbank flooding frequency.	Need to determine where wetland vs upland trees are to determine whether can raise stream water surface elevation.
9	Sligo Creek (Vicinity of Balfour Dr Ray Rd intersection to NW Branch confluence)	Historically channelized with ponded sections	No wetlands mapped along segment (11/14/14)	Increase stream habitat heterogeneity (mix of riffles, runs, pools), habitat degraded (homogenized) by channelization. Notch various grade-control structures to induce thalweg formation.	Numerous cross-stream structures. Bank stabilization works in many cases buried in sediment and not visible. Unclear whether boulder field appropriate for coastal plain stream (is exotic habitat type)

USACE Segment	General Location (up to down)	General Habit Condition Segment Scale [Review of Google Earth Photos, linear measurements in Google Earth (i.e., not following thalweg) plus previous site visit]	Wetlands Along Candidate Segment (NWI Map Review)	Habitat Restoration Opportunities and Needs	Habitat Assessment and Restoration Project Issues/Uncertainties
10	Chillum Rd Tributary (Chillum Rd to Nicholson St)	Upper portion from Chillum Rd downstream 0.13 miles (to vicinity of Longford Dr) probably historically channelized (straight). Channel includes boulder and gabion basket stabilization (not sure what total stabilized length is). Downstream of this 0.13 miles, channel not stabilized but severe entrenchment/bank erosion with lots of meandering.	No wetlands mapped along segment (11/14/14)	Decrease locally severe erosion/instability. Manage invasive riparian vegetation. Excavate out broader channel/floodplain area along north bank of stream in Chillum Park. No recreation negative impacts (narrow mowed lawn).	

USACE Segment	General Location (up to down)	General Habit Condition Segment Scale [Review of Google Earth Photos, linear measurements in Google Earth (i.e., not following thalweg) plus previous site visit]	Wetlands Along Candidate Segment (NWI Map Review)	Habitat Restoration Opportunities and Needs	Habitat Assessment and Restoration Project Issues/Uncertainties
11	Indian Creek – College Park	Based on map/aerial photo review, stream in 0.2 miles downstream of I95 channelized; Map review indicates probable channelization and massive effects of historic quarrying etc., between Greenbelt Metro Drive and Greenbelt Rd. Reach immediately upstream of Greenbelt Rd uniform width and ponded but meandering. Probably channelized/dredged with spoil deposited on east bank (high west bank topography)? Channelized from Greenbelt Rd downstream to end of segment; Generally minimal channel or bank erosion up to above Greenbelt Rd to reed grass patch. From that point downstream, habitat degraded/simplified by historic channelization/dredging and modern ponding such that homogeneous habitat conditions occur. Majority is pool/glide. Minimal runs or riffles, except where artificially formed. Minimal stream shading. Notable stand of invasive bush honeysuckle on west bank upstream of Greenbelt Rd.	Majority of segment S of Greenbelt Rd is mapped as being within PFO wetland. Majority of wetland parcels lie on W bank of stream. Between just S of Greenbelt Metro Dr. and N end of industrial complex just N of Greenbelt Rd., segment is mapped as within PFO and PEM wetland. Within braided stream section south of beltway, stream is mapped as PFO wetland.	Increase stream habitat heterogeneity (mix of riffles, runs, pools, velocities, depths) homogenized by channelization. Within channelized portions, possibly rewater drained wetlands by raising stream elevation to raise groundwater elevation and increase frequency of overbank flooding. Excavate to create multistage channel, probably on E bank (W bank mature trees). Just south and west of braided stream portion, restore Phragmites wetlands to forested wetlands. East bank north of Greenbelt Rd has substantial poured concrete, degrading riparian habitat. Could modify this to increase capability of plants to grow on east bank. Could remove this entirely to establish floodplain and riparian buffer.	Braided vs single channel stream, wetland vs stream trade-off concerns in reach above Green Belt Rd and below Greenbelt Metro Drive. Wetland impact concerns. Structure/property flooding concerns could preclude raising stream water surface elevation. Property ownership and liability for historic impacts (gravel quarrying, industrial/commercial activity disturbances).

USACE Segment	General Location (up to down)	General Habit Condition Segment Scale [Review of Google Earth Photos, linear measurements in Google Earth (i.e., not following thalweg) plus previous site visit]	Wetlands Along Candidate Segment (NWI Map Review)	Habitat Restoration Opportunities and Needs	Habitat Assessment and Restoration Project Issues/Uncertainties
12	Little Paint Branch	From I95 to Cherry Hill Rd., stream historically channelized. From Cherry Hill Rd ¼ mi downstream, no obvious historic channelization. Stream floodplain often low, frequent flooding into floodplain. From ¼ mi below Cherry Hill Rd, stream channel historically channelized 0.3 mi further downstream to where trail crosses stream	Segment from 495 through S end is mapped as lying within PFO wetland. Stream lies within middle of PFO parcel except at S end of segment where W bank of segment not mapped as PFO.	Increase stream habitat heterogeneity (mix of riffles, runs, pools, velocities, depths) where habitat degraded (homogenized) by channelization. Raise stream water surface elevation to raise groundwater level and increase stream/floodplain interactions in channelized sections to rewater wetlands.	Flooding concerns to structures/properties. Wetland impact concerns.
13	Lower Northwest Branch	Segment originates just below Piedmont contact. Historically channelized in uppermost reach, then severe channel and bank instability to above archery range. Then historically channelized with unstable channel and banks in archer range. Below University Boulevard, stream channelized through majority of Lane Recreational Center. Portion of stream is systematically stabilized with boulders in Lane Recreation Center.	Large part of segment above University Boulevard mapped as flowing adjacent to or within PFO1A wetland.	Increase stream habitat heterogeneity (mix of riffles, runs, pools, velocities, depths) where habitat degraded (homogenized) by channelization. Reduce severe channel and bank instability and increase overbank flooding and or raise stream grade within mapped wetland area.	Need to determine where wetland vs upland trees are to determine whether can raise stream water surface elevation.

USACE Segment	General Location (up to down)	General Habit Condition Segment Scale [Review of Google Earth Photos, linear measurements in Google Earth (i.e., not following thalweg) plus previous site visit]	Wetlands Along Candidate Segment (NWI Map Review)	Habitat Restoration Opportunities and Needs	Habitat Assessment and Restoration Project Issues/Uncertainties
15	Northeast Branch	Stream is entirely channelized and stabilized with boulders. Stream has minimal shade. Stream has occasional large point bar deposits downstream of Paint Branch Parkway, in these areas boulder stabilization works are buried by sediment.	S-flowing tributary on W bank opposite MNCPPC flows through mapped PFO1A parcel. NE Branch at Briers Mill Run flows through mapped PF01A. Mapped PF01A parcels inland from NE Branch on both banks S of Paint Branch Parkway.	Increase stream habitat heterogeneity (mix of riffles, runs, pools, velocities, depths) where habitat degraded (homogenized) by channelization. Alter grade control structures to influence/reduce ponding conditions	Uncertain what stream-parallel infrastructure present. Uncertain whether boulder works could be modified.

PROCEDURES

In Fall 2013, NAB prepared a model approval plan providing documentation to the USACE Ecosystem Planning Center of Expertise (EcoPCX) on proposed utilization of existing methods and data of Montgomery County Department of Environmental Protection (MCDEP) and Maryland Biological Stream Survey (MBSS data) for the Anacostia Watershed. These methods could characterize changes in finfish biological condition that could be expected with stream geomorphic restoration projects. In December 2013, Baltimore District further explored correlations between finfish indices of biological condition (including finfish index of biotic integrity) and individual metrics of the habitat condition scores that could be improved by USACE in restoration projects. Weak positive relationships between individual habitat parameters and fish index of biotic integrity (FIBI) were evident. The strongest correlations between any individual habitat parameter and FIBI was for instream cover at 0.1887, followed by riparian buffer at 0.1499. The correlation between instream cover plus riparian buffer versus FIBI was 0.2688, which was as high as the score considering all habitat metrics combined versus FIBI. Theoretically, this indicates that just improving instream cover and increasing riparian buffer width would produce significant benefits to FIBI. However, increasing cover in a sustainable manner in these rapidly eroding systems requires that erosion of the channel also be dealt with, or longevity of instream cover restoration efforts (such as via structures) would likely be reduced. Thus, comprehensive geomorphic restoration work is appropriate if sustainable habitat improvement benefits are to be realized. Overall though, without water quality improvements, finfish biological response to instream habitat improvement could be weak. Instead improvement in biological condition would be reliant upon comprehensive watershed restoration measures. In accordance with this finding, the EcoPCX advised Baltimore District in 2014 that it would be appropriate to measure habitat improvements by a habitat metric rather than by forecast change in biotic integrity.

Physical Habitat Index

The Physical Habitat Index (PHI) was used in the quantification of the environmental benefits of potential stream restoration alternatives in Prince George’s County, Maryland, for the Anacostia Watershed Restoration, Prince George’s County study. MBSS (2003) procedures were chosen to assess habitat conditions because they have been utilized by the Prince George’s County Department of the Environment (PGDOE) since the 1990s and thus allowed for ready comparison of previous to current conditions. PGDOE has used the protocols to assess existing conditions recently through contracts with Tetra Tech. MBSS has also sampled extensively throughout Prince George’s County during several rounds of stream surveys. Use of these procedures was coordinated with USACE Ecological Center of Expertise. Table 3 shows the sequence of steps used for the assessment of stream habitat.

Table 3. Steps in the assessment of the Physical Habitat Index.

Step	Location	Assessment Step
1	Office & Field	Subdivide project stream sites into representative reaches based on habitat conditions.
2	Field	Assess stream reach habitat condition at representative 246 ft (75 m) section.
3	Office	Compute PHI
4	Office	Quantify Existing Stream Habitat
5	Office	Forecast future stream habitat for with and without project conditions
6	Office	Quantify changes in habitat between future with and without project conditions

1. Segment Subdivision Into Reaches

The stream reaches selected for the study were subdivided into segments for analysis of habitat quality. Streams often have the presence/absence of several natural and built environment features and conditions that have major controlling effect on habitat conditions within segments. Because of the screening criteria utilized in the study, the candidate segments generally possess wooded riparian corridors with pervasive conditions of erosion. Instream habitat conditions within any segment vary longitudinally. Instream habitat conditions can vary along a gradual gradient in response to changes in relative importance of watershed versus local hydrologic influences accompanying increase in drainage area proceeding downstream, or show pronounced changes at major points of substrate change. Additionally, there are often localized erosional and depositional areas that extend for only short lengths of stream. These often occur in the vicinity of woody debris jams, coarse sediment deposits (particularly cobble and gravel), bedrock outcrops, and built environment features such as stormwater outfall pipes, concrete structures, and boulder stabilization works.

Segments can contain reaches with any combination of these features and conditions. Segments which possess a range of varying habitat conditions along their length can be divided into reaches at break points based on presence/absence of these features/conditions. Reaches were sampled rather than the entire segment because this is cost and time efficient. PHI was calculated for each reach. Tables 4 and 5 provide a summary of affecting/controlling habitat conditions used to divide segments into reaches. Table 1-1 and maps provided in Attachment 1 show the habitat segments for each site.

Table 1-2 (Attachment 1) provides a summary of various data for the selected stream reaches and Table 1-3 (Attachment 1) summarizes stream reach metrics such as reach length, width, and area. Tables 1-4 to 1-15 (Attachment 1) provide field observations and information used to determine reach endpoints.

Table 4: Channel physical materials affecting habitat conditions.

Stream Substrate
Piped or in culvert
Concrete channel
Natural meander (not channelized)
Channelized (earthen)
Stabilized discontinuously but systematically
Stabilized continuously
Earth (alluvium, colluvium, in-place soil)
Bedrock channel/banks

Table 5: Flows affecting habitat.

Flow
Intermittent flow (such as via loss into substrate)
Frequent backwater from downstream
Ponded (lentic rather than lotic)
Receiving flow from joining stream and stormwater outfalls

2. Reach Habitat Condition Assessment

Within each reach, a representative 246 ft (75 m) length measured along the channel thalweg capturing the range of conditions in that reach was field-identified and habitat sampled as per MBSS procedures (MDDNR 2013). Only parameters pertinent to PHI analysis were collected. The stream reach was assessed per MBSS field protocols and the data recorded onto MBSS data sheets. Not all habitat metrics collected on the data sheet were used to calculate PHI but all habitat metrics were collected for consistency with past and future monitoring efforts. The distance from the stream to the nearest road was recorded in meters, utilizing GIS and aerial photography. This distance was used to determine the remoteness score. Information on the metrics used to calculate PHI are reproduced in Tables 6 and 7.

Table 6. Habitat assessment parameters utilized for PHI (from MDDNR 2013).
(Note: The units of measurements used below are as dictated by MBSS protocol)

Metric	Units	Value Range*	Notes
Watershed Area	Acres	19.95-93,325.4 acres (Coastal Plain) 28.84-38,904.5 acres (Piedmont)	

Metric	Units	Value Range*	Notes
Remoteness	Meters	0-700	Based on measured distance (in meters) from stream to nearest road. If road were greater than 700 m from stream, a remoteness score of 20 is assigned (see section 3).
Percent Shading	Percentage	5.2-99 (Coastal Plain) 4-100 (Piedmont)	Rated based on estimates of the degree and duration of shading at a site during summer, including any effects of shading caused by landforms.
Embeddedness	Percentage	0-100	Not used in Coastal Plain PHI. Rated as a percentage based on the fraction of surface area of larger particles* that is surrounded by fine sediments on the stream bottom. In low gradient streams with substantial natural deposition, the correlation between embeddedness and fishability or ecological health may be weak or non-existent, but this metric is rated in all streams to provide similar information from all sites statewide. (*> 0.5")
Epibenthic Substrate	Unitless	0-20	Rated based on the amount and variety of hard, stable substrates usable by benthic macroinvertebrates. Because they inhibit colonization, floculent materials or fine sediments surrounding otherwise good substrates are assigned low scores. Scores are also reduced when substrates are less stable.

Metric	Units	Value Range*	Notes
Instream Habitat	Unitless	0-20	Rated based on perceived value of habitat to the fish community. Within each category, higher scores should be assigned to sites with a variety of habitat types and particle sizes. In addition, higher scores should be assigned to sites with a high degree of hypsographic complexity (uneven bottom). In streams where ferric hydroxide is present, instream habitat scores are not lowered unless the precipitate has changed the gross physical nature of the substrate. In streams where substrate types are favorable but flows are so low that fish are essentially precluded from using the habitat, low scores are assigned. If none of the habitat within a segment is useable by fish, a score of zero is assigned.
Total number instream woody debris and rootwads	Enumerated	0-32	
Erosion Extent	Meters	0-75**	Based on procedures in MDDNR 2013.
Severity	Unitless	0 = none; 1=min; 2=mod; 3=severe	
Riffle Quality	Unitless	0-20	Not used in Coastal Plain PHI Rated based on the depth, complexity, and functional importance of riffle/run habitat in the segment, with highest scores assigned to segments dominated by deeper riffle/run areas, stable substrates, and a variety of current velocities.

*Value Range: Watershed Area, Percent Shading, and Total Number of Instream Woody Debris and Rootwads based on data reported in MDDNR 2003. These values informed the development of the PHI.
**Bank erosion may exceed 75m in braided streams.

Table 7. Selected Metrics from MBSS Stream Habitat Assessment Guidance Sheet (MDDNR 2013)

Habitat Parameter	Optimal 16-20	Sub-Optimal 11-15	Marginal 6-10	Poor 0-5
Instream Habitat	Greater than 50% of a variety of cobble, boulder, submerged logs, undercut banks, snags, root wads, aquatic plants, or other stable habitat	30-50% of stable habitat. Adequate habitat	10-30% mix of stable habitat. Habitat availability less than desirable	Less than 10% stable habitat. Lack of habitat is obvious
Epifaunal Substrate	Preferred substrate abundant, stable, and at full colonization potential (riffles well developed and dominated by cobble; and/or woody debris prevalent, not new, and not transient)	Abundance of cobble with gravel &/or boulders common; or woody debris, aquatic veg., undercut banks, or other productive surfaces common but not prevalent /suited for full colonization	Large boulders and/or bedrock prevalent; cobble, woody debris, or other preferred surfaces uncommon	Stable substrate lacking; or particles are over 75% surrounded by fine sediment or flocculent material
Riffle/Run Quality	Riffle/run depth generally >10 cm, with maximum depth greater than 50 cm (maximum score); substrate stable (e.g. cobble, boulder) & variety of current velocities	Riffle/run depth generally 5-10 cm, variety of current velocities	Riffle/run depth generally 1-5 cm; primarily a single current velocity	Riffle/run depth < 1 cm; or riffle/run substrates concreted
Embeddedness[a]	Percentage that gravel, cobble, and boulder particles are surrounded by fine sediment or flocculent material. Based on approximated observation and compared to MBSS representative conditions.			
Shading[b]	Percentage of segment that is shaded by overhanging vegetation or other structures (duration is considered in scoring). 0% = fully exposed to sunlight all day in summer; 100% = fully and densely shaded all day in summer. Percentage is approximated based on a visual assessment.			

a) Embeddedness- Rated as a percentage based on the fraction of surface area of larger particles that is surrounded by fine sediments on the stream bottom. Based on riffle substrates – area with the fastest flow within riffle or run habitats. Several substrates should be examined within the riffle to determine the approximate average condition within the fast part of the riffle. In low gradient streams with substantial natural deposition, the correlation between embeddedness and fishability or ecological health may be weak or non-existent, but this metric is rated in all streams to provide similar information from all sites statewide. See MDDNR 2013 page 26 for more information on methodology.

b) Shading- Rated based on estimates of the degree and duration of shading at a site during summer, including any effects of shading caused by landforms (MDDNR 2013, page 26).

3. Compute PHI

The metrics collected in the field are entered into a spreadsheet (PhysicalHabitatIndexModel.xlsx) which calculates PHI utilizing the equations listed below. Separate worksheets for Coastal Plain or Piedmont stream reaches were used as appropriate.

PHI was developed by MBSS for Maryland streams, thus its calculations are based on data collected in Maryland streams and it is not valid for use outside of Maryland.

a. Metrics are first transformed:

<u>Coastal Plain</u>

REMOTE = Remoteness Score
    Remoteness Score = 0.615 + (0.733*(√distance in meters from road))
TSHADING = arcsine(square root(percent shading/100))
RESEPISUB = epibenthic substrate score - (3.5233+2.5821(Log(Watershed Area in acres))
RESINSTRHAB = instream habitat score - (0.5505 + 4.2475(Log(Watershed Area in acres))
RESWOOD = total # of instream woody debris and rootwads - (-12.24+8.8120(Log(Watershed Area in acres))
TBANKSTAB = square root of the final value calculated
    BANKSTAB = if bank stability on 0-20 score = 0-20 score
    BANKSTAB = if erosion extent is used = [((erosion extent)/-15) x severity] for each bank + 20
        Note: severity is altered so that original severity 0 = 0, 1 = 1, 2 = 1.5, and 3 = 2.0

<u>Piedmont</u>

EMBEDDED = percent embeddedness
REMOTE = Remoteness Score
    Remoteness Score = 0.615 + (0.733*(√distance in meters from road))
RESTSHADING = arcsine(square root(percent shading/100)) - (1.7528 - 0.1990(Log(Watershed Area in acres))
EPISUB = epibenthic substrate score
RESINSTRHAB = instream habitat score - (9.9876 + 1.5476(Log(Watershed Area in acres))
WOOD = total number of instream woody debris and rootwads
TBANKSTAB = square root of the final value calculated
    BANKSTAB = if bank stability on 0-20 score = 0-20 score
    BANKSTAB = if erosion extent is used = [((erosion extent)/-15) x severity] for each bank + 20
        Note: severity is altered so that original severity 0 = 0, 1 = 1, 2 = 1.5, and 3 = 2.0
RESRIFFQUAL = riffle quality score - (5.8467 + 2.4075(Log(Watershed Area in acres))

b. The transformed metrics are then scaled:

<u>Coastal Plain</u>

REMOTE = (value)/(18.570)
TSHADING = (value - 0.226)/(1.120)
RESEPISUB = (value + 13.199)/(17.213)
RESINSTRHAB = (value + 15.094)/(18.023)
RESWOOD = (value + 28.903)/(33.803)
TBANKSTAB = (value)/(4.472)

<u>Piedmont</u>

EMBEDDED = (100 - value)/(90)
REMOTE = (value)/(16)
RESTSHADING = (value + 1.142)/(1.405)
EPISUB = (value - 1)/(17)

RESINSTRHAB = (value + 12.805)/(15.745)
WOOD = (value)/(12)
TBANKSTAB = (value - 1)/(3.243)
RESRIFFQUAL = (value + 16.252)/(19.637)

c. Final scores are calculated:

Coastal Plain
Coastal Plain PHI = (sum of metric scores)/6

Piedmont
Piedmont PHI = (sum of metric scores)/8

The resulting PHI score is multiplied by 100. The score corresponds to one of four narrative classes: minimally degraded; partially degraded; degraded; severely degraded (Table 8).

Table 8. Description of PHI Scoring Classes (MDDNR, 2011)

Narrative Class	Score
Minimally Degraded	81-100
Partially Degraded	66-80
Degraded	51-65
Severely Degraded	0-50

MD DNR. 2011. Results from Round 3 of the Maryland Biological Stream Survey (2007-2009). Prepared by: Versar, Inc. 77 pages. http://www.dnr.maryland.gov/streams/R3ReportIntro.asp

Normalization
The range of possible values for individual metrics can result in final PHI scores that are over or under the acceptable 0 to 100 range. While it is highly unlikely that streams with such scores will be encountered, scores were normalized so that all possible scores are within 0–100, and then rescaled from 0–1. Coastal Plain streams have a possible PHI range from -9.82 to 135.88 while Piedmont streams have a possible range from -3.44 to 134.77. No final PHI scores were outside of the acceptable range of 0–100. Tables 2-1 and 2-2 (Attachment 2) provide all metric scores and resulting PHI FWOP scores for Piedmont and Coastal Plain stream reaches.

4. Quantify Existing Stream Habitat

Quantifying stream habitat for use in the calculation of benefits requires consideration of habitat quantity and quality.

Habitat Quantity
Physical habitat quantity is determined using stream length and stream order. Generally, for the calculation of stream quantity for use in the calculation of habitat benefits, stream width is used. In this case, the use of stream width was problematic, so stream order was used as a surrogate. Many of the study streams have been over-widened through channelization, so restoration would

result in a decrease in the channel width. This would falsely result in a decrease in project benefits (stream habitat units) for the post-restoration condition (future with project). Stream order was used as a surrogate for width because order shows a close correlation to stream width, depth, wetted perimeter, and volume, and is simpler to determine/measure. This is supported by empirical relationships between dimensions of bankfull channel geometry and discharge or drainage area established for coastal plain streams in Maryland (USFWS, 2003). Using this empirically established relationship between drainage area and width, stream widths were calculated for each site (Table 9). Based on this, similar to stream order relationships, a fourth order stream is about four times wider than a first order stream; therefore, the use of order as a surrogate for width is supported (Table 9).

Table 9: Evaluation of use of stream width as a surrogate for stream order using established relationships for streams in the Maryland Coastal Plain.

Stream Site	Stream Order	DA (mi2)	Width (ft)	Width Scaled
Site 10	1	2.02	13.5	1
Site 1	1	2.52	14.6	1
Site 12	2	10.5	25.2	2
Site 9	2	11.2	25.8	2
Site 7	2	16.4	29.8	2
Site 11	4	27.4	36.2	3
Site 5	3	31.1	38.0	3
Site 13	3	34.1	39.4	3
Site 3	3	35.6	40.0	3
Site 15	4	69.2	51.5	4

W=10.3(DA)^0.38
Widths were calculated for each given drainage area (DA) based on the equation above. Widths were then scaled based on the smallest width to compare to known stream order.
Reference: USFWS. 2003. Bankful Discharge and Channel Characteristics in the Coastal Plain Hydrologic Region. CBFO-S03-02, July 2003.

Stream lengths were determined from field GPS data and GIS data. Stream order for reaches was interpreted from maps and aerial photographs. Stream length was multiplied by stream order to generate a single number representing habitat quantity. In cases where stream reaches are piped or contained within a dewatered concrete channel, that reach is considered as having zero habitat quantity under existing conditions.

Total Habitat Availability

Habitat available within a stream reach is a function of habitat quantity and habitat quality. The total habitat available within a reach is represented by the simple equation:

Habitat Quantity x PHI = Stream Habitat Units (SHU)

For a segment, total habitat availability is the simple sum of SHUs for all the reaches within the segment. The benefits derived from restoration of the stream study reach are referred to as "Project Specific Benefits" as opposed to the "Aggregate Benefits" discussed later in this document.

5. Forecast future stream habitat with and without project

Without Project

Stream water quality is expected to improve over the 50-year evaluation period. In 2011 Prince George's County initiated development of its local strategies to fulfill Phase II Watershed Implementation Plan (WIP) requirements to meet Chesapeake Bay Watershed TMDLs. By 2025 non-federal (not originating from federally owned lands) nutrient loads delivered to the Chesapeake Bay from Prince George's County will be reduced from 2009 loads by 9.32 percent for total nitrogen and 3.61 percent for total phosphorus. These reductions will be accomplished through implementation of stormwater BMPs and retrofits, impervious surface reduction and disconnection, agriculture BMPs, and other methods and account for projected population growth in the county. Prince George's County will retrofit water quality treatment for 7,109 acres of untreated impervious area throughout the county by 2017, which does not include treatment of state or federal area.

Maryland Department of the Environment (MDE) requires that urban stormwater runoff be managed through "… a unified approach for sizing stormwater BMPs in the State of Maryland to meet pollutant removal goals, maintain groundwater recharge, reduce channel erosion, prevent overbank flooding, and pass extreme floods." Design features required by MDE for MS4 stormwater permits include the use of pre-treatment vegetation, wetland pockets and pools, flow reduction techniques, native plants, meadows, trees, permeable soils, and the creation of sinuous flow paths.

Current stormwater management policy required in COMAR for redevelopment basically specifies a 50% reduction in impervious surface area below existing conditions. Since this may be impractical due to site constraints, environmental site design (ESD) practices are to be used to the maximum extent practicable (MEP) to meet the equivalent in water quality control of a 50% decrease in impervious surface area. Various alternative BMPs that do not necessarily meet the performance criteria established in this manual may be implemented for redevelopment projects provided that it is demonstrated that impervious area reduction and ESD have been implemented to the maximum extent practicable (MEP).

While stormwater retrofits and upgrades will help address stormwater quantity, it is expected that stormwater runoff quantity control will remain inadequate for decades. While stream geomorphic conditions would be expected to eventually achieve a condition of dynamic equilibrium with stormwater runoff, based on the pattern evidenced in urban streams of the study area and elsewhere in Maryland, the streams reaching an equilibrium condition would likely take many decades to centuries and only after substantial quantities of sediment were eroded and trees lost to bank erosion. Accordingly, absent a geomorphic restoration project, future habitat conditions without project in the streams are assumed to be equivalent to current conditions.

With Restoration Project

With a geomorphic restoration project, future stream conditions would differ from without project conditions. Forecasting the change in condition from existing to future provides benefits for input into the cost-effectiveness analyses.

i Reach Habitat Quantity

Possible change in stream length could occur via either increasing or decreasing stream sinuosity.

Changes in other physical metric changes of width, depth, wetted perimeter, and volume could change. However, accurately determining these over a segment length is challenging. Because stream order is used as a proxy to represent these stream attributes these changes are not determined.

ii Reach Habitat Quality Change

Based on findings of habitat assessments of other previously restored reaches in the Anacostia Watershed (MCDEP, 2013), it is expected that instream habitat quality of existing erosion surface streams could be improved up to minimally degraded or partially degraded. Many streams in the Anacostia Watershed lie in wooded settings; therefore there is minimal opportunity for improvement in the percent shading score. While the habitat quality of the buffer area may be improved through plantings, invasive species control, or similar measures, these efforts would not appreciably change the shading. However, trees will be planted where opportunities exist. Change in individual parameters could theoretically be as great as 20. Tables 2-3 through 2-6 (Attachment 2) provide all metric scores and resulting PHI FWP scores for Piedmont and Coastal Plain stream reaches as projected for design alternative 1 (Tables 2-3 and 2-4) and design alternative 2 (Tables 2-5 and 2-6).

Sensitivity

Most PHI metrics may be influenced by a stream geomorphic restoration project. However, watershed area and remoteness score will not be affected by a project. Similarly, percent shading is unlikely to be affected appreciably by a project. Theoretically, sites with all scores at the extremes of the metric value range can produce final PHI scores that are greater than 100 and less than 0. This occurs because the PHI computations are based on observed streams in Maryland and those extreme conditions have not been sampled and thus are not reflected in the PHI equations. If a final PHI score is outside of the acceptable range of 0-100 the scoring for the stream must be reviewed and if the scores are representative of stream conditions, Maryland DNR should be contacted for further consultation as these would constitute novel conditions. The best attainable condition (BAC) for restored streams would not exceed the conditions of the most natural streams in the watershed (Stoddard et al. 2006). BAC represents the highest value stream condition that can be reached given current conditions and limits of restoration techniques. If we assume that a geomorphic restoration project can improve stream conditions from one level to the next best level at the same relative condition, PHI can improve to 58, “degraded”. If we assume that conditions can further be improved, with more instream woody debris, less erosion, and relatively modest improvements in other scores, we can reach a score of at least 66, “moderately degraded”. Other streams with different combinations of metric scores demonstrate similar results and sensitivity to metric changes. However, in all cases BAC is achievable. Tables 2-7 and 2-8 (Attachment 2) provide all metric scores and resulting BAC PHI scores for Piedmont and Coastal Plain stream reaches.

iii Segment Total Habitat Availability Change

As with existing conditions, total habitat availability under forecasted future conditions would be the sum of all the reach habitat quantities for a given segment.

iv. Aggregate Benefits

In order to capture the total benefits from implementing the recommended stream restoration projects, the Aggregate Benefits metric incorporates both fish passage (passage opened through removal of a physical fish blockage) and connectivity (connection of project reaches to already existing restoration projects). This metric captures the value provided by connecting habitat improved under these projects to existing restoration, as well as the value of opening stream courses upriver of project sites to fish passage.

Fish Blockages

Opportunities for remediation of fish blockages within the Anacostia Watershed of Prince George's County were evaluated by the study team. The Anacostia Restoration Plan (ARP) identified fish blockages within the watershed and regional fisheries experts (from MWCOG) were consulted on these and other potential blockages. The inventory in the ARP includes consideration of the severity and likely longevity of the blockage. Fish blockages were considered for remediation only when within the study segments identified to be candidates for geomorphic restoration work. Conceptual design drawings and cost estimates for restoration of the study segments, include both stream restoration and fish blockage remediation. Although fish passage could also potentially be provided by independent projects within those segments without comprehensive geomorphic restoration, this was not the formulation strategy undertaken in this study. Projects to provide fish passage if undertaken independently would be small-scale projects because the structures forming blockages in study stream segments are low in height.

When fish passage needs are evaluated, natural blockages (waterfalls, beaver dams) are often viewed to be inherently good, and seldom targeted for remediation. Conversely, anthropogenic blockages are generally considered to be inherently harmful to aquatic ecosystems. In the study area, the natural limit of the historical range of anadromous fish is the Fall Line, which is the boundary between the Coastal Plain and Piedmont physiographic provinces. Presence of natural blockages within the extent of their range was assumed to represent stream habitat that would remain inaccessible to resident and or anadromous fish, depending on the severity of the blockage. Accordingly, this study considered only anthropogenic fish blockages for remediation. Fish blockages can affect either up and or downstream movements of aquatic life. Downstream blockages can occur when downstream flow first passes through turbines or other structures that kill aquatic life. There are no downstream blockages of this type in the study area. Field work was conducted to assess stream habitat and geomorphic conditions and to identify fish blockages.

Fish blockages present in the study area differ in which fish are affected, based on the movement capabilities of a given fish. For example, American eel are highly mobile and even able to crawl over moist land for short distances. Blockages for eels may have vertical surfaces or would require long crawls over land to bypass. No eel blockages were identified within Anacostia study stream segments in Prince George's County.

Resident fish blockages would include eel blockages (if there had been any) plus vertical blockages and long reaches of continuously high currents or de-watered reaches that are not periodically made passable by flooding or downstream backwater. For the purposes of this study, dewatered reaches were assumed to occur at least in large part because of boom/bust flow conditions caused by stormwater runoff as well as excess erosion/sedimentation causing loss of water into the stream bed. (Dewatered reaches occur in many pipes and concrete channels as well. However, intermittent streams do naturally occur in the study area). Piped streams and streams in concrete channels typically possess flows that are periodically scouring such that aquatic life cannot traverse upstream. Anthropogenic vertical structures or flow conditions can be verified as fish blockages by comparing upstream and downstream fish data. Blockages can also be verified by lack of physical evidence indicating overtopping of structures in channels and floodplains.

Anadromous fish blockages include all eel and resident fish blockages plus vertical drops of 1 foot or greater during spring flow when anadromous fish migrate upstream. Many complete and partial anadromous fish blockages occur in the study area. Anadromous fish passage benefits for blockage remediation were only counted where no downstream blockages exist. Benefits of providing fish passage were determined by length and order of stream upstream of the blockage to which access for fish from downstream would be provided. Stream lengths opened by blockage removal were measured in GIS. Fish passage benefits were assumed to proceed upstream to the next manmade or natural blockage. For Northwest Branch, the natural blockage was generally the limits of the natural range of anadromous fish at the Fall Line. Table 10 shows the fish blockages on the study stream reaches for which fish passage benefits are counted within the Aggregate Benefits metric.

Connectivity

The project stream reaches are located in highly urbanized areas of Prince George's County, where impervious cover is high and pervasive habitat degradation occurs in streams. Any remaining higher quality habitat areas are likely physically separated (fragmented) from other stream areas with comparable higher quality conditions. Connectivity, or the connection of habitat patches, has long been recognized as a fundamental factor in determining the distribution of species; therefore, benefits were considered for the connection of study streams to previously restored stream segments.

An inventory was made of all previous stream restoration projects adjacent to the study's stream reaches. Based on best professional judgment, small gaps between restoration projects (less than approximately 800 feet) were considered a reasonable distance across which to count sites for connectivity benefits. If restored projects were located longer distances away from a project site, connected benefits were not counted. Therefore, large gaps were used to identify the extent of the connectivity benefits to a study stream reach. Attachment 3 includes previous restoration projects associated with each project site.

Table 10: Fish blockages present in the study stream segments (* indicates blockages that would be removed under the recommended plan).

Site No.	ARP Identifier	Description	Passage Opened by Removal (ft)
1	Several identified in ARP (see MWCOG, 2009)	Several blockages for anadromous and resident fish (and potentially eel) located in close proximity upstream and downstream of Ammendale Road. These blockages are associated with culverts and storm water management features. Benefits claimed for one resident fish blockage upstream of Ammendale Road. Removal of this blockage would not benefit anadromous fish due to presence of blockages (storm water management feature) immediately downstream.	3,257
***3**	NW-L-04-F-10	Anadromous fish blockage on Northwest Branch at downstream end of Ager Road consists of a 1 ft concrete sill. Not a blockage for resident fish as backwater effects could would likely ameliorate conditions for resident fish passage. ARP also notes debris and log jams with 1 ft drop height blocks 95% of flow. ARP ranks blockage as Tier I Project (Tier I are project providing greatest benefits), with priority 13/806 projects for Northwest Branch.	18,984
7	PB-M-04-F-7 PB-M-04-F-6	Two anadromous fish blockages (partial) in close proximity that that result from box culverts at I-495 underpasses. Fish ladders are present but inaccessible. Drop height of 1 foot. Debris and log jams also present.	5,876
***9**	SC-L-04-F-1	Anadromous fish blockage consisting of steel weir with 1 foot drop on Sligo Creek upstream of Northwest Branch confluence. Passable for resident fish. ARP notes this as a complete fish blockage due to a 1 ft high sheet pile weir. One of top five fish blockage removal priorities for MWCOG.	3,084

<u>Calculation of Aggregate Benefits</u>

Aggregate benefits are calculated similarly to the "Project Specific In-Stream Benefits" (derived from restoration at a given study reach) discussed earlier, specifically: habitat quantity x PHI. Habitat quantity for aggregate benefits was defined as 1) the length of the stream that would be accessible for fish following removal of a fish passage blockage at a project site and/or 2) the length of stream that has been restored by other efforts and is connected to reaches under consideration for restoration by this investigation. To capture habitat quality, PHI data for stream reaches where aggregate benefits extend were obtained from existing MBSS and/or Tetra Tech monitoring sites or from post-project monitoring performed by the project "owner." In some cases, where data were not available for a given stream reach, data were extrapolated from the closest monitoring data. Some stream reaches were connected to more than one project. The total aggregate benefits (SHUs incorporating total quantity restored or opened for fish passage) for each stream reach were used as a metric in the cost effectiveness/incremental cost analysis (CE/ICA). However, when reaches were combined to develop the alternatives used for input into the CE/ICAs, steps were taken to not double count projects. Some stream reaches, e.g. site 13, have no connected projects or fish blockages and therefore were determined to provide no aggregate benefits. Table 3-1 (Attachment 3) provides the complete summary of PHI (including the source of the data) and project-specific SHUs for each linked prior stream restoration project or length opened via blockage removal on a study stream site.

Figure 1 shows the aggregate benefits for each site, incorporating the study stream site itself, connected restoration projects, and fish passage opened by removal of a blockage. For example, aggregate benefits for site 3 include the site itself (shown in orange), connected downstream restoration projects (shown in yellow), and upstream fish passage opened from removal of a blockage (shown by the purple dashed line).

6. Quantify total future habitat quantity change

For each segment, the difference between with-project total habitat quantity and existing conditions total habitat quantity is determined by simple subtraction. That difference constitutes the in-stream project habitat quantity.

Aggregate Benefits Determination

Two CE/ICAs were run, one for the Northwest Branch alternatives and one for the Northeast Branch alternatives. Average annual environmental benefits input into each of the two CE/ICAs include benefits for the two metrics: Project Specific In-Stream Benefits and Aggregate Benefits (Section 3.5 of main report). Project Specific In-Stream Habitat Benefits and Aggregate Benefits were combined to develop one average annual benefit variable that represents a more complete quantified value of the benefits attributed to each plan than the Project Specific In-Stream benefit metric alone for Northwest Branch and Northeast Branch, respectively. While both of these metrics are measured in SHUs, the SHUs are not equivalently comparable, since one is measured based on area that will be restored, whereas the other is based on previously restored area. Since it is not appropriate to simply add the two metrics together for evaluation purposes, a combined normalized score was calculated. Within the Planning Suite software, using the two metrics for each separate branch, each metric was normalized using the maximum amount for the appropriate branch and added together with equal weighting to obtain a raw weighted score in a range of 0 to 1. The combined benefit was calculated as follows for each branch:

$$Northwest\ Branch\ Combined\ Benefits = 0.5 \times \frac{\sum In\ Stream\ Benefit}{5953} + 0.5 \times \frac{\sum Aggregate\ Benefit}{59640}$$

$$Northeast\ Branch\ Combined\ Benefits = 0.5 \times \frac{\sum In\ Stream\ Benefit}{13932} + 0.5 \times \frac{\sum Aggregate\ Benefit}{76602}$$

In these two equations, the denominator is the maximum SHUs for each subwatershed (i.e. SHUs for the highest level alternative). The numerator is the sum of benefits for a given alternative.

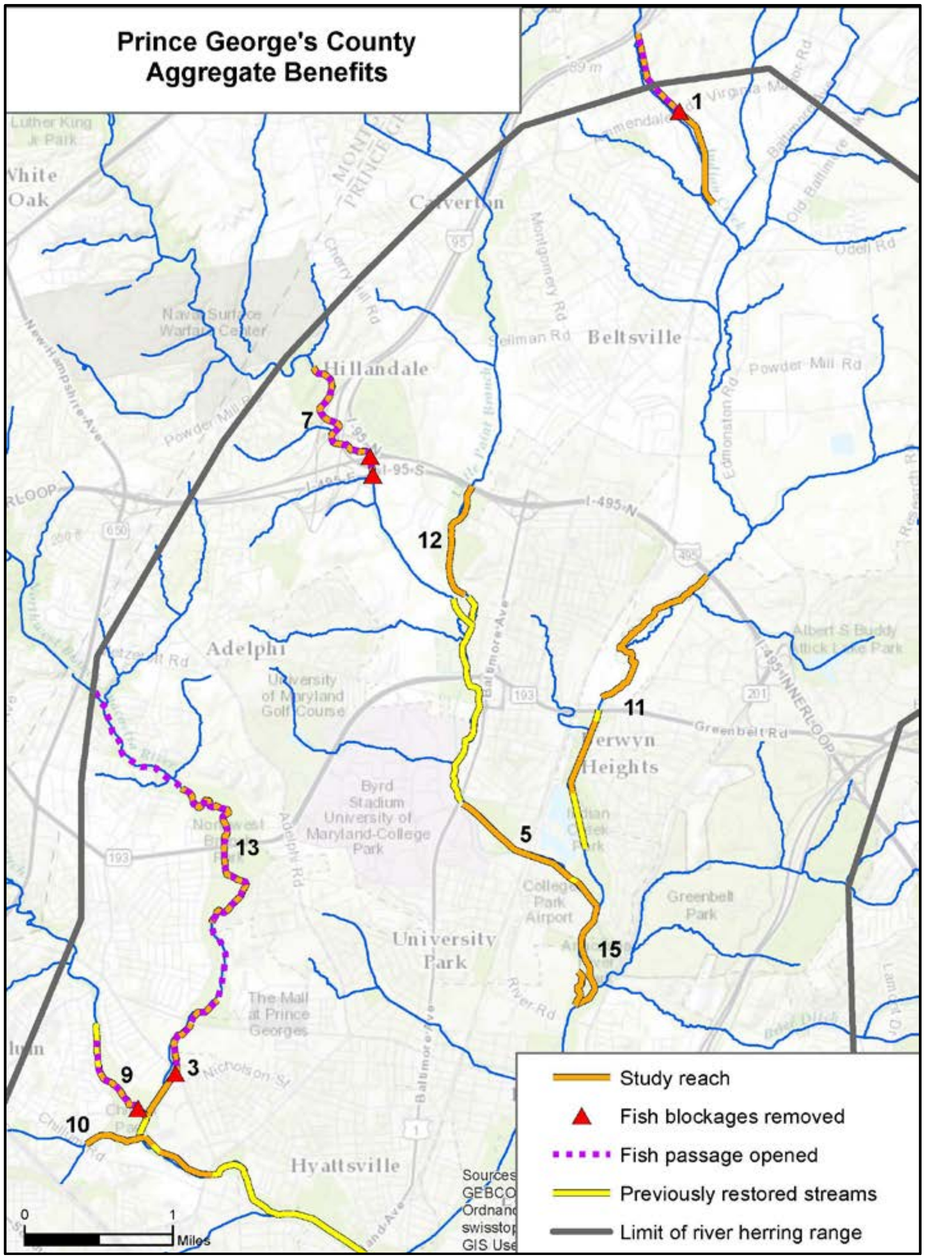

Figure 1. Aggregate Benefits for each Project Site.

The CE/ICAs were then performed using the combined benefits ("Combined Index") and the average annual cost for each alternative plan to determine the most cost-effective and efficient (best-buy) alternatives. Based on the outcomes of team discussion at USACE review meetings, two CE/ICAs were run to evaluate a solution for each of the Northwest Branch and Northeast Branch subwatersheds. A summary of the project specific and aggregate benefits (SHUs) for the alternatives considered in the two CE/ICAs is shown in Table 11.

Table 11. Summary of Total Habitat Benefits (SHUs) for the Alternatives Considered in the CE/ICAs (* indicates alternatives in the recommended plan).

Northwest Branch Alternatives	Project Specific SHUs	Aggregate SHUs
3	2068	53679
3, 9	2738	58330
3, 9, 10	2860	59640
3, 13	5162	53679
*3, 9, 13	5832	58330
3, 9, 10, 13	5953	59640
Northeast Branch Alternatives		
11, 15	7975	22703
*11, 15, 5	10626	63131
11, 15, 5, 7	12035	69507
11, 15, 5, 12	11666	67846
11, 15, 1	8832	25083
11, 15, 5, 1	11483	65511
11, 15, 5, 12, 1	12523	70226
11, 15, 5, 12, 7	13075	74222
11, 15, 5, 12, 1, 7	13932	76602

Revision of Benefits for Final Report

As a result of agency review of the draft feasibility report and environmental assessment, the benefits calculation described above was revised slightly to use relationships established for drainage area and stream width in the calculation of stream quantity, instead of using stream order as a proxy for stream width.

As shown in Table 9, USFWS has published relationships for streams in the Coastal Plain Physiographic Province in Maryland that relate drainage area to width, cross-sectional area, and depth (USFWS, 2003). The equation relating drainage area (DA; mi^2) to width (ft) is:

$$\text{Width} = 10.3DA^{0.38} \quad (R^2 = 0.8,\ se\ (\%) = 10.4,\ F = 86,\ p = <0.001)$$

For the two stream segments (habitat segments 7A and 7B) that are located in the Piedmont Physiographic Province a similar equation was used: Width = $14.78DA^{0.39}$ (USFWS, 2002). For this calculation, an assumption was made that the USFWS relationship is applicable to streams in urban landscapes. Although USFWS (2003) identified that the streams used to develop the relationship were not reference streams, the streams were not situated in heavily urbanized areas. Urbanized streams are projected to have greater widths for a given drainage area compared to streams in more natural conditions. The streams that are being considered for restoration in this project are situated within parkland and therefore, may be more similar to those used to develop the relationship than those is strictly urban settings. However, with widths expected to be greater in urban settings, the use of the USFWS equation would be a conservative estimate of the benefits projected for each project site, since the widths calculated using the equation would be an underestimation of actual widths (and SHUs). Drainage areas were determined using USGS StreamStats (https://water.usgs.gov/osw/streamstats/).

Stream lengths were also revised following the calculation of SHUs using stream order. Lengths were revised based on the development of more detailed feasibility level designs. With the use of stream width calculated via the USFWS equation, SHUs for both the project specific and aggregate benefits are calculated as: Stream Width x Stream Length x PHI = SHU. Table 12 shows the SHUs (with units of acres) for the alternatives following the revision in benefits. Minor revisions were also made to correct errors in the spreadsheets.

Since the benefits were revised, the PHI tables in Attachment 2 and Attachment 3 include the scoring for the revised benefits and updates related to advancing the designs to feasibility level. The PHI tables for the conceptual designs that were in the draft report are available upon request.

Table 12. Revised Total Habitat Benefits (* indicates alternatives in the recommended plan).

Northwest Branch Alternatives	Project Specific SHUs (acres)	Aggregate SHUs (acres)
3	0.51	16.88
3, 9	0.72	18.30
3, 9, 10	0.76	18.70
3, 13	1.37	16.88
*3, 9, 13	1.58	18.30
3, 9, 10, 13	1.62	18.70
Northeast Branch Alternatives		
11, 15	1.64	8.37
*11, 15, 5	2.34	16.05
11, 15, 5, 7	2.88	18.23
11, 15, 5, 12	2.64	17.26
11, 15, 1	1.90	9.09
11, 15, 5, 1	2.60	16.77
11, 15, 5, 12, 1	2.90	17.98
11, 15, 5, 12, 7	3.18	19.44
11, 15, 5, 12, 1, 7	3.44	20.16

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Attachment 1: Stream Reach Data and Maps

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Attachment 1: Habitat Segment Maps and Codes

Each study stream segment was subdivided into representative reaches based on habitat conditions. The habitat segment maps for each stream reach show these subdivisions. The codes located in the map legends are defined below in Table 1-1.

Table 1-1: Habitat Segment Codes for PHI Scoring

Predominant Attribute	Code	Notes
Channel Conditions		
Piped or in culvert	No code	Applicable in/near bridges. No code - assumed no change in habitat conditions with-project because of need to protect bridge
Concrete channel	No code	Applicable in/near bridges. No code - assumed no change in habitat conditions with-project because of need to protect bridge
	c	Channelized - straightened with few or no meanders, whether by excavation or fill
	m	Meander, not channelized such that it is affecting instream habitat
Substrate and Bank Conditions		
	s	Stabilized continuously (few or no gaps) typically with boulders, but may include gabions, concrete, etc.
	g	Stabilized systematically, but discontinuously (with gaps); typically with bounders, but may include gabions, concrete, etc.
	e	Notable sediment bars in stream channel
	b	Bedrock channel banks
	n	Fined-grained substrate (sand, silt, clay)
	o	Coarse grained substrate (cobble, gravel)
	h	High bank height (based on relative differences within segment; higher banks typically have greater erosion/instability)
	l	Low bank height (based on relative differences within segment)
	w	Woody debris jams
Flow Conditions		
	i	Intermittent flow (includes loss into substrate)
	d	Frequent backwater from downstream
	p	Ponded - lentic rather than lotic
	f	Receiving flow from joining stream and stormwater outfalls

	r	Riffle/runs dominant
	t	Pools/glides dominant (deeper than homogeneous shallow depth category below)
	u	Homogeneous shallow depths, slow velocities
Other		
Palustrine, forested wetland	PFO	Stream reach intimately linked with a wetland classified as PFO, Palustrine scrub-shrub (PSS), or Palustrine emergent (PEM) by the National Wetlands Inventory.
Tributary	T	Segment is a tributary to the numbered site. Tributary conditions often differ from mainstem conditions.
Physiographic Province	C	Segment located in Coastal Plain physiographic province
Physiographic Province	P	Segment located in Piedmont physiographic province

Considerations:

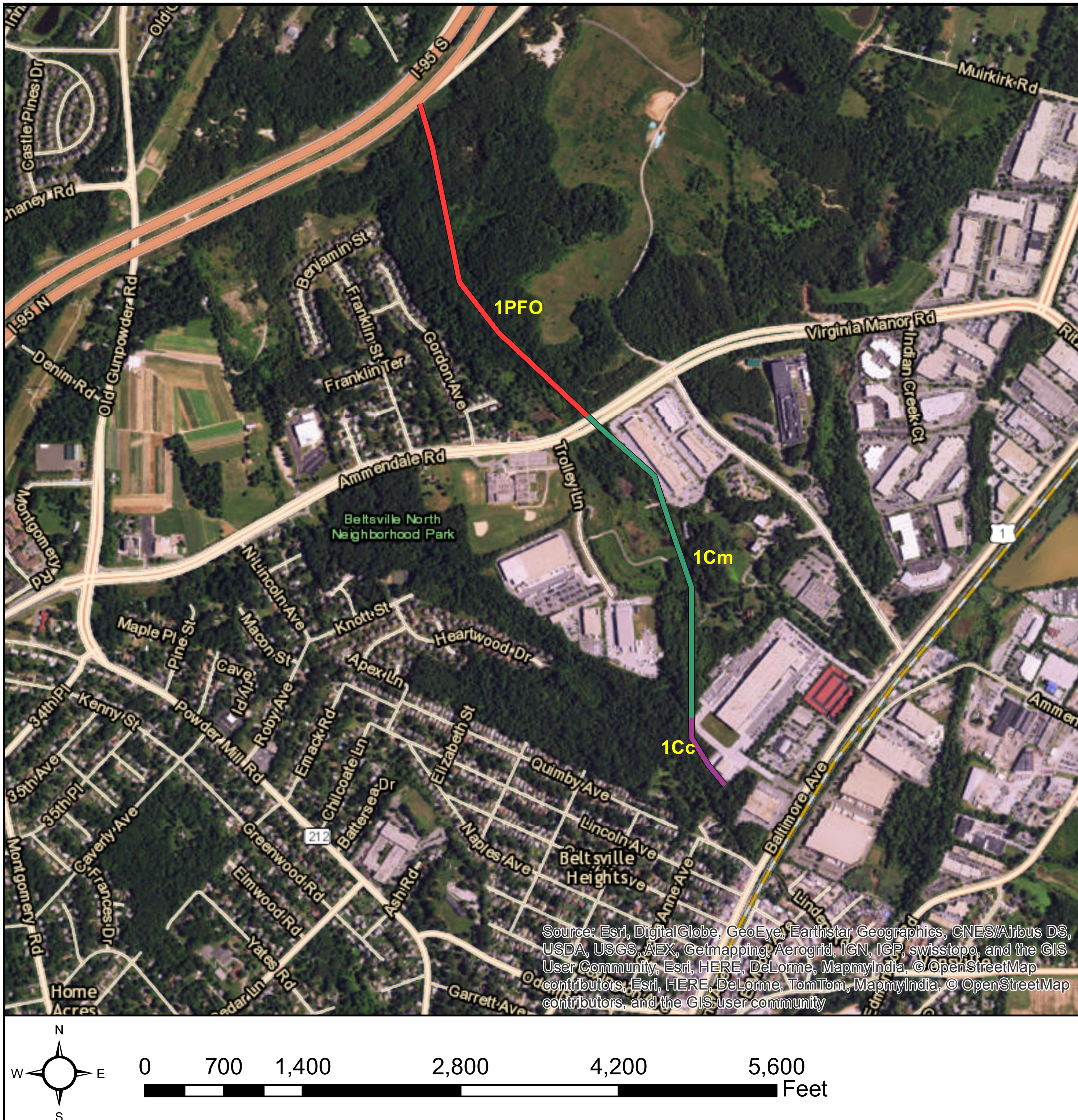
- PHI data from a representative reach may be used to represent multiple reaches within a given segment assuming habitat conditions are similar.
- Attributes are identified that correlate with and allow ready discrimination between habitat conditions.
- Reach habitat conditions may correlate with any combination or number of natural and/or built-feature attributes.
- Portions of segments under/in vicinity of bridges often have concrete channels, continuous stabilization, and or culverts.

Anacostia Watershed Restoration
Prince George's County

Subwatershed: Indian Creek
Site: Indian Creek
Project Segment #: 1

Reach	Habitat Type Code[1]	Legend	Length (ft)
1A	1Cc		695
1B	1Cm		2994
1C	1PFO		3268

1 Type Code Definition see attached table

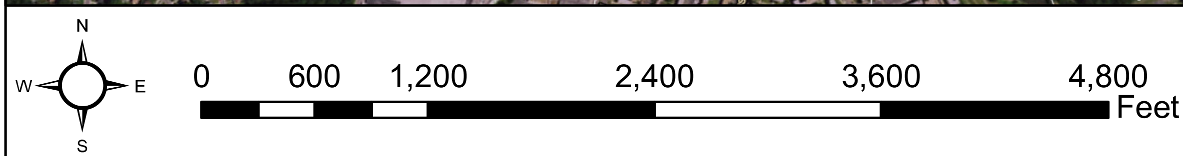


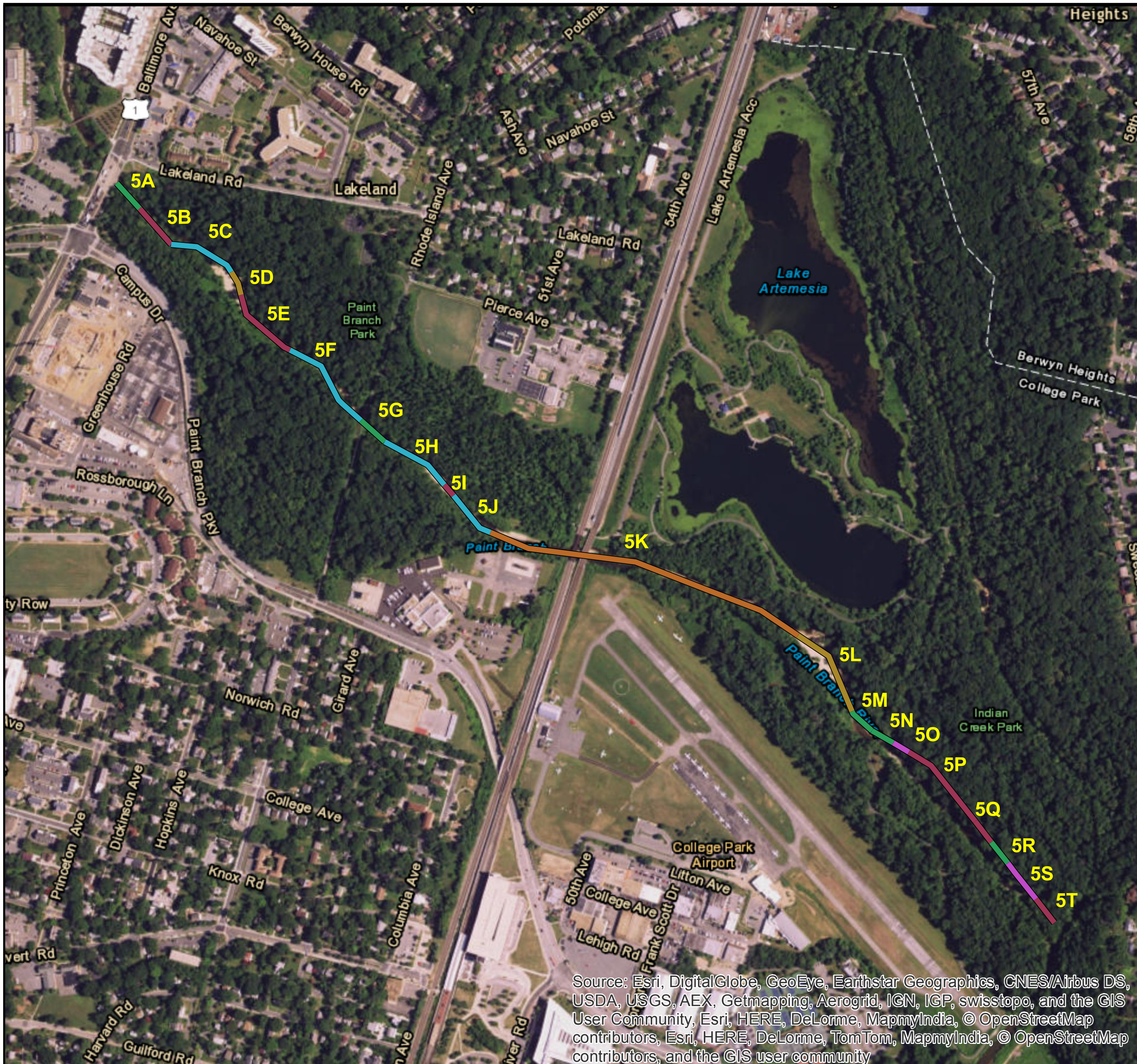
Anacostia Watershed Restoration Prince George's County

Subwatershed: Northwest Branch
Site: Hyattsville
Project Segment #: 3

Reach	Habitat Type Code	Legend	Length (ft)
3A	3Cce		817
3B	3Cm		470
3C	3Ccp		377
3D	3Ccp		208
3E	3Cce		86
3F	3Ccp		51
3G	3Ccst		218
3H	None		235
3I	3Ccp		1375
3J	3Ccst		456
3K	9Cs		156
3L	3Ccst		339
3M	9Cs		203
3N	3Ccst		171
3O	3Ccu		95
3P	3Ccu		761
3Q	3Ccpg		1268

1 Type Code Definition see attached table



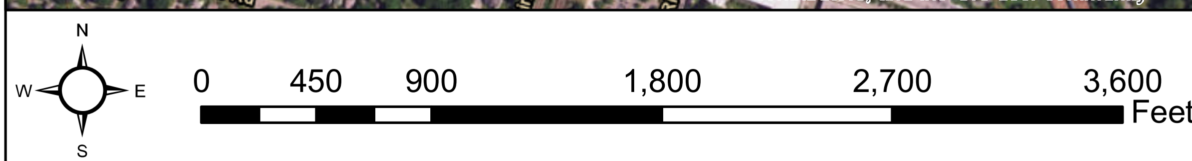


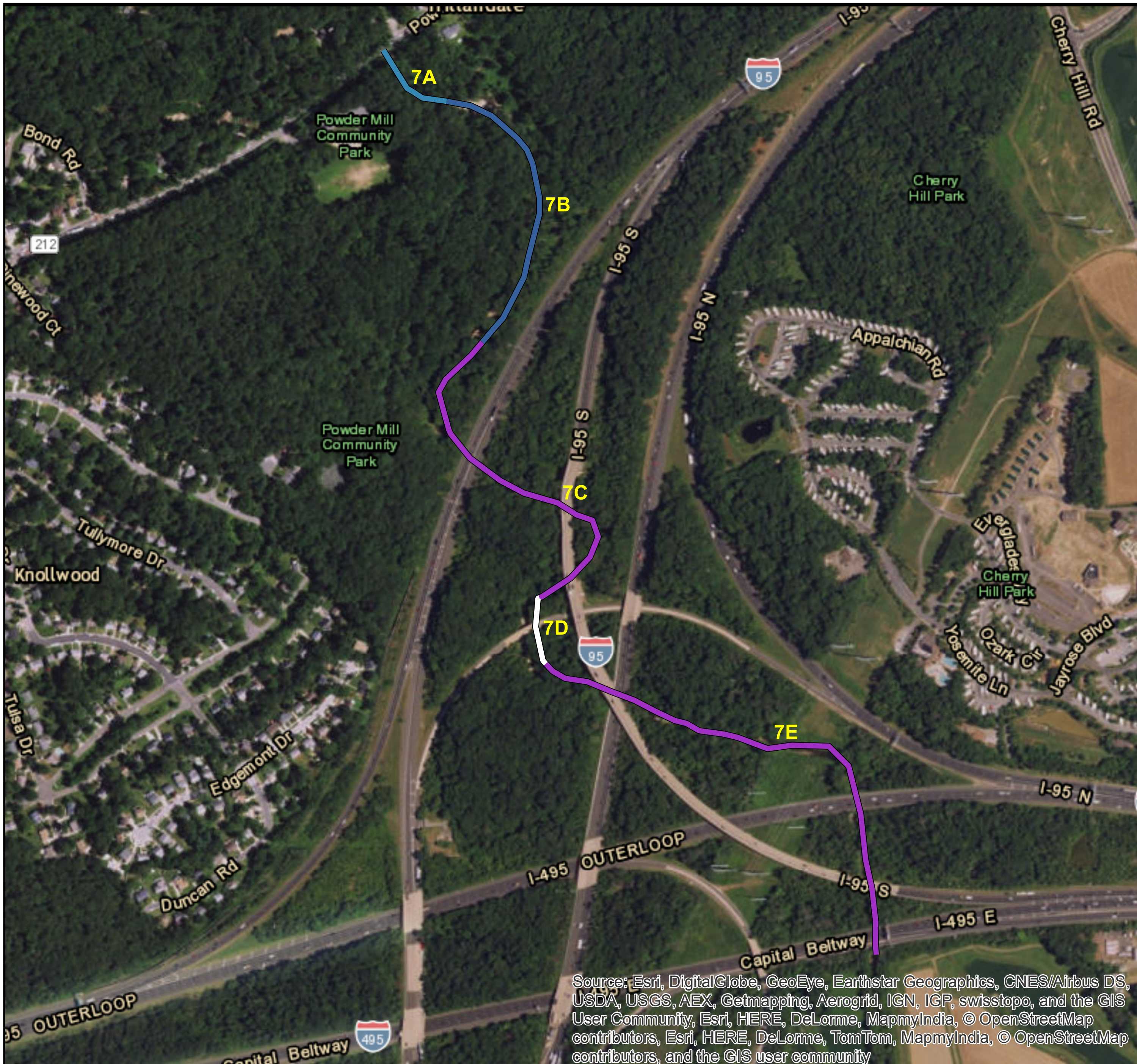
Anacostia Watershed Restoration Prince George's County

Subwatershed: Paint Branch
Site: Paint Branch
Project Segment #: 5

Reach	Habitat Type Code	Legend	Length (ft)
5A	5Ccst		176
5B	5Ccgu		244
5C	5Ccehu		359
5D	5Cw		128
5E	5Ccgu		396
5F	5Ccehu		534
5G	5Ccst		164
5H	5Ccehu		386
5I	5Ccgu		72
5J	5Ccehu		273
5K	5Ccle		1694
5L	5Cw		497
5M	5Ccst		146
5N	5Ccst		126
5O	9Cs		94
5P	5Ccgu		502
5Q	5Ccgu		135
5R	5Ccst		137
5S	9Cs		235
5T	5Ccgu		155

1 Type Code Definition see attached table



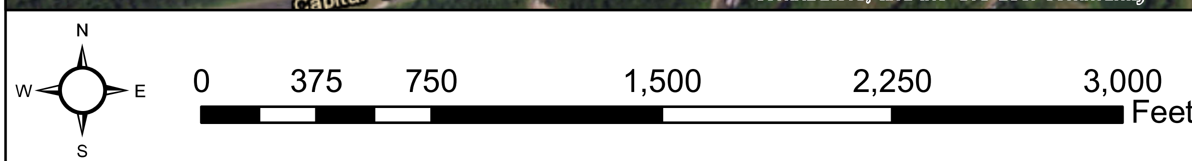


Anacostia Watershed Restoration Prince George's County

Subwatershed: Paint Branch
Site: Paint Branch I-95
Project Segment #: 7

Reach	Habitat Type Code[1]	Legend	Length (ft)
7A	7Pb		376
7B	7Pe		1314
7C	7Cc		1653
7D	None		295
7E	7Cc		2239

1 Type Code Definition see attached table

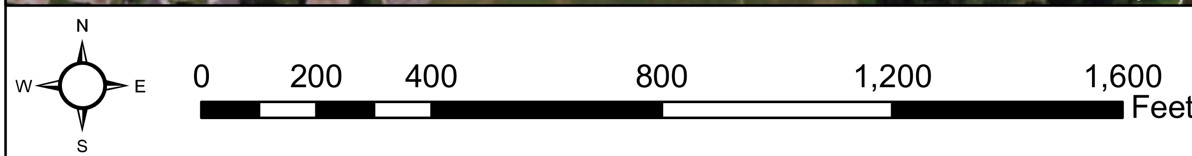


Anacostia Watershed Restoration
Prince George's County

Subwatershed: Sligo Creek
Site: Sligo Creek
Project Segment #: 9

Reach	Habitat Type Code[1]	Legend	Length (ft)
9A	9Cg	(teal line)	568
9B	9Cs	(purple line)	243
9C	9Cg	(teal line)	1430

1 Type Code Definition see attached table

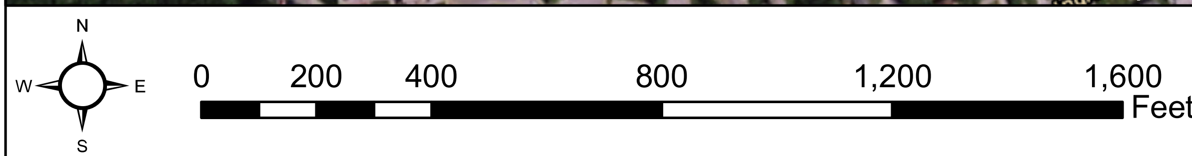


Anacostia Watershed Restoration Prince George's County

Subwatershed: Northwest Branch
Site: Chillum Road
Project Segment #: 10

Reach	Habitat Type Code[1]	Legend	Length (ft)
10A	10Cs		370
10B	10Cg		441
10C	10Ce		798
10D	10Cg		486

1 Type Code Definition see attached table

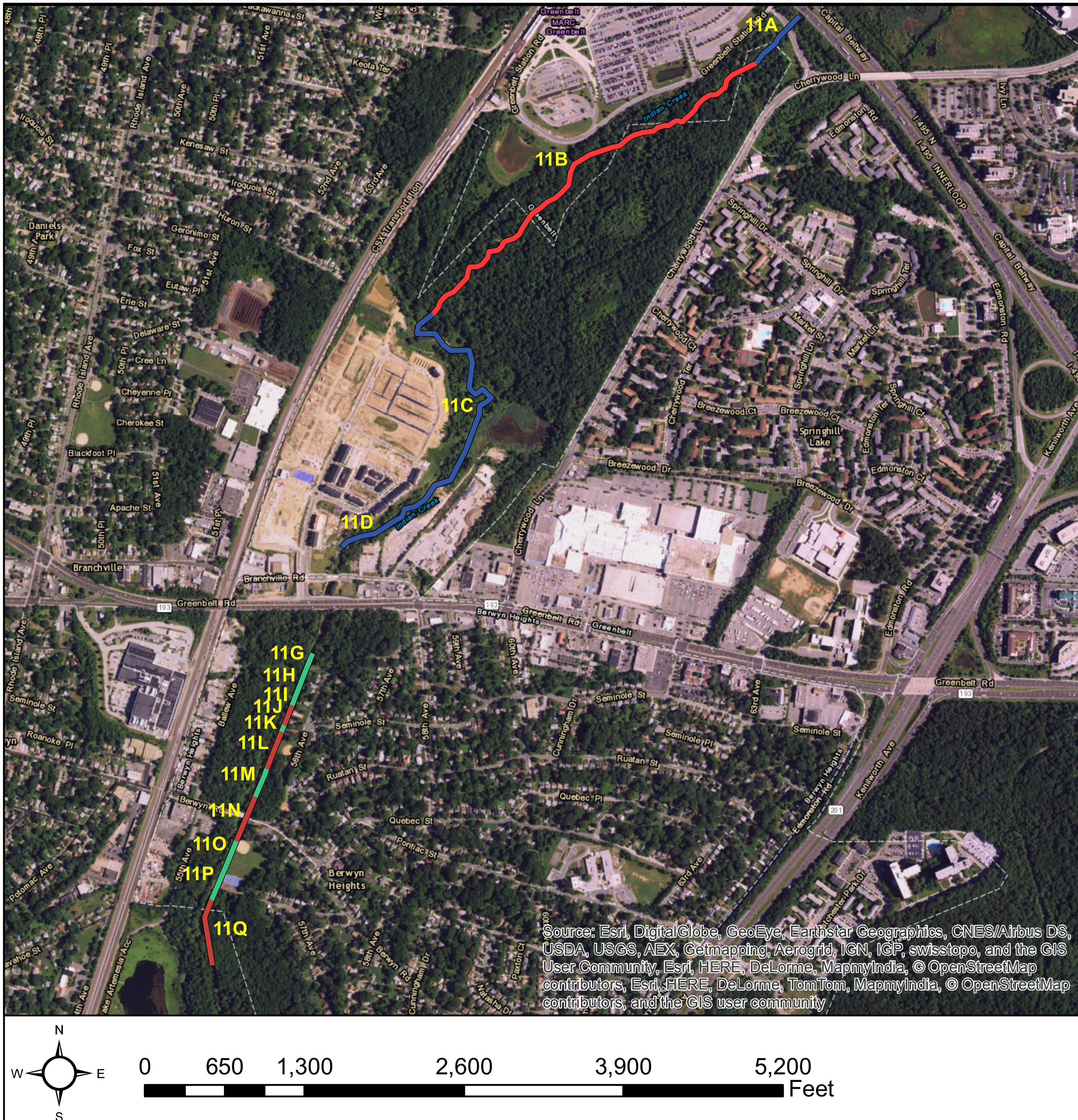


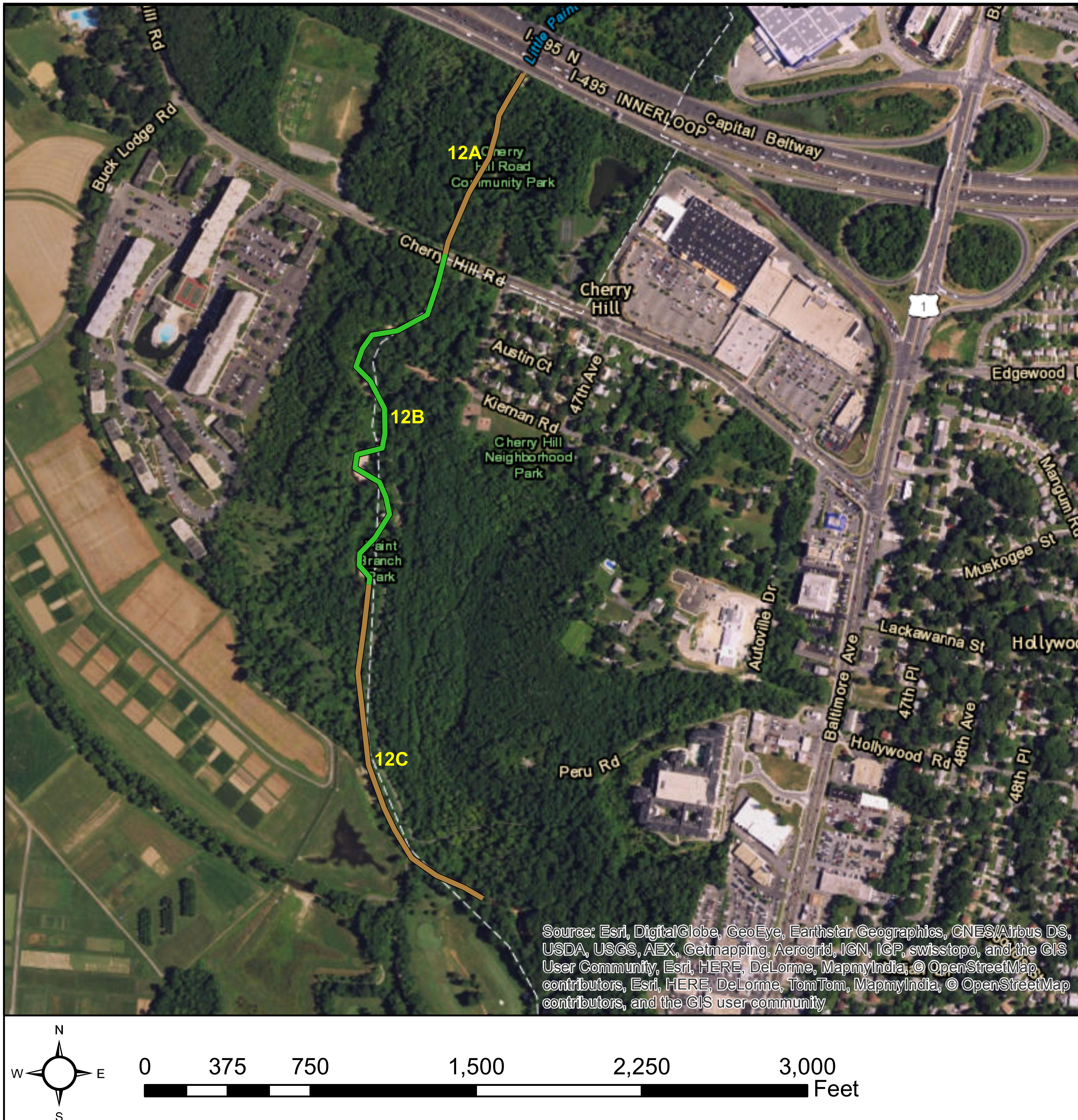
Anacostia Watershed Restoration
Prince George's County

Subwatershed: Indian Creek
Site: Indian Creek - College Park
Project Segment #: 11

Reach	Habitat Type Code[1]	Legend	Length (ft)
11A	11Ccp		524
11B	11PFO		3571
11C	11Ccp		2762
11D	11Ccp		352
11E	None		324
11F	None		112
11G	11Ccg		139
11H	11Ccg		247
11I	11Ccg		70
11J	11Cc		176
11K	11Ccg		58
11L	11Cc		325
11M	11Ccg		245
11N	11Cc		394
11O	11Ccg		204
11P	11Ccg		316
11Q	11Cc		549

1 Type Code Definition see attached table





Anacostia Watershed Restoration Prince George's County

Subwatershed: Little Paint Branch
Site: Little Paint Branch
Project Segment #: 12

Reach	Habitat Type Code[1]	Legend	Length (ft)
12A	12Cc		896
12B	12Cm		1974
12C	12Cc		1660

1 Type Code Definition see attached table

Anacostia Watershed Restoration Prince George's County

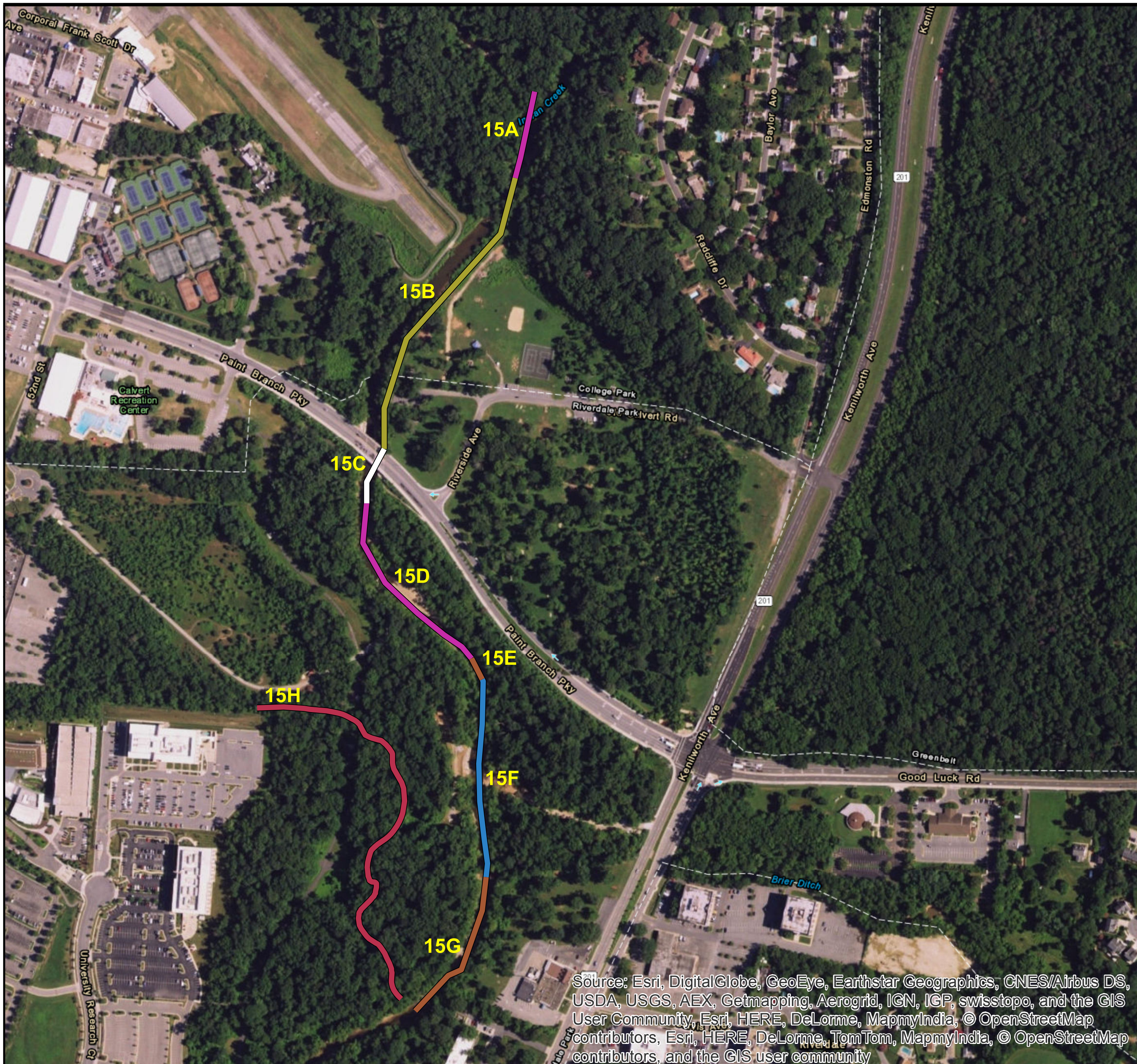
Subwatershed: Northwest Branch
Site: Riggs Road
Project Segment #: 13

Reach	Habitat Type Code[1]	Legend	Length (ft)
13A	13Cmhe		2258
13B	13Cml		1506
13C	13Cct		792
13D	13Ccsr		844
13E	13Cc		1296
13F	13Ccsr		489
13G	13Ccsr		505

1 Type Code Definition see attached table

Anacostia Watershed Restoration
Prince George's County

Subwatershed: Northeast Branch
Site: Northeast Branch
Project Segment #: 15



Reach	Habitat Type Code[1]	Legend	Length (ft)
15A	15Ccor	(magenta line)	328
15B	15Ccgt	(olive line)	1163
15C	None	(white line)	220
15D	15Ccor	(magenta line)	754
15E	15Cce	(brown line)	86
15F	15Ccp	(blue line)	741
15G	15Cce	(brown line)	593
15H	15TCm	(red line)	1635

1 Type Code Definition see attached table

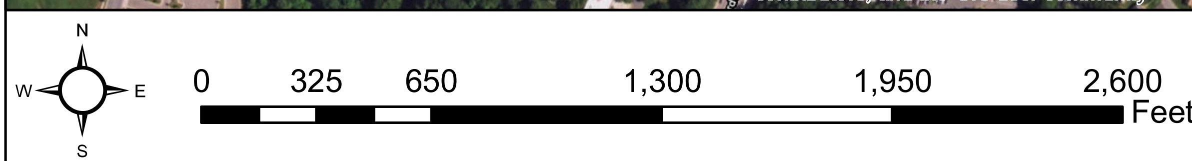


Table 1-2: PHA Data Summary																
			RHA STATION				Station Endpoints									
							Upstream			Downstream						
Habitat Station Code	**USACE SEGMENT NO.**	**SEGMENT NAME**	**LOCATION NOTES**	**HABITAT DESCRIPTION**	**HABITAT CODE**	**DATES ASSESSED**	**Latitude**	**Longitude**	**Accuracy (ft)**	**Latitude**	**Longitude**	**Accuracy (ft)**	**Endpoint Comments**	**Endpoint GPS Gadget**	**Watershed Area (acres)**	
1AD	1	Indian Creek - I95	E of Caroline Ave	Mature forest	**1Cm**	6/27/2014	39.04934	76.90416	22	39.04854	76.90438	65	NR	CS	1235	
1BU	1	Indian Creek - I95	SE of Trolley Ln Cul de Sac	Channelized, not stabilized. Substantial floodplain fill W bank	**1Cc**	4/14/2015	39.052009	76.90425	131?					SK	1210	
2AD	3	Northwest Branch - Hyattsville	Off Nicholson Street. Kudzu eradication site	Channelized, all pool	**3Ccp**	7/1/2014	NR	NR		38.96074	76.97206	19	Down end sapling box eldar	CS	22720	
2BU	3	Northwest Branch - Hyattsville	Upstream of 500	Channelized, deep pool, no bars, no riffle/run, boulders one bank	**3Ccpg**	10/28/2014	38.95258	76.96752	45	NR	NR	NR	Up silver maple, down river birch	CS	31616	
2CD	3	Northwest Branch - Hyattsville	Upstream of W Hyattsville metro bridge	Lower channelized, shallow	**3Ccu**	10/28/2014	38.95437	76.97131	16	38.95402	76.97068	13	Up river birch S bank, down box eldar S bank	CS	31488	
2DD	3	Northwest Branch - Hyattsville	Upstream of 410	Earth, channelized, extensive bars	**3Cce**	10/31/2014	38.96904	76.96646	45	38.96850	76.96680	45	Up box eldar SE bank, down bitternut hickory SE bank	CS	22272	
2ED	3	Northwest Branch - Hyattsville		Gabion pool, channelized	**3Ccst**	11/5/2014	38.95579	76.97399	26	38.95542	76.97336	16	Up river birch E bank, down sycamore E bank	CS	31296	
2FD	3	Northwest Branch - Hyattsville	Downstream of 410	Unstabil, not channelized	**3Cm**	10/31/2014	38.96696	76.96914	13	38.96640	76.96966	16	Up sycamore W bank, down spice bush	CS	22592	
3A	5	Paint Branch	Below Route 1	Generic continuous boulder stabilization on banks, continuous pool. Riffles absent	**5Ccst**	11/7/2014	NA	NA		NA	NA		NA	CS	19584	
3BD	5	Paint Branch	Downstream of Rte 1, Upstream of pedestrian bridge	Channelized, unstabilized, eroding tall earth bank one side, homogeneous shallow habitat, large continuous channel parallel bar	**5Ccehu**	6/26/2014	NR	NR		38.98673	76.93022	32	NR	CS	19648	
3CD	5	Paint Branch		Gravel bars, woody debris jam, braided flow	**5Cw**	11/7/2014	38.98265	76.92159	26	38.98192	76.92116	26	Up tulip tree NE bank, down silver maple E bank	CS	19904	
3DD	5	Paint Branch	Lowermost reach	Channelized, some boulder stabilization, shallow but w/some pool area, no continuous channel parallel bar	**5Ccgu**	11/7/2014	38.98051	76.91925	32	38.98002	76.91870	16	Down sycamore NE bank, Up opposite shrub NE bank	CS	19904	

Table 1-2: PHA Data Summary

			RHA STATION				Station Endpoints								
							Upstream			Downstream					
Habitat Station Code	**USACE SEGMENT NO.**	**SEGMENT NAME**	**LOCATION NOTES**	**HABITAT DESCRIPTION**	**HABITAT CODE**	**DATES ASSESSED**	**Latitude**	**Longitude**	**Accuracy (ft)**	**Latitude**	**Longitude**	**Accuracy (ft)**	**Endpoint Comments**	**Endpoint GPS Gadget**	**Watershed Area (acres)**
3ED	5	Paint Branch	Downstream of RR bridge	Channelized, minimal stabilization, low-bank, minimal erosion, braided flow	**5Ccle**	11/5/2014	38.98358	76.92382	13	38.98351	76.92368	22	Up sycamore within channel bar, down sycamore E bank	CS	19840
4A	7	Paint Branch - I95 Interchange	Power Line	Channelized, woody vegetation cleared	**7Cc**	7/23/2014	39.02349	-76.94705	ND	39.02329	-76.9461	ND	Determined in office by SK via aerial photo interpretation	CS	10432
4BD	7	Paint Branch - I95 Interchange	Upstream of 95	Alluvium, point bars, some woody debris jams	**7Pe**	7/31/2014	39.02843	76.95130	42	39.02817	76.95141	65	Up muscle wood, Down muscle wood	CS	10048
4CD	7	Paint Branch - I95 Interchange	Downstream of Rte 212	Pdmt Bedrock, Stabilized Locally	**7Pb**	7/31/2014	39.03144	76.95234	26	39.03137	76.95201	42	Up musclewood W bank, Down rusty vertical axle E bank	CS	9856
5AD	9	Sligo Creek	Just upstream NW Branch Confluence	Shallow pools w/occasional riffles. Ponded by structures.	**9Cg**	7/1/2014	38.95909	76.97469	22	38.95911	76.97439	45	Up multitrunk silver maple, down box eldar root N bank	CS	7168
5BD	9	Sligo Creek		Ecodisney boulder works	**9Cs**	10/21/2014	38.96164	76.97813	13	38.96134	76.97739	26	Up mulberry, down mulberry	CS	7040
6AD	10	Chillum Road Tributary	Upstream-most, below Chillum Rd	Continuously stabilized and channelized	**10Cs**	10/17/2014	38.95600	76.98075	26	38.95630	76.98036	22	Up elm S bank, down elm N bank	CS	1242
6BD	10	Chillum Road Tributary	Downstream of pedestrian bridge	Systematic discontinuous stabilization, channelized	**10Cg**	10/17/2014	38.95675	76.97964	16	38.95688	76.97890	19	Down S bank mulberry, uup S bank box eldar	CS	1254
6CD	10	Chillum Road Tributary	Lower	Unstabilized, earth channel, unstable	**10Ce**	10/21/2014	38.95597	76.97642	13	38.95589	76.97632	13	Up large elm, down large downed silver maple	CS	1286
7AD	11	Indian Creek - College Park	Downstream of Berwyn Rd	Channelized, systematically stabilized. Pond/glide.	**11Ccg**	11/10/2014	38.99287	76.91993	42	38.99264	76.92026	22	Up sycamore, Down basket oak	CS	18176
7BU	11	Indian Creek - College Park	Downstream of Berwyn Heights Park	Channelized, not systematically stabilized. Long, homogeneous ponded reaches.	**11Cc**	11/10/2014	38.99154	76.92059	13	NR	NR	NR	Synthetic, only one endpoint recorded.	CS	18176
7E	11	Indian Creek - College Park	Upstream of Greenbelt Rd	Channelized, deep pool, no bars, no riffle/run, minimal woody debris. Riparian habitat disturbed on one bank from historic activity	**11Ccp**	11/10/2014	NA	NA	NA	NA	NA	NA	Synthetic, no specific endpoint	NA	17536

Table 1-2: PHA Data Summary															
			RHA STATION				Station Endpoints								
							Upstream			Downstream					
Habitat Station Code	**USACE SEGMENT NO.**	**SEGMENT NAME**	**LOCATION NOTES**	**HABITAT DESCRIPTION**	**HABITAT CODE**	**DATES ASSESSED**	**Latitude**	**Longitude**	**Accuracy (ft)**	**Latitude**	**Longitude**	**Accuracy (ft)**	**Endpoint Comments**	**Endpoint GPS Gadget**	**Watershed Area (acres)**
7CD	12	Little Paint Branch	Downstream of unchannelized reach downstream of Cherry Hill Rd	Channelized, earth	**12Cc**	7/23/2014	39.01289	76.93584	19	39.01198	76.93601	16	Up multitrunk ash, down river birch	CS	6720
7DD	12	Little Paint Branch	Downstream of Cherry Hill Rd	Unchannelized, earth	**12Cm**	6/16/2014	39.01432	76.9356	26	39.01381	76.93587	16	Up tulip tree sapling E bank, Down sycamore sapling	CS	6720
8AD	13	NW Branch Anacostia Mainstem	Below pedestrian bridge, upstream of University Boulevard	Earth channel, Unstabilized, Unchannelized, Severe bank/channel erosion, large sand bars, timber jams	**13Cmhe**	4/2/2015	38.98937	76.96636	32	38.98927	76.96587	16	Up box elder & woody debris; down slumping elm	CS	21312
8BD	13	NW Branch Anacostia Mainstem	Archery range, upstream of University Boulevard	Meander, erosion, not stab, bars	**13Cml**	4/14/2015	38.985647	76.963973	52	38.985342	76.96395	52	Up box elder sapling, down box elder sapling and large sycamore	SK	21504
8CD	13	NW Branch Anacostia Mainstem	Below University Blvd, in Lane Manor Recreation Center	Channelized earth, not stabilized	**13Cct**	4/14/2015	38.983977	76.964622	46	38.974702	76.9528733	46	Box eldars, W bank	SK	53
8DD	13	NW Branch Anacostia Mainstem	Below University Blvd, in Lane Manor Recreation Center	Channelized, systematically stabilized w/boulders. Run/riffle	**13Ccsr**	4/9/2015	38.98202	76.96381	22	38.98176	76.96293	42	Up elm W bank; down ash	CS	21760
8ED	13	NW Branch Anacostia Mainstem	Near downstream end of segment	Channelized, not stabilized. Moderate erosion	**13Cc**	4/9/2015	38.97941	76.96307	16	38.97892	76.96361	16	Up & down, box eldars W bank	CS	21760
9AD	15	NE Branch Anacostia Mainstem	Upstream of Paint Branch Parkway	Channelized, systematic boulder stabilized, no bar deposits, minimal erosion	**15Ccgt**	3/30/2015	38.9766	76.908	45	38.97612	76.91942	42	Upstream end just downstream of airport.	CS	115
9BD	15	NE Branch Anacostia Mainstem	Downstream of Paint Branch Parkway	Channelized, systematic boulder stabilized, large bar deposits, riffles	**15Ccor**	4/2/2015	38.97477	76.91965	26	38.97419	76.91971	32	River birch E bank both up and down	CS	192

Table 1-2: PHA Data Summary															
			RHA STATION				Station Endpoints								
							Upstream			Downstream					
Habitat Station Code	**USACE SEGMENT NO.**	**SEGMENT NAME**	**LOCATION NOTES**	**HABITAT DESCRIPTION**	**HABITAT CODE**	**DATES ASSESSED**	**Latitude**	**Longitude**	**Accuracy (ft)**	**Latitude**	**Longitude**	**Accuracy (ft)**	**Endpoint Comments**	**Endpoint GPS Gadget**	**Watershed Area (acres)**
9CD	15	NE Branch Anacostia Mainstem	Downstream of Paint Branch Parkway	Channelized, systematic boulder stabilized, sediment point bar deposits against boulders on W bank, between grade-control structures. Erosion behind boulders E bank	**15Ccp**	3/31/2015	38.97298	76.91832	32	38.9722	76.91806	45	Downstream end upstream of active sanitary sewer crossing work and temporary bridge.	CS	685
9DD	15	NE Branch Anacostia Mainstem	Opposite MNCPPC building	Channelized, systematic boulder stabilized, sediment point bar deposits against boulders on W bank, no bank erosion behind boulders E bank	**15Cce**	3/31/2015	38.97005	96.91873	16	38.96967	76.91922	13	Sycamore sapling W bank, upstream end	CS	44288
10DD	15	NE Branch Anacostia Tributary	Downstream of Paint Branch Parkway	Unchannelized, unstabilized, earthen channel w/locally severe bank erosion	**15TCm**	3/31/2015	38.97056	76.91974	26	38.97042	76.91975	26	Downstream at NE Branch confluence. Upstream end Anacostia paved trail.	CS	486
habitat code relates to data sheet having watershed area and nearest road data															
NA	Not applicable. See reach notes														
NR	Not recorded														
Endpoint GPS Gadget															
CS	CS Blackberry														
SK	SK Blackberry														

Table 1-4: Stream Segment Access Information - Anacostia Prince George's County		
Segment No.	**Segment Name**	**Parking and Stream Access**
1	Indian Creek - I95	To access downstream end of segment, park on Caroline Ave north of Quimby Ave. From Route 1, drive west on various small roads to access Caroline Ave, then turn north on Caroline Ave. Walk north into woods along informal trails to access stream. To access middle of segment, park in vicinity of Trolley Lane cul de sac. Can also park at MLK School. Walk east to stream then up/down. (No trail)
3	Northwest Branch	For southern end of segment: park on Nicholson Street off Ager Road, then walk down trail and cut across woods to west or south to stream. For northern end of segment: park on West Park Drive, access via Amherst Rd, walk east through woods to stream, then along stream (no trail)
5	Paint Branch	From Route 1, drive east on Lakeland Rd, then make right on Rhode Island Ave, then left on Pierce Avenue. Park behind community center, then walk along paved trails. Can access stream from pedestrian bridge or by walking south through woods from trails.
7	Paint Branch - I95 Interchange	Access problematic for all but upper end. To access uppermost segment, park in Powder Mill Community Park on Powder Mill Rd. Walk SE from parking lot through woods to stream on informal trails. After reaching stream, no further trails. Walk downstream along stream to access remainder of stream. To access segment from downstream, get permission to enter agricultural research lands off Cherry Hill Rd. Drive west/north on gravel and dirt roads to park about where stream goes under beltway. Then walk upstream along stream. No trails.
9	Sligo	For northern end of segment, park on Sligo Parkway near Powhatan Road intersection. Walk west across ballfields to access stream. Walk in stream to access downstream points. For southern end of segment, can park on Nicholson Street and take paved trails of Anacostia trail system across the river then up Sligo Creek.
10	Chillum	Park on 16th Avenue off Chillum Road, access stream at pedestrian bridge. No trail for points downstream of bridge, walk in stream valley to access. Points upstream of bridge can be accessed via walking on lawn parallel to stream or walking in stream.
11	Indian Creek - College Park	Park in Indian Creek Park in Berwyn Heights on Berwyn Road and use Anacostia trail system (paved) to access portion of segment downstream of Greenbelt Rd. Walk through informal trails through woods to access west bank or portion of stream immediately downstream of Greenbelt Rd. To access stream upstream of Greenbelt Rd., can park on Branchville Rd and walk upstream on west bank on paved road/trail then behind multifamily housing. East bank is not readily accessible there.
12	Little Paint Branch	Park in "Little Paint Branch Stream Valley Park" on Cherry Hill Road. For upstream, follow paved trail upstream. To go downstream, walk west along and cross Cherry Hill Road, then head south on trail. RHA segment is across from park bench labelled "PPVA Donation"
13New	Lower Northwest Branch	Lower boundary about Fordham St (downstream of Univ Blvd); upper boundary about Rosette Ln just downstream of Riggs Rd. Access from Adelphi Manor archery range on N side of E bank off University Boulevard, or through Lane Manor Recreation Center on S side of W bank off W Park Dr. Also, can access via Anacostia trail access point below power line off Cool Spring Rd
15	Northeast Branch	Upper point is confluence of Paint and Indian Creek; lower point is just downstream of Brier Ditch confluence. Access off Paint Branch Parkway, park on SW side of NE Branch to utilize Anacostia trail and parking lot, or park on NE side in Riverside Ave parking lot in park.
Between 3&13	Northwest Branch - East-West Highway	Parked on West Park Drive, then walked E through park to access stream.

Table 1-5: Embeddedness - Individual Data Points and Average											
	USACE Segment No. and Date										
Embeddedness Sample	**1**	**3**	**3**	**3**	**5**	**5**	**5**	**5**	**7**	**7**	**7**
Date	**6/27/2014**	**10/28/2014**	**10/31/2014**	**10/31/2014**	**6/26/2014**	**11/7/2014**	**11/7/2014**	**11/5/2014**	**7/23/2014**	**7/31/2014**	**7/31/2014**
Habitat Type Code	**1Cm**	**3Ccu**	**3Cce**	**3Cm**	**5Ccehu**	**5Ccgu**	**5Cw**	**5Ccle**	**7Cc**	**7Pe**	**7Pb**
1	40	40	40	20	30	40	20	60	65	65	50
2	20	50	40	40	60	50	15	40	50	25	60
3	50	20	35	40	50	35	25	40	80	50	70
4	20	30	55	50	40	40	30	40	60	70	40
5	60	60	35	55	20	50	10	50	75	80	50
6	50	70	45	35	20	60	15	70	95	10	40
7	50	85	35	40	20	25	15	65	100	60	40
8	10	80	30	40	40	35	25	60	25	15	80
9	10	75	20	20	10	75	15	60	75	10	75
10	5	85	30	30	30	60	10	55	95	10	80
Mean	32	60	37	37	32	47	18	54	72	40	59

Table 1-5: Embeddedness - Individual Data Points and Average												
Embeddedness Sample	**9**	**9**	**10**	**10**	**12**	**12**	**13**	**13**	**13**	**15**	**15**	**15**
Date	**7/1/2014**	**10/21/2014**	**10/21/2014**	**10/17/2014**	**7/23/2014**	**6/16/2014**	**4/9/2015**	**4/2/2015**	**4/14/2015**	**3/31/2015**	**4/2/2015**	**3/31/2015**
Habitat Type Code	**9Cg**	**9Cs**	**10Ce**	**10Cs**	**12Cc**	**12Cm**	**13Cc**	**13Cmhe**	**13Cml**	**15TCm**	**15Ccor**	**15Ccp**
1	50	40	20	50	40	40	40	10	35	45	50	25
2	40	30	30	30	10	10	50	45	40	50	30	50
3	50	20	20	60	50	25	5	10	5	50	70	0
4	10	30	60	30	60	25	30	50	5	25	50	10
5	50	30	30	40	80	15	10	20	10	35	20	20
6	40	10	40	85	50	60	60	10	25	40	30	30
7	30	25	20	70	40	5	50	60	30	35	30	40
8	40	30	30	90	50	30	40	45	15	35	15	25
9	60	10	20	10	50	40	50	20	10	35	50	0
10	60	20	30	20	60	75	60	40	5	40	35	30
Mean	43	25	30	49	49	33	40	31	18	39	38	23

Table 1-6: Reach Coordinates and Condition - Segment 1

Stream Segment 1 Reaches and Reach Data: **Indian Creek - I95** Strahler Stream Order Determined by Andrew Roach4/22/2015: 1

Reach Subdivision Assessment D June 26, 2014; July 31, 2014; March 30, 2015

NFR: Not field recorded. Determined using GIS. Upstream reach coordinates recorded using SK phone.

Reach Data by Mainstem or Tributary in Rows Below. Top upstream, bottom downstream.
One Reach per Row Below

					Predominant Conditions						Endpoint Upstream			Endpoint Downstream			Coordinate Notes
Tally No.	**Code Letter for CEICA**	**Segment Mainstem or Tributary**	**Overall Flow Direction**	**Physiographic Province**	**Channel and Bank Material**	**Channelized?**	**Continuously Stabilized?**	**Systematic Discontinuously Stabilized?**	**Notes**	**Representative RHA Station Habitat Type Code (for CEICA)**	**Latitude**	**Longitude**	**Accuracy (ft)**	**Latitude**	**Longitude**	**Accuracy (ft)**	
	1A	M	SE	CP	Earth banks, bed gravel	Yes	No	No	Patch stabilization	1Cc	NFR	NFR	NFR	39.05049	76.90377		Upstream end is downstream of SWM/FRM feature
	1B	M	SE	CP	Earth banks, bed gravel	No	No	No	Mature pine forest with native understory	1Cm	39.05049	76.90377		NFR	NFR	NFR	Coordinate recorded 4/14/2015. Identify downstream end as edge of woods/upstream end of concrete channel on aerial image.
	1C	M	SE	CP	Earth banks, bed gravel	No	No	No	PFO	1PFO	NFR	NFR	NFR	39.05049	76.90377		

Additional habitat type reaches
- Within SWM/FRM feature
- Upstream of Ammendale Rd in beaver pond

Table 1-7: Reach Coordinates and Condition - Segment 3

Stream Segment 3 Reaches and Reach Data: **Northwest Branch - Hyattsville** Strahler Stream Order Determined by Andrew Roach4/22/2015: 3

Reach Subdivision Assessment Dat June 11, 2014; Oct 24, 2014; Oct 28, 2014; Oct 31, 2014

NFR: Not field recorded. Determined using GIS.

Reach Data by Mainstem or Tributary in Rows Below. Top upstream, bottom downstream.

One Reach per Row Below

					Predominant Conditions					**Representative RHA Station**		**Endpoint Upstream**			**Endpoint Downstream**			
Tally No.	**Code Letter for CEICA**	**Segment Mainstem or Tributary**	**Overall Flow Direction**	**Physiographic Province**	**Channel and Bank Material**	**Channelized?**	**Continuously Stabilized?**	**Systematically Stabilized?**	**Notes**	**Habitat Type Code (for CEICA)**	**Notes**	**Latitude**	**Longitude**	**Accuracy (ft)**	**Latitude**	**Longitude**	**Accuracy (ft)**	**Notes**
1	3A	M		CP		No?	No	No	Stream banks/channel not stabilized. Recent tree plantings. Ponded all pool. S bank erosion 2 to 3 m.	3Cce	Unstabilized like 3Cm, but all pool. Assigned 3Cce because of proximity.	38.96853	76.96849	16	38.96641	76.96925	16	Upstream end is 410 Bridge grade control structure
2	3B	M		CP		No	No	No	Not stabilized nor channelized. Gravel bar/braided, Woody debris jam in reach	3Cm		38.96641	76.96925	16	38.96588	76.97062	39	
3	3C	M		CP		No?	No	Yes	Primarly ponded/pool. Some riffle on boulders/concrete	*3Ccp*	*Upper segment probably warranting additional pool/boulder habitat type*	38.96588	76.97062	39	38.96496	76.97092	16	Upstream end just upstream of pedestrian bridge
4	3D			CP		Yes?	No	No	Patch bank stabilization, run/riffle from exotic materials. Minimal/no bars. Minimal bank erosion.	*3Ccp*	*Probably warranting additional run/riffle habitat type*	38.96496	76.97092	16	38.96443	76.97101	19	
5	3E	M		CP		Yes	No	No	Erosion minor to moderate. Run/riffle. No bank stabilization, bank heights 2 m, erosion minor to locally moderate	*3Cce*	*Probably warranting additional run/riffle habitat type*	38.96443	76.97101	19	38.96417	76.971	19	
6	3F	M		CP		Yes		No	Patch bank stabilization, ponded	*3Ccp*	*Upper segment probably warranting additional pool/boulder habitat type*	38.96417	76.971	19	38.96406	76.97102	16	
7	3G	M		CP		Yes		Yes	Systematic boulder/concrete stabilization. Ponded	*3Ccst*	*Upper segment probably warranting additional pool/boulder habitat type*	38.96406	76.97102	16	38.96347	76.97075	13	Downstream end is concrete grade-control structure upstream of Ager Rd which forms riffle
8	3H	M		CP		Yes			Riffle then under bridge habitat, then sill	None	Under bridge	38.96347	76.97075	13	38.96281	76.97093	13	Ager Rd bridge
9	3I	M		CP	Concrete rubble and boulder stabilization.	Yes		Yes	Predominantly pond/glide. Entire channel wetted, no bars except minor bar formation from anthropogenic placement (?). Minor to moderate bank erosion.	3Ccp		38.96281	76.97093	13	38.9597	76.97318	32	
10	3J	M		CP	Sands, muds, cobble.	Yes	Yes		Point bars in channel. Mostly ponded. Various bank stabilization works (boulders, gabion baskets)	3Ccst		38.9597	76.97318	32	38.95645	76.97441	32	Downstream end is concrete blanket sill just below Chillum confluence
11	3K	M		CP		Yes	Yes		Artificial boulder riffle	(Use Sligo Creek Ecodisneyland: 9Cs)		38.95645	76.97441	32	38.95594	76.9744	16	

					Predominant Conditions					Representative RHA Station		Endpoint Upstream			Endpoint Downstream			
Tally No.	Code Letter for CEICA	Segment Mainstem or Tributary	Overall Flow Direction	Physiographic Province	Channel and Bank Material	Channelized?	Continuously Stabilized?	Systematically Stabilized?	Notes	Habitat Type Code (for CEICA)	Notes	Latitude	Longitude	Accuracy (ft)	Latitude	Longitude	Accuracy (ft)	Notes
12	3L	M		CP		Yes	Yes		Ponded. Stabilized with variety of gabions, boulders. Local minor to moderate erosion E bank.	3Ccst		38.95594	76.9744	16	38.9553	76.97353	26	Downstream end is boulder riffle grade control
13	3M	M		CP		Yes	Yes		Artificial boulder riffle	(Use Sligo Creek Ecodisneyland: 9Cs)		38.9553	76.97353	26	38.95534	76.97345	26	
14	3N	M		CP		Yes	Yes		Ponded. Stabilized with variety of gabions, boulders. Local minor to moderate erosion E bank.	3Ccst		38.95534	76.97345	26	38.95492	76.97235	45	Downstream end is naturally formed riffle
15	3O	M		CP		Yes	Yes		Naturally formed riffle. Boulder, cobble, gravel	*3Ccu*	*Probably warranting additional run/riffle habitat type*	38.95492	76.97235	45	38.95481	76.97202	55	
16	3P	M		CP	Banks boulder stabilized, but boulders often buried in sediment.	Yes	Yes	No	Wide, shallow. Pool/glide w/infrequent riffle	3Ccu		38.95481	76.97202	55	38.95362	76.96979	85	
17	3Q	M		CP	Banks boulder stabilized, but boulders often buried in sediment.	Yes	Yes	No	Uniform pool/glide deeper than above but w/few pronounced deep areas. Some large channel parallel bars just downstream of MARC bridge, E bank	3Ccpg		38.95362	76.96979	85	38.9526	76.9665	26	Upstream end just downstream of MARC station pedestrian bridge. Downstream end is upstream end of artificial riffle immediately upstream of Route 500.

Coordinates of Notable Points in Stream Segment

Large patch Japanese knotweed			38.96608	76.97018	19				Heurich Park
Artificial riffle below Ager Rd - concrete rubble			38.96281	76.97093	13				
Flap valves releasing water into boulders			38.96588	76.97062	39				
Concrete blanket sill just below Chillum confluence			38.95645	76.97441	32				
Concrete grade-control structure			38.96347	76.97075	13				
Concrete sill with 1 ft drop, likely blockage for anadromous but not resident fish. Riffle on downstream side of sill made of concrete rubble			38.96281	76.97093	13				Just downstream of Agar Rd bridge
Kudzu notable			NFR	NFR	NFR				Downstream of Agar Rd
Bars w/cobbles & boulder (anthropogenic placement?) Massive kudzu area			38.96047	76.97259	26				
Severe erosion 2-3 m, E bank, immediately downstream of pedestrian bridge			38.95889	76.97352	13				

3 Multiple stations to characterize because of confounding effects of combinations of with/without stabilization and channelization. Also, exclude artificial boulder grade control riffles.

Table 1-8: Reach Coordinates and Condition - Segment 5

Stream Segment 5 Reaches and Reach D Paint Strahler Stream Order Determined by Andrew Roach4/22/2015: 3
Reach Subdivision Assess June 26, 2014; Nov 5, 2014; Nov 7, 2014;
NFR: Not field recorded. Determined using GIS.

Reach Data by Mainstem or Tributary in Rows Below. Top upstream, bottom downstream.
One Reach per Row Below

					Predominant Conditions							Endpoint Upstream			Endpoint Downstream			
Tally No.	Code Letter for CEICA	Segment Mainstem or Tributary	Overall Flow Direction	Physiographic Province	Channel and Bank Material	Channelized?	Continuously Stabilized?	Systematic Discontinuously Stabilized?	Notes	Representative RHA Station Habitat Type Code (for CEICA)	RHA Best Fit Notes	Latitude	Longitude	Accuracy (ft)	Latitude	Longitude	Accuracy (ft)	Notes
1	5A	M	SE	CP	Banks stablized w/boulders, rubble, concrete; Channel natural gravel, etc.	Yes	Yes	No	Water fills entire channel	5Ccst		NFR	NFR	NFR	38.9891	76.93398	13	Upstreammost point is Route 1
2	5B	M	SE	CP					Full wetted bottom, minimal bars, homogeneous instream shallow	5Ccgu	Not sure boulders present, but otherwise 5Ccgu appears best fit	38.9891	76.93398	13	38.988879	76.93342	13	
3	5C	M	SE	CP					Homogeneous instream habitat, but not full wetted bottom. Channel-parallel gravel bars on channel margin	5Ccehu		38.988879	76.93342	13	38.98826	76.93223	16	
4	5D	M	SE	CP					Woody debris jam, gravel bars	5Cw	Boulder stabilization present, but mostly fronted by gravel bar. Boulders don't affect stream much (?)	38.98826	76.93223	16	38.98785	76.93221	22	
5	5E	M	SE	CP	Boulders SW bank	Yes			Deep along boulders, Water fills channel, Opposite non stabilized bank 2 m high, shallow water	5Ccgu	In between 5Ccgu and 5Ccst	38.98785	76.93221	22	38.98697	76.93135	26	
6	5F	M	SE	CP		Yes	No		Stream occupies only small part of channel, has gravel bars.	5Ccehu		38.98697	76.93135	26	38.98622	76.92992	26	
7	5G	M	SE	CP	Boulders both banks bridge vicinity	Yes	Yes		Boulders failing both banks.	5Ccst		38.98622	76.92992	26	NFR	NFR	NFR	Downstream end is downstream end of pedestrian bridge boulders

					Predominant Conditions							Endpoint Upstream			Endpoint Downstream			
Tally No.	Code Letter for CEICA	Segment Mainstem or Tributary	Overall Flow Direction	Physiographic Province	Channel and Bank Material	Channelized?	Continuously Stabilized?	Systematic Discontinuously Stabilized?	Notes	Representative RHA Station Habitat Type Code (for CEICA)	RHA Best Fit Notes	Latitude	Longitude	Accuracy (ft)	Latitude	Longitude	Accuracy (ft)	Notes
8	5H	M	SE	CP		Yes	No		Gravel bars. Sewer line in W bank, stabilizes bank/channel locally downstream of pedest bridge	5Ccehu		NFR	NFR	NFR	38.98536	76.92824	22	Upstream end is downstream end of pedestrian bridge boulders.
9	5I	M	SE	CP					Short reach w/failing concrete rubble stablization, pool along stabilized bank	5Ccgu		38.98536	76.92824	22	38.98502	76.92834	13	
10	5J	M	SE	CP		Yes	No		Gravel bars, stream fills only portion of channel. Tall erosional banks as per all above down to this point	5Ccehu		38.98502	76.92834	13	38.9845	76.92767	13	Downstream point is just upstream of Metro RR bridge
11	5K	M	SE	CP					Bank height drops to ~1 m, vegetated bank slopes, stream fills more of channel but still has gravel bars. Could separate out bridge as separate habitat type.	5Ccle		38.9845	76.92767	13	38.9803	76.92232	16	Upstream point is just upstream of Metro RR bridge
12	5L	M	SE	CP					Gravel deposit/woody debris jam, bank height increase	5Cw		38.9803	76.92232	16	38.98188	76.92124	22	Downstream end just upstream of pedestrian bridge
13	5M	M	SE	CP					Single thread stream, deep channel, high 3 m banks	5Ccst	Not sure boulders present, but otherwise boulders appear best fit	38.98188	76.92124	22	38.98183	76.92088	32	Downstream end is bridge boulder stabilization works
14	5N	M	SE	CP			Boulder stabilization works, bridge		Pool/glide	5Ccst		38.98183	76.92088	32	38.98126	76.92052	32	Downstream end is boulder grade-control stablization works upstream end
15	5O	M	SE	CP					Boulder grade control structure		Use data from Sligo or elsewhere	38.98126	76.92052	32	38.98111	76.9203	26	
16	5P	M	SE	CP				Patchwork boulder stabilization R bank	Stream covers majority of channel w/some gravel bars, some severe erosion	5Ccgu		38.98111	76.9203	26	38.98019	76.91903	22	
17	5Q	M	SE	CP					Stream uniformly wide glide w/severe to moderate erosion where not stabilized. Banks 2-3 m high	5Ccgu		38.98019	76.91903	22	38.98011	76.91874	42	

					Predominant Conditions							Endpoint Upstream			Endpoint Downstream			
Tally No.	Code Letter for CEICA	Segment Mainstem or Tributary	Overall Flow Direction	Physiographic Province	Channel and Bank Material	Channelized?	Continuously Stabilized?	Systematic Discontinuously Stabilized?	Notes	Representative RHA Station Habitat Type Code (for CEICA)	RHA Best Fit Notes	Latitude	Longitude	Accuracy (ft)	Latitude	Longitude	Accuracy (ft)	Notes
18	5R	M	SE	CP			Boulders both banks		Stream deeper narrowed by boulders	5Ccst		38.98011	76.91874	42	38.97964	76.91847	55	End at steel weir
19	5S	M	SE	CP					Boulder grade control structure		Use data from Sligo or elsewhere	38.97964	76.91847	55	38.9795	76.91831	22	
20	5T	M	SE	CP				Systematically stabilized, one or both banks w/boulders.	Shallow depth, homogeneous velocity run/glide, presumably because of backwater effects	5Ccgu		38.97907	76.91795	22	38.97897	76.91748	55	Ends at NE Branch Confluence

Additional Segment 5 Notable Points and Subreach Notes

Bamboo patch			38.9888	76.93362	26	38.98844	76.93319	26	Double-check downstream coordinate in field book
Sewer line in bank			38.98578	76.9295	16				
Concrete rubble E bank			38.98536	76.92824	22	38.98502	76.92834	13	
Downstream end RR bridge boulders			38.984	76.92567	55				
Metal pedestrian bridge boulder stabilization						38.98183	76.92088	32	
Steel weir			38.97964	76.91847	55				

5 1) Earth channel high bank not stabilized, 2) Earth channel low bank not stabilized, 3) Earth (gravel) channel woody debris jam, 4) Boulder stabilized channel

Note: Paint Branch general observations. Pools absent from homogeneous shallow channelized reaches except where timber jams occur, then locally pools form.
If Paint Branch channelized and stabilized, then water fills bottom and stream has deep pools.
If Paint Branch channelized but not stabilized large gravel bars and no deep pools
Any spots w/large woody debris have highly variable local conditions, including deep pools

Channelized, eroding tall earth banks, homogeneous shallow habitat, channel-parallel gravel bars on channel outer edge
Gravel bars, woody debris jam, braided flow
Channelized, shallow, homogeneous, some boulder stabilization
Generic continuous boulder stabilization on banks, continuous pool
Channelized, unstabilized, low-bank, minimal erosion, braided flow

Trees on N bank topped for airport

Table 1-9: Reach Coordinates and Condition - Segment 7

Stream Segment 7 Reaches and Reach Data: **Paint Branch - I95 Interchange** Strahler Stream Order Determined by Andrew Roach4/22/2015: 2

Reach Subdivision and Sampling Station Assessment Dates: 7/23/2014; 7/31/2014 Note: other than concrete trapezoidal channel, bridges not divided out as habitat type

NFR: Not field recorded. Determined using GIS.

Note: CP reaches below highways inadequately sampled/subdivided in that boulder reaches with deep pools and some shade occurred that are more similar to Piedmont because of boulders. However, uncertain how to deal with complex infrastructure effects or whether can even do work there because of access challenges, etc.

Reach Data by Mainstem or Tributary in Rows Below. Top upstream, bottom downstream.

One Reach per Row Below

					Predominant Conditions					Endpoint Upstream			Endpoint Downstream				Representative RHA Station	
Tally No.	Code Letter for CEICA	Segment Mainstem or Tributary	Overall Flow Direction	Physiographic Province	Channel and Bank Material	Channelized?	Continuously Stabilized?	Systematic Discontinuous Stabilization?	Notes	Latitude	Longitude	Accuracy (ft)	Latitude	Longitude	Accuracy (ft)	Coordinate Notes	Habitat Type Code (for CEICA)	Notes
1	7A	M	SE	P	Bedrock	No (except channelized at uppermost end immediately downstream of Route 212)	No	No	Notable bedrock outcrops, plus bars. Some deep pools and cliffs. Channel/bank erosion. Stabilization immediately downstream of Route 212	NFR	NFR	NFR	39.031	76.95208	19	Upstream end of segment is Route 212	7Pb	
2	7B	M	S (meanders)	P	Alluvium, soil	No (possible historic?)	No	No	Long reach. Minimal/no bedrock outcrops. Moderate to severe bank erosion, point bars. Occasional failing patch stabilization works.	39.031	76.95208	19	39.0274	76.95255	19		7Pe	
3	7C	M	SE	CP	Alluvium, soil, boulder stabilization	Yes	No	No?	Highway construction channelization, etc. Patch stabilization, locally severe bank erosion.	39.0274	76.95255	19	39.02503	76.95098	55	Downstream end is concrete channel	7Cc	Some shading versus 0% below power line
4	7D	M	SE		Concrete sloped banks	Yes	Yes		Trapezoidal channel	39.02503	76.95098	55	39.02423	76.95071	42		None	Assume no or minimal work
5	7E	M	SE, S	CP	Alluvium, soil, boulder stabilization	Yes	No	No?	Highway construction channelization, etc. Patch stabilization, locally severe bank erosion.	39.02423	76.95071	42	NFR	NFR	NFR	Downstream end of segment is beltway	7Cc	Some shading versus 0% below power line

Coordinates of Notable Points in Stream Segment

Locally severe bank erosion	39.02623	76.95023	NR				Below highway bridge
Downstreammost bedrock outcroppings in stream	39.02367	76.94778	22				
Concrete structure with fish passage works?							Below beltway?

B Blackberry phone
NR not recorded

Table 1-10: Reach Coordinates and Condition - Segment 9

Stream Segment 9 Reaches and Reach Data: **Sligo Creek** Strahler Stream Order Determined by Andrew Roach4/22/2015: 2

Reach Subdivision Assessment Dates: June 11, 2014; Oct 21, 2014

NFR: Not field recorded. Determined using GIS.

Reach Data by Mainstem or Tributary in Rows Below. Top upstream, bottom downstream.
One Reach per Row Below

					Predominant Conditions							Endpoint Coordinates Upstream			Endpoint Coordinates Downstream			
Tally No.	**Code Letter for CEICA**	**Segment Mainstem or Tributary**	**Overall Flow Direction**	**Physiographic Province**	**Channel and Bank Material**	**Channelized?**	**Continuously Stabilized?***	**Systematic Discontinuous Stabilization?***	**Ponded from Downstream Structure?**	**Notes**	**Representative RHA Station Habitat Type Code (for CEICA)***	**Latitude**	**Longitude**	**Accuracy (ft)**	**Latitude**	**Longitude**	**Accuracy (ft)**	**Coordinate Notes**
1	9A	M	S	CP	Boulder stabilization, gabion stabilization, earth	Yes	No	Yes	Substantially	Shallow pools from ponding caused by downstream structures, but w/occasional shallow riffles. Not fully impounded. Reach contains other cross-stream structures, but these don't affect overall habitat type.	9Cg	38.96224	76.97906	26	38.96164	76.97813	13	Upstream end is downstream end of another grade-control ecodisneyland boulder field
2	9B	M	SE	CP	Boulder works	Yes	Yes	No	No	Ecodisneyland boulder field	9Cs	38.96164	76.97813	13	38.96132	76.97716	32	
3	9C	M	SE	CP	Boulder stabilization, earth	Yes	No	Yes	Substantially	Shallow pools formed by ponding upstream of structures, but w/occasional shallow riffles. Not fully impounded. Reach contains other cross-stream structures, but these don't affect overall habitat type.	9Cg	38.96132	76.97716	32	38.95851	76.97404	13	Downstream end is confluence w/NW Branch; upstream end is downstream end of boulder field.

*Stabilization works affecting stream channel. Reach w/substantial stabilization works buried in excess sediment in bank included in discontinuous category because can't easily evaluate whether present and may not be felt by stream.

Additional Segment 9 Notable Points and Subreach Notes

Steel weir w/boulders upstream	38.96158	76.97831	16
Steel weir	38.95929	76.97556	16
Concrete sill	38.9594	76.97544	55

Table 1-11: Reach Coordinates and Condition - Segment 10

Stream Segment 10 Reaches and Reach Data: **Chillum Road Tributary** Strahler Stream Order Determined by Andrew Roach4/22/2015: 1
Reach Subdivision Assessment Dates: 7/1/2014; Oct 17, 2014; Oct 21, 2014
NFR: Not field recorded. Determined using GIS.

Reach Data by Mainstem or Tributary in Rows Below. Top upstream, bottom downstream.
One Reach per Row Below

					Predominant Conditions				Representative RHA Station Habitat Type Code (for CEICA)	Endpoint Coordinates Upstream (Decimal degrees [B])			Endpoint Coordinates Downstream (Decimal Degrees [B])			Coordinate Notes
Tally No.	Code Letter for CEICA	Segment Mainstem or Tributary	Overall Flow Direction	Physiographic Province	Channel and Bank Material	Channelized?	Continuously Stabilized?	Discontinuous Systematically Stabilized?		Latitude	Longitude	Accuracy (ft)	Latitude	Longitude	Accuracy (ft)	
1	10A	M	E	CP	Boulder, gabion, concrete	Y	Y	N	10Cs	38.95603	76.98101	26	38.9563	76.98036	22	Assigned lower end of RHA sampling reach as lower end of this reach
2	10B	M	E	CP	Boulder, earth	Y	N	Y	10Cg	38.9563	76.98036	22	38.95666	76.97848	22	
3	10C	M	E	CP	Earth	N?	N	N	10Ce	38.95666	76.97848	22	38.95608	76.97593	19	
4	10D	M	E	CP	Boulder, earth	Y	N	Y	10Cg	38.95608	76.97593	19	38.95641	76.97491	39	Confluence with NW Branch downstream end pt

Additional Segment 10 Notable Points and Subreach Notes								
	Pipe crossing w/boulders	38.95666	76.97944	19				

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Table 1-12: Reach Coordinates and Condition - Segment 11

Stream Segment 11 Reaches and Reach Data: **Indian Creek - College Park** Strahler Stream Order Determined by Andrew Roach 4/22/2015: 4

Reach Subdivision Assessment Dates: June 12, 2014; June 26, 2014; Nov 10, 2014; **Segment highly problematic to habitat type upstream of Greenbelt Rd**

NFR: Not field recorded. Determined using GIS. Probable water quality problems upstream of Greenbelt Rd

Reach Data by Mainstem or Tributary in Rows Below. Top upstream, bottom downstream.
One Reach per Row Below

					Predominant Conditions					Endpoint Upstream			Endpoint Downstream				Representative RHA	
Inverse Tally No.	Code Letter for CEICA	Segment Mainstem or Tributary	Overall Flow Direction	Physiographic Province	Channel and Bank Material	Channelized?	Continuously Stabilized?	Systematic Discontinuous Stabilization?	Notes	Latitude	Longitude	Accuracy (ft)	Latitude	Longitude	Accuracy (ft)	Coordinate Notes	Habitat Type Code (for CEICA)	Notes
17	11A					Yes			Channelized, deep pool, no bars, no riffle/run, minimal woody debris	Dr, plus Greenbelt Rd up to reed grass in braided reach							11Ccp	Synthetic habitat type
16	11B					No	No	No	Braided intermittent stream network								11PFO	
15	11C	M	SW	CP		Yes	SE bank, yes	No	Concrete debris and poured concrete SE bank; NW bank unstabilized, vertical 0.8 m. Bottom 95% embedded, some woody debris (couldn't count - poor visiility, poor access)	39.0011	76.91392	45	38.99909	76.91686	13	Upstream coordinate is as far as I walked on Nov 10, 2014	11Ccp	Synthetic habitat type
14	11D	M	S	CP		Yes	?	Yes	Boulder stabilized W bank. E bank earthen (?) (fill?). Ponded. Pond >3 ft. Concrete boulder debris in channel	38.99909	76.91686	26	38.99914	76.91696	19		11Ccp	Synthetic habitat type
13	11E	M	SW	CP		Yes	Yes	No	Concrete trapezoidal channel, ponded. Pond > 3ft. Concrete boulder debris in channel	38.99914	76.91696	19	Greenbelt Rd			Greenbelt Rd downstream end, upstream end upstream of Branchville Rd	None	Assume can't modify concrete
12	11F	M		CP		Yes	NR	NR	Greenbelt Rd bridge	NR	NR	NR	NR	NR	NR		None	
11	11G	M	SW	CP		Yes	Yes		Boulder stabilized. Pool.	38.99699	76.91773	22	38.9967	76.9179	19	Upstream end is riffle grade control structure below Greenbelt Rd	11Ccg	
10	11H	M	SW	CP		Yes			SE bank moderate erosion, NW bank w/historic severe erosion, but now stable material at slope toe. Depth and embeddedness similar to stabilized reaches, except pool depth <2 ft	38.9967	76.9179	19	38.99608	76.9183	26		11Ccg	
9	11I	M	SW	CP		Yes		Yes	Stormwater outfall with boulder stabilization for part of reach	38.99608	76.9183	26	39.99614	76.91844	19		11Ccg	
8	11J	M	SW	CP		Yes			Back to pool/glide minor to moderate bank erosion condition as per below	39.99614	76.91844	19	38.99544	76.91859	26		11Cc	
7	11K	M	SW	CP		Yes			Severe/moderate erosion NW bank. Riffle w/gravel and transported boulders.	38.99544	76.91859	26	38.99544	76.91859	26	Readings as recorded. (Short reach presumably)	11Ccg	

					Predominant Conditions					Endpoint Upstream			Endpoint Downstream				Representative RHA	
Inverse Tally No.	**Code Letter for CEICA**	**Segment Mainstem or Tributary**	**Overall Flow Direction**	**Physiographic Province**	**Channel and Bank Material**	**Channelized?**	**Continuously Stabilized?**	**Systematic Discontinuous Stabilization?**	**Notes**	**Latitude**	**Longitude**	**Accuracy (ft)**	**Latitude**	**Longitude**	**Accuracy (ft)**	**Coordinate Notes**	**Habitat Type Code (for CEICA)**	**Notes**
6	11L	M	SW	CP		Yes			Pool/glide, 2 ft maximum depth. Cobble and gravel bottom w/substantial embeddedness. Minor to moderate bank erosion, ~50 cm height.	38.99544	76.91859	26	38.99451	76.91922	26		11Cc	
5	11M	M	SW	CP		Yes			Ponded. SE bank more notable erosion, 1 to 2 m	38.99451	76.91922	26	38.99389	76.91956	32		11Ccg	
4	11N	M	SW	CP		Yes	No	No	Ponded. Generally minor bank erosion	38.99389	76.91956	32	38.993	76.91993	13		11Cc	
3	11O	M	SW	CP		Yes	No	Yes, stone toe SE bank	Ponded, but greater depth than ponding below.	38.993	76.91993	13	38.99234	76.92022	22	Upstream end is riffle grade control structure below Berwyn Rd	11Ccg	
2	11P	M	SW	CP		Yes	No	No (Patch)	Ponded. W bank heights ~2 m, moderate erosion. E bank <0.5 m, minor erosion. Caused by stormwater outfall. Some boulders in stream bank and bed.	38.99234	76.92022	22	38.99209	76.92065	22	Upstream end is stormwater outfall	11Ccg	
1	11Q	M	SW/SE	CP		Yes	No	No	Stream shallow ponded upstream of gabion baskets. Low banks, minimal erosion	38.99209	76.92065	22	38.99063	76.92102	22	Gabion baskets at downstream end	11Cc	

Additional Segment 15 Notable Points and Subreach Notes

Notes	Latitude	Longitude	Accuracy (ft)	Latitude	Longitude	Accuracy (ft)	Coordinate Notes
Valley w forested wetlands and lots of recent sand deposits.							W of Cherrywood Lane
Reed grass ponds							
Invasive exotic woody understory vegetation, NW bank	38.99983	76.91569	13	39.00073	76.91436	22	Upstream of Branchville Rd
Riffle grade control structure	38.99699	76.91773	22				Below Greenbelt Rd
Riffle grade control structure	38.993	76.91993	13				Below Berwyn Rd
Stormwater outfall structure	38.99234	76.92022	22				
Gabion baskets (3) filled w/cobbles. Grade-control structures? Artificial riffle at gabion baskets. Some erosion up/down of baskets	38.99063	76.92102	22				

1: channelized not stabilized;
1: channelized and stabilized;
1: braided streams through former gravel mining area?

Table 1-13: Reach Coordinates and Condition - Segment 12

Stream Segment 12 Reaches and Reach Data: **Little Paint Branch** Strahler Stream Order Determined by Andrew Roach4/22/2015: 2
Reach Subdivision Assessment Dates: June 12, 2014; June 27, 2014; July 23, 2014;
NFR: Not field recorded. Determined using GIS.

Reach Data by Mainstem or Tributary in Rows Below. Top upstream, bottom downstream.
One Reach per Row Below

					Predominant Conditions							Endpoint Coordinate Upstream			Endpoint Coordinate Downstream				
Tally No.	Code Letter for CEICA	Segment Mainstem or Tributary	Overall Flow Direction	Physiographic Province	Channel and Bank Material	Channelized?	Continuously Stabilized?	Discontinuous Systematic Stabilization?	Notes	Representative RHA Station Habitat Type Code (for CEICA)	Reach Location Notes	Latitude	Longitude	Accuracy	Latitude	Longitude	Accuracy	Coordinate Notes	Location Notes
1	12A	M	S	CP	Earth	Yes	No	No	Only observed from Cherry Hill Rd - didn't walk up. Aerial photos and USGS maps show straight channel so confident though.	12Cc	Immediately upstream of Cherry Hill Rd	NR	NR	NR	NR	NR	NR	Interpreted from aerial photos. NFR.	
2	12B	M	S	CP	Earth	No	No	No		12Cm	Immediately downstream of Cherry Hill Rd	NR	NR	NR	NR	NR	NR	Interpreted from aerial photos. NFR.	Enter stream across from park bench "PPVA Donation"
3	12C	M	S	CP	Earth	Yes	No	No		12Cc	Further downstream than unchannelized portion	NR	NR	NR	NR	NR	NR	Interpreted from aerial photos. NFR.	

Additional Segment 12 Notable Points and Subreach Notes: None recorded

Table 1-14: Reach Coordinates and Condition - Segment 13

Stream Segment 13 Reaches and Reach Data: Lower Northwest Branch **Note: Lower end extends in Segment 13 "old" (previous rejected version)**

Reach Subdivision Assessment Dates: 4/2/2015, 4/9/2015, 4/14/2015, (also see Seg 13 old for lowermost end of new Seg 13)

NFR: Not field recorded. Would need to be determined using GIS. All coordinates determined using Chris's Blackberry USACE phone Strahler Stream Order Determined by Andrew Roach4/22/2015: 3

Reach Data by Mainstem or Tributary in Rows Below. Top upstream, bottom downstream.
One Reach per Row Below

					Predominant Conditions					Endpoint Upstream			Endpoint Downstream				Representative RHA Station	
Tally No.	Code Letter for CEICA	Segment Mainstem or Tributary	Overall Flow Direction	Physiographic Province	Channel and Bank Material	Channelized?	Continuously Stabilized?	Systematic Discontinuous Stabilization?	Notes	Latitude	Longitude	Accuracy (ft)	Latitude	Longitude	Accuracy (ft)	Coordinate Notes	Habitat Type Code (for CEICA)	Notes
1	13A	M	SE	CP	Alluvium	No	No	No	Highly unstable, severe erosional reach. Eroding banks >2 m, large bars	38.99059	76.96953	22	38.98782	76.96406	26	Upstream end of highly unstable severe erosional reach is segment upstream end	13Cmhe	
2	13B	M	S	CP	Alluvium	No? (Possible historic?)	No	No	Eroding banks 1.5 m. Some patchwork stabilization, not systematic (see inventory below)	38.98845	76.9636	13	38.98511	76.96416	16	Downstream end is concrete rubble upstream of Route 193	13Cml	
3	13C	M	S	CP	Alluvium	Yes	No	No	Minor/moderate erosion	NFR	NFR	NFR	38.98248	76.96399	16	Reach upstream end is Route 193, downstream end is upstream end of systematic boulder works	13Cct	
4	13D	M	SE	CP	Boulders	Yes	Yes	NA	Ecodisneyland: boulder channel and banks riffle and run	38.98248	76.96399	16	38.98073	76.9619	19	Two bridges cross within reach	13Ccsr	
5	13E	M	S	CP	Alluvium, some in-place soil/strata on eroding E banks	Yes	No	No	Patchwork stabilization	38.98073	76.9619	19	38.97819	76.96392	26	Downstream reach end is upstream end of boulder stabilization works, E bank	13Cc	
6	13F	M	W	CP	Boulders (E bank)	Yes	Yes (E bank)		All pool within boulder stabilized reach	38.97819	76.96392	26	38.97836	76.96395	16			Use data from other stream segment, no Seg 13 field data recorded
7	13G	M	SW	CP	Boulders	Yes?	Yes		Ecodisneyland: Boulder riffle grade control	38.97841	76.96443	16	38.97838	76.96484	26			Use data from other stream segment, no Seg 13 field data recorded

Additional Segment 13 Notable Points and Subreach Notes

Bamboo patch, NE side of paved trail	38.98936	76.96745	26	38.98959	76.96766	22	
Paved trail threatened by erosion, NE bank	38.98956	76.96783	19				Below power lines
Pedestrian bridge boulders, SW bank				38.9888	76.96707	16	
Stone toe stabilization, E bank	38.98845	76.9636	13	38.98846	76.9635	13	
Stone toe stabilization, W bank	38.98778	76.9643	22	38.98706	76.96399	16	
Concrete grade control structure	NFR	NFR	NFR				Just upstream of archery range parking lot, upstream of 193
Patch stabilization, W bank	38.98073	76.9619	19				Extends down to notable severe bank erosion area below
Notable severe bank erosion, SE bank	38.98002	76.96204	32	38.97958	76.96262	22	
Patch stabilization, NW bank	38.9796	76.96286	19				
Concrete supports for former pedestrian trail bridge (bridge removed, paved trail	38.97894	76.96327	42				

Table 1-15: Reach Coordinates and Condition - Segment 14

Stream Segment 15 Reaches and Reach Data: **Northeast Branch** Strahler Stream Order Determined by Andrew Roach 4/22/2015: 4
Reach Subdivision Assessment Dates: March 30, 2015; March 31, 2015; April 1, 2015
NFR: Not field recorded. Determined using GIS.

Reach Data by Mainstem or Tributary in Rows Below. Top upstream, bottom downstream.
One Reach per Row Below

					Predominant Conditions					Endpoint Upstream			Endpoint Downstream				Representative RHA Station	
Tally No.	**Code Letter for CEICA**	**Segment Mainstem or Tributary**	**Overall Flow Direction**	**Physiographic Province**	**Channel and Bank Material**	**Channelized?**	**Continuously Stabilized?**	**Systematic Discontinuous Stabilization?**	**Notes**	**Latitude**	**Longitude**	**Accuracy (ft)**	**Latitude**	**Longitude**	**Accuracy (ft)**	**Coordinate Notes**	**Habitat Type Code (for CEICA)**	**Notes**
1	15A	M	S	CP	Cobble, boulder	Yes? (Historic?)	No	Boulders, E bank	Gravel bar, riffles	38.97871	76.91744	26	38.97809	76.91779	32	Upstream end of segment	15Ccor	
2	15B	M	SW	CP		Yes	No	Yes, either or both banks stone toe	Predominantly pool	38.97809	76.91779	32	38.97559	76.91942	26	Includes airport. Downstream end is grade-control structure	15Ccgt	
3	15C			CP	Boulder	Yes	Yes		Not assigned a habitat type.	NFR	NFR	NFR	NFR	NFR	NFR	Under Paint Branch Parkway.		
4	15D	M	S	CP	Boulder bank	Yes	Yes, boulders in banks		Large point bars	38.97494	76.91958	42	38.97309	76.91833	16	Upstream end is downstream end of Paint Branch Pkwy bridge boulder stabilization works.	15Ccor	
5	15E	M	S	CP		Yes	Yes, boulders in banks		No point bars. I think all glide/run (but that not recorded in notes)	38.97309	76.91833	16	38.97305	76.91825	26		15Cce	Intergradational habitat type. Assigned closest fit of samples
6	15F	M	S	CP		Yes	Yes, boulders in banks		Water fills entire channel either as run or pool upstream of grade-control structures	38.97305	76.91825	26	38.97093	76.91808	32		15Ccp	
7	15G	M	SE	CP		Yes	Yes, boulders in banks		Broad channel, moderate bars, pool along cut bank	38.97093	76.91808	32	38.9695	76.9194	32	Upstream end is Brier's Ditch. Downstream end is downstream end walked to, assumed downstream end of segment.	15Cce	
	15H	T	S, SE		Earth	No	No		Some stabilization at upper end, boulder stabilization at lower end	38.97247	76.92008	26	38.96962	76.91968	22	Upstream end is paved Anacostia trail. Downstream end is upstream end of NE Branch boulder stabilization works. Left gap from this point to actual NE Branch (because boulder-controlled conditions rather than earth channel/bank conditions)	15TCm	

Additional Segment 15 Notable Points and Subreach Notes																		
		M							Small bamboo patch	38.97828	76.91763	45						
		M							Gabion baskets	38.97749	76.91798	16	38.97691	76.91858	13	Airport		
		M							Gabion/concrete grade control structure. Causes upstream ponding	38.97567	76.9195	26	38.97559	76.91942	26	Upstream of Paint Branch Pkwy		
		M							Bridge				38.97494	76.91958	42	Downstream end bridge boulder stabilization works		
		M							Concrete gabion grade control structure	38.97396	76.91957	16						
		M							Concrete gabion grade control structure	38.97309	76.91833	16						
		M							Grade control structure over large diameter pipe	38.97139	76.91819	32						
		M							Bamboo patch	38.97018	76.91858	45	38.96995	76.91898	16	Recorded as NE bank, but I think actually NW bank		
		M							Grade control concrete/gabion basket	38.97305	76.91825	26						
		T							Boulder grade control structure	38.97244	76.91981	22						
		T							Concrete trapezoidal channel	38.9724	76.91966	36						
		T							Boulder grade control structure, sewer crossing	38.9716	76.91952	36						
		T							Boulder bank stabilization works along NE Branch	38.96962	76.91968	22	38.96953	76.91957	16			

Note: could probably have lumped mainstem reaches together and had fewer sampling stations. Downstreammost station is intergradational between station just below Paint Branch Parkway and station between grade-control structures.

Table 2-1: Piedmont Physiographic Province FWOP PHI Metrics and Scores

Stream		Metric Values Input												Transform Bank Severity		Prepare Metric Values								Scale Metric Values								Final Score	Normalize Final Score	Rescaled Final Score
									Left Bank Stability		Right Bank Stability																							
Reach No.	Habitat Code	Watershed Area (acres)	% Embeddedness	Remoteness (meters)	%Shading	Epibenthic Substrate Score	Instream Habitat Score	Total No. Instream Woody Debris and Rootwads	Erosion Extent (meters)	Severity	Erosion Extent (meters)	Severity	Riffle Quality Score	Left	Right	EMBEDDED	REMOTE	RESTSHADING	EPISUB	RESINSTRHAB	WOOD	TBANKSTANB	RESRIFFQUAL	EMBEDDED	REMOTE	RESTSHADING	EPISUB	RESINSTRHAB	WOOD	TBANKSTANB	RESRIFFQUAL	Piedmont PHI	Normalized Piedmont PHI	Rescaled Piedmont PHI
7A	7Pb	9856	59	114.5	50	8	16	5	52	2	16	2	13	1.5	1.5	59	8.46	-0.1727	8	-0.17	5	3.63	-2.46	0.46	0.53	0.69	0.41	0.8	0.42	0.81	0.7	**60.241**	**46.075**	**0.461**
7B	7Pe	10048	40	400.5	30	13	13	17	75	2	67	2	13	1.5	1.5	40	15.3	-0.3767	13	-3.18	17	2.41	-2.48	0.67	0.96	0.54	0.71	0.61	1.42	0.43	0.7	**75.448**	**57.078**	**0.571**

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Attachment 2: PHI Scores

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Table 2-2: Coastal Plain Physiographic Province FWOP PHI Metrics and Scores																												
Stream		Metric Values Input										Transform Bank Severity		Prepare Metric Values						Scale Metric Values						Final Score	Normalize Final Score	Rescaled Final Score
								Left Bank Stability		Right Bank Stability																		
Reach Code	Habitat Code	Watershed Area (acres)	Remoteness (meters)	%Shading	Epibenthic Substrate Score	Instream Habitat Score	Total No. Instream Woody Debris and Rootwads	Erosion Extent (meters)	Severity	Erosion Extent (meters)	Severity	Left	Right	REMOTE	TSHADING	RESEPISUB	RESINSTRHAB	RESWOOD	TBANKSTAN	REMOTE	TSHADING	RESEPISUB	RESINSTRHAB	RESWOOD	TBANKSTAN	Coastal Plain PHI	Normalized Coastal Plain PHI	Rescaled Coastla Plain PHI
1A	1Cc	1209.6	211.8	15.00	7	7	3	75	2	75	2	1.5	1.5	11.28	0.398	-4.483	-6.64	-11.9	2.236	0.608	0.153	0.506	0.469	0.502	0.5	**45.640**	**38.066**	**0.381**
1B	1Cm	1235.2	1908.8	80.00	13	13	5	75	2	75	3	1.5	2	32.64	1.107	1.494	-0.68	-10	1.581	1.758	0.787	0.854	0.8	0.559	0.354	**85.171**	**65.196**	**0.652**
3A	3Cce	22272	249.0	35.00	12	11	28	58	2	47	2	1.5	1.5	12.18	0.633	-2.750	-8.02	1.928	3.082	0.656	0.363	0.607	0.393	0.912	0.689	**60.341**	**48.155**	**0.482**
3B	3Cm	22592	143.3	5.00	10	10	32	71	3	46	1	2	1	9.391	0.226	-4.766	-9.04	5.873	2.733	0.506	0	0.49	0.336	1.029	0.611	**49.512**	**40.723**	**0.407**
3C	*3Ccp*	22720	114.8	15.00	10	15	5	75	2	75	2	1.5	1.5	8.468	0.398	-4.772	-4.05	-21.1	2.236	0.456	0.153	0.49	0.613	0.229	0.5	**40.681**	**34.662**	**0.347**
3D	*3Ccp*	22720	63.3	15.00	10	15	5	75	2	75	2	1.5	1.5	6.445	0.398	-4.772	-4.05	-21.1	2.236	0.347	0.153	0.49	0.613	0.229	0.5	**38.865**	**33.416**	**0.334**
3E	*3Cce*	22272	26.1	35.00	12	11	28	58	2	47	2	1.5	1.5	4.359	0.633	-2.750	-8.02	1.928	3.082	0.235	0.363	0.607	0.393	0.912	0.689	**53.319**	**43.336**	**0.433**
3F	*3Ccp*	22720	15.5	15.00	10	15	5	75	2	75	2	1.5	1.5	3.498	0.398	-4.772	-4.05	-21.1	2.236	0.188	0.153	0.49	0.613	0.229	0.5	**36.220**	**31.601**	**0.316**
3G	*3Ccst*	31296	66.4	5.00	3	3	5	21	1	0	0	1	0	6.588	0.226	-12.131	-16.6	-22.4	4.313	0.355	0	0.062	-0.09	0.193	0.964	**24.797**	**23.761**	**0.238**
3H	None		71.5																									
3I	3Ccp	22720	419.0	15.00	10	15	5	75	2	75	2	1.5	1.5	15.62	0.398	-4.772	-4.05	-21.1	2.236	0.841	0.153	0.49	0.613	0.229	0.5	**47.098**	**39.067**	**0.391**
3J	3Ccst	31296	139.0	5.00	3	3	5	21	1	0	0	1	0	9.258	0.226	-12.131	-16.6	-22.4	4.313	0.499	0	0.062	-0.09	0.193	0.964	**27.194**	**25.406**	**0.254**
3K	9Cs	7040	47.7	5.00	15	20	2	3	1	0	0	1	0	5.675	0.226	1.542	3.107	-19.7	4.45	0.306	0	0.856	1.01	0.273	0.995	**57.329**	**46.088**	**0.461**
3L	3Ccst	31296	103.4	5.00	3	3	5	21	1	0	0	1	0	8.07	0.226	-12.131	-16.6	-22.4	4.313	0.435	0	0.062	-0.09	0.193	0.964	**26.127**	**24.674**	**0.247**
3M	9Cs	7040	61.9	5.00	15	20	2	3	1	0	0	1	0	6.381	0.226	1.542	3.107	-19.7	4.45	0.344	0	0.856	1.01	0.273	0.995	**57.962**	**46.523**	**0.465**
3N	3Ccst	31296	52.1	5.00	3	3	5	21	1	0	0	1	0	5.908	0.226	-12.131	-16.6	-22.4	4.313	0.318	0	0.062	-0.09	0.193	0.964	**24.187**	**23.343**	**0.233**
3O	*3Ccu*	31488	29.0	15.00	3	8	3	50	1	12	1	1	1	4.563	0.398	-12.138	-11.7	-24.4	3.983	0.246	0.153	0.062	0.191	0.133	0.891	**27.924**	**25.907**	**0.259**
3P	3Ccu	31488	232.0	15.00	3	8	3	50	1	12	1	1	1	11.78	0.398	-12.138	-11.7	-24.4	3.983	0.634	0.153	0.062	0.191	0.133	0.891	**34.401**	**30.353**	**0.304**
3Q	3Ccpg	31616	386.4	25.00	6	8	14	75	2	75	1	1.5	1	15.02	0.524	-9.143	-11.7	-13.4	2.739	0.809	0.266	0.236	0.19	0.458	0.612	**42.856**	**36.155**	**0.362**
5A	5Ccst	19584	53.7	5.00	6	6	0	35	2	0	0	1.5	0	5.985	0.226	-8.605	-12.8	-25.6	4.062	0.322	0	0.267	0.128	0.098	0.908	**28.728**	**26.459**	**0.265**
5B	5Ccgu	19904	74.5	5.00	8	6	7	75	3	33	2	2	1.5	6.941	0.226	-6.624	-12.8	-18.6	2.588	0.374	0	0.382	0.127	0.304	0.579	**29.407**	**26.925**	**0.269**
5C	5Ccehu	19648	109.3	10.00	14	8	5	75	3	5	1	2	1	8.279	0.322	-0.609	-10.8	-20.6	3.109	0.446	0.085	0.731	0.239	0.246	0.695	**40.714**	**34.685**	**0.347**
5D	5Cw	19904	39.1	10.00	12	12	29	75	2	75	1	1.5	1	5.2	0.322	-2.624	-6.81	3.358	2.739	0.28	0.085	0.614	0.46	0.954	0.612	**50.105**	**41.130**	**0.411**
5E	5Ccgu	19904	120.8	5.00	8	6	7	75	3	33	2	2	1.5	8.67	0.226	-6.624	-12.8	-18.6	2.588	0.467	0	0.382	0.127	0.304	0.579	**30.958**	**27.990**	**0.280**
5F	5Ccehu	19648	162.6	10.00	14	8	5	75	3	5	1	2	1	9.963	0.322	-0.609	-10.8	-20.6	3.109	0.536	0.085	0.731	0.239	0.246	0.695	**42.225**	**35.722**	**0.357**
5G	5Ccst	19584	49.9	5.00	6	6	0	35	2	0	0	1.5	0	5.794	0.226	-8.605	-12.8	-25.6	4.062	0.312	0	0.267	0.128	0.098	0.908	**28.557**	**26.342**	**0.263**
5H	5Ccehu	19648	117.7	10.00	14	8	5	75	3	5	1	2	1	8.569	0.322	-0.609	-10.8	-20.6	3.109	0.461	0.085	0.731	0.239	0.246	0.695	**40.974**	**34.864**	**0.349**
5I	5Ccgu	19904	22.0	5.00	8	6	7	75	3	33	2	2	1.5	4.054	0.226	-6.624	-12.8	-18.6	2.588	0.218	0	0.382	0.127	0.304	0.579	**26.816**	**25.147**	**0.251**
5J	5Ccehu	19648	83.1	10.00	14	8	5	75	3	5	1	2	1	7.297	0.322	-0.609	-10.8	-20.6	3.109	0.393	0.085	0.731	0.239	0.246	0.695	**39.833**	**34.080**	**0.341**
5K	5Ccle	19840	516.4	15.00	6	3	18	75	1	75	2	1	1.5	17.27	0.398	-8.620	-15.8	-7.63	2.739	0.93	0.153	0.266	-0.04	0.629	0.612	**42.529**	**35.931**	**0.359**
5L	5Cw	19904	151.5	10.00	12	12	29	75	2	75	1	1.5	1	9.639	0.322	-2.624	-6.81	3.358	2.739	0.519	0.085	0.614	0.46	0.954	0.612	**54.088**	**43.864**	**0.439**

Table 2-2: Coastal Plain Physiographic Province FWOP PHI Metrics and Scores

Stream		Metric Values Input						Left Bank Stability		Right Bank Stability		Transform Bank Severity		Prepare Metric Values						Scale Metric Values						Final Score	Normalize Final Score	Rescaled Final Score
Reach Code	Habitat Code	Watershed Area (acres)	Remoteness (meters)	%Shading	Epibenthic Substrate Score	Instream Habitat Score	Total No. Instream Woody Debris and Rootwads	Erosion Extent (meters)	Severity	Erosion Extent (meters)	Severity	Left	Right	REMOTE	TSHADING	RESEPISUB	RESINSTRHAB	RESWOOD	TBANKSTAN	REMOTE	TSHADING	RESEPISUB	RESINSTRHAB	RESWOOD	TBANKSTAN	Coastal Plain PHI	Normalized Coastal Plain PHI	Rescaled Coastla Plain PHI
5M	5Ccst	19584	44.4	5.00	6	6	0	35	2	0	0	1.5	0	5.5	0.226	-8.605	-12.8	-25.6	4.062	0.296	0	0.267	0.128	0.098	0.908	**28.293**	**26.161**	**0.262**
5N	5Ccst	19584	38.4	5.00	6	6	0	35	2	0	0	1.5	0	5.156	0.226	-8.605	-12.8	-25.6	4.062	0.278	0	0.267	0.128	0.098	0.908	**27.984**	**25.949**	**0.259**
5O	9Cs	7040	28.5	5.00	15	20	2	3	1	0	0	1	0	4.531	0.226	1.542	3.107	-19.7	4.45	0.244	0	0.856	1.01	0.273	0.995	**56.303**	**45.384**	**0.454**
5P	5Ccgu	19904	152.9	5.00	8	6	7	75	3	33	2	2	1.5	9.679	0.226	-6.624	-12.8	-18.6	2.588	0.521	0	0.382	0.127	0.304	0.579	**31.864**	**28.612**	**0.286**
5Q	5Ccgu	19904	41.2	5.00	8	6	7	75	3	33	2	2	1.5	5.32	0.226	-6.624	-12.8	-18.6	2.588	0.286	0	0.382	0.127	0.304	0.579	**27.952**	**25.926**	**0.259**
5R	5Ccst	19584	41.8	5.00	6	6	0	35	2	0	0	1.5	0	5.353	0.226	-8.605	-12.8	-25.6	4.062	0.288	0	0.267	0.128	0.098	0.908	**28.162**	**26.070**	**0.261**
5S	9Cs	7040	71.7	5.00	15	20	2	3	1	0	0	1	0	6.823	0.226	1.542	3.107	-19.7	4.45	0.367	0	0.856	1.01	0.273	0.995	**58.359**	**46.795**	**0.468**
5T	5Ccgu	19904	47.3	5.00	8	6	7	75	3	33	2	2	1.5	5.654	0.226	-6.624	-12.8	-18.6	2.588	0.304	0	0.382	0.127	0.304	0.579	**28.251**	**26.132**	**0.261**
7C	7Cc	10432	504.0	0.00	8	8	4	20	2	45	2	1.5	1.5	17.07	0	-5.899	-9.62	-19.2	3.674	0.919	0	0.424	0.304	0.288	0.822	**42.582**	**35.967**	**0.360**
7D	None		89.9																									
7E	7Cc	10432	682.3	0.00	8	8	4	20	2	45	2	1.5	1.5	19.76	0	-5.899	-9.62	-19.2	3.674	1.064	0	0.424	0.304	0.288	0.822	**44.998**	**37.625**	**0.376**
9A	9Cg	7168	173.2	15.00	6	8	6	55	2	75	2	1.5	1.5	10.26	0.398	-7.478	-8.93	-15.7	2.646	0.553	0.153	0.332	0.342	0.39	0.592	**39.360**	**33.756**	**0.338**
9B	9Cs	7040	74.2	5.00	15	20	2	3	1	0	0	1	0	6.928	0.226	1.542	3.107	-19.7	4.45	0.373	0	0.856	1.01	0.273	0.995	**58.453**	**46.860**	**0.469**
9C	9Cg	7168	435.8	15.00	6	8	6	55	2	75	2	1.5	1.5	15.92	0.398	-7.478	-8.93	-15.7	2.646	0.857	0.153	0.332	0.342	0.39	0.592	**44.436**	**37.240**	**0.372**
10A	10Cs	1241.6	112.7	35.00	8	10	2	16	1	5	1	1	1	8.396	0.633	-3.512	-3.69	-13	4.313	0.452	0.363	0.563	0.633	0.47	0.964	**57.418**	**46.149**	**0.461**
10B	10Cg	1254.4	134.5	15.00	10	12	15	36	2	13	1	1.5	1	9.117	0.398	-1.524	-1.71	-0.06	3.941	0.491	0.153	0.678	0.743	0.853	0.881	**63.326**	**50.204**	**0.502**
10C	10Ce	1286.4	243.4	5.00	8	8	10	12	1	36	2	1	1.5	12.05	0.226	-3.552	-5.76	-5.16	3.95	0.649	0	0.56	0.518	0.702	0.883	**55.209**	**44.633**	**0.446**
10D	10Cg	1254.4	148.2	15.00	10	12	15	36	2	13	1	1.5	1	9.537	0.398	-1.524	-1.71	-0.06	3.941	0.514	0.153	0.678	0.743	0.853	0.881	**63.703**	**50.463**	**0.505**
11A	11Ccp	17536	1820.2	10.00	5	5	2	35	1	75	1	1	1	31.89	0.322	-9.482	-13.6	-23.2	3.559	1.717	0.085	0.216	0.084	0.17	0.796	**51.144**	**41.843**	**0.418**
11B	11Ccp	17536	269.9	10.00	5	5	2	35	1	75	1	1	1	12.66	0.322	-9.482	-13.6	-23.2	3.559	0.682	0.085	0.216	0.084	0.17	0.796	**33.884**	**29.998**	**0.300**
11C	11Ccp	17536	107.1	10.00	5	5	2	35	1	75	1	1	1	8.202	0.322	-9.482	-13.6	-23.2	3.559	0.442	0.085	0.216	0.084	0.17	0.796	**29.885**	**27.253**	**0.273**
11D	11Ccp	17536	30.0	10.00	5	5	2	35	1	75	1	1	1	4.627	0.322	-9.482	-13.6	-23.2	3.559	0.249	0.085	0.216	0.084	0.17	0.796	**26.677**	**25.052**	**0.251**
11E	None	#N/A	98.9																									
11F	None	#N/A	34.0																									
11G	11Ccg	18176	42.4	5.00	4	6	10	0	0	75	2	0	1.5	5.389	0.226	-10.522	-12.6	-15.3	3.536	0.29	0	0.156	0.136	0.403	0.791	**29.574**	**27.040**	**0.270**
11H	11Ccg	18176	75.1	5.00	4	6	10	0	0	75	2	0	1.5	6.969	0.226	-10.522	-12.6	-15.3	3.536	0.375	0	0.156	0.136	0.403	0.791	**30.992**	**28.013**	**0.280**
11I	11Ccg	18176	21.5	5.00	4	6	10	0	0	75	2	0	1.5	4.01	0.226	-10.522	-12.6	-15.3	3.536	0.216	0	0.156	0.136	0.403	0.791	**28.337**	**26.191**	**0.262**
11J	11Cc	18176	53.6	5.00	7	5	6	75	1	75	1	1	1	5.98	0.226	-7.522	-13.6	-19.3	3.162	0.322	0	0.33	0.081	0.284	0.707	**28.722**	**26.455**	**0.265**
11K	11Ccg	18176	17.5	5.00	4	6	10	0	0	75	2	0	1.5	3.685	0.226	-10.522	-12.6	-15.3	3.536	0.198	0	0.156	0.136	0.403	0.791	**28.046**	**25.991**	**0.260**
11L	11Cc	18176	99.1	5.00	7	5	6	75	1	75	1	1	1	7.912	0.226	-7.522	-13.6	-19.3	3.162	0.426	0	0.33	0.081	0.284	0.707	**30.456**	**27.645**	**0.276**
11M	11Ccg	18176	74.7	5.00	4	6	10	0	0	75	2	0	1.5	6.95	0.226	-10.522	-12.6	-15.3	3.536	0.374	0	0.156	0.136	0.403	0.791	**30.976**	**28.002**	**0.280**

Table 2-2: Coastal Plain Physiographic Province FWOP PHI Metrics and Scores

Stream		Metric Values Input										Transform Bank Severity		Prepare Metric Values						Scale Metric Values						Final Score	Normalize Final Score	Rescaled Final Score
								Left Bank Stability		Right Bank Stability																		
Reach Code	Habitat Code	Watershed Area (acres)	Remoteness (meters)	%Shading	Epibenthic Substrate Score	Instream Habitat Score	Total No. Instream Woody Debris and Rootwads	Erosion Extent (meters)	Severity	Erosion Extent (meters)	Severity	Left	Right	REMOTE	TSHADING	RESEPISUB	RESINSTRHAB	RESWOOD	TBANKSTAN	REMOTE	TSHADING	RESEPISUB	RESINSTRHAB	RESWOOD	TBANKSTAN	Coastal Plain PHI	Normalized Coastal Plain PHI	Rescaled Coastla Plain PHI
11N	11Cc	18176	120.0	5.00	7	5	6	75	1	75	1	1	1	8.645	0.226	-7.522	-13.6	-19.3	3.162	0.466	0	0.33	0.081	0.284	0.707	**31.114**	**28.097**	**0.281**
11O	11Ccg	18176	62.3	5.00	4	6	10	0	0	75	2	0	1.5	6.398	0.226	-10.522	-12.6	-15.3	3.536	0.345	0	0.156	0.136	0.403	0.791	**30.481**	**27.662**	**0.277**
11P	11Ccg	18176	96.4	5.00	4	6	10	0	0	75	2	0	1.5	7.811	0.226	-10.522	-12.6	-15.3	3.536	0.421	0	0.156	0.136	0.403	0.791	**31.748**	**28.532**	**0.285**
11Q	11Cc	18176	167.4	5.00	7	5	6	75	1	75	1	1	1	10.1	0.226	-7.522	-13.6	-19.3	3.162	0.544	0	0.33	0.081	0.284	0.707	**32.419**	**28.992**	**0.290**
12A	12Cc	6720	273.2	5.00	7	5	2	4	1	43	1	1	1	12.73	0.226	-6.406	-11.8	-19.5	4.107	0.686	0	0.395	0.182	0.279	0.918	**40.984**	**34.870**	**0.349**
12B	12Cm	6720	601.6	5.00	13	7	8	65	2	15	1	1.5	1	18.59	0.226	-0.406	-9.81	-13.5	3.536	1.001	0	0.743	0.293	0.456	0.791	**54.734**	**44.307**	**0.443**
12C	12Cc	6720	506.0	5.00	7	5	2	4	1	43	1	1	1	17.1	0.226	-6.406	-11.8	-19.5	4.107	0.921	0	0.395	0.182	0.279	0.918	**44.908**	**37.564**	**0.376**
13A	13Cmhe	21312	688.4	10.00	5	8	14	75	3	75	1	2	1	19.85	0.322	-9.700	-10.9	-11.9	2.236	1.069	0.085	0.203	0.231	0.503	0.5	**43.185**	**36.381**	**0.364**
13B	13Cml	21504	459.0	10.00	10	8	31	75	3	75	3	2	2	16.32	0.322	-4.710	-11	5.062	0	0.879	0.085	0.493	0.23	1.005	0	**44.866**	**37.535**	**0.375**
13C	13Cct	52.736	241.3	75.00	8	8	17	75	2	75	2	1.5	1.5	12	1.047	0.030	0.135	14.06	2.236	0.646	0.733	0.769	0.845	1.271	0.5	**79.402**	**61.237**	**0.612**
13D	13Ccsr	21760	257.1	5.00	17	14	8	75	1	75	1	1	1	12.37	0.226	2.276	-4.97	-18	3.162	0.666	0	0.899	0.561	0.323	0.707	**52.605**	**42.846**	**0.428**
13E	13Cc	21760	395.2	10.00	10	7	17	75	2	75	2	1.5	1.5	15.19	0.322	-4.724	-12	-8.98	2.236	0.818	0.085	0.492	0.173	0.589	0.5	**44.301**	**37.147**	**0.371**
13F	13Ccsr	21760	149.2	5.00	17	14	8	75	1	75	1	1	1	9.567	0.226	2.276	-4.97	-18	3.162	0.515	0	0.899	0.561	0.323	0.707	**50.091**	**41.121**	**0.411**
13G	13Ccsr	21760	153.9	5.00	17	14	8	75	1	75	1	1	1	9.709	0.226	2.276	-4.97	-18	3.162	0.523	0	0.899	0.561	0.323	0.707	**50.218**	**41.208**	**0.412**
15A	15Ccor	192	100.0	10.00	12	12	19	75	1	75	1	1	1	7.945	0.322	2.581	1.751	11.12	3.162	0.428	0.085	0.917	0.935	1.184	0.707	**70.931**	**55.423**	**0.554**
15B	15Ccgt	115.2	354.4	25.00	7	6	2	75	1	75	1	1	1	14.41	0.524	-1.846	-3.31	-3.93	3.162	0.776	0.266	0.66	0.654	0.739	0.707	**63.358**	**50.226**	**0.502**
15C	None		66.9																									
15D	15Ccor	192	229.8	10.00	12	12	19	75	1	75	1	1	1	11.73	0.322	2.581	1.751	11.12	3.162	0.631	0.085	0.917	0.935	1.184	0.707	**74.325**	**57.752**	**0.578**
15E	15Cce	44288	26.4	15.00	8	8	5	75	1	75	1	1	1	4.378	0.398	-7.520	-12.3	-23.7	3.162	0.236	0.153	0.33	0.156	0.154	0.707	**28.929**	**26.597**	**0.266**
15F	15Ccp	684.8	225.8	10.00	10	10	18	43	1	28	3	1	2	11.63	0.322	-0.845	-2.59	5.253	3.661	0.626	0.085	0.718	0.694	1.01	0.819	**65.866**	**51.947**	**0.519**
15G	15Cce	44288	180.8	15.00	8	8	5	75	1	75	1	1	1	10.47	0.398	-7.520	-12.3	-23.7	3.162	0.564	0.153	0.33	0.156	0.154	0.707	**34.398**	**30.350**	**0.304**
15H	15TCm	486.4	498.2	35.00	10	12	9	75	2	54	2	1.5	1.5	16.98	0.633	-0.461	0.036	-2.44	2.665	0.914	0.363	0.74	0.84	0.783	0.596	**70.598**	**55.195**	**0.552**

Table 2-3: Piedmont Physiographic Province FWP PHI Metrics and Scores for design alternative 1

Stream		Metric Values Input												Transform Bank Severity		Prepare Metric Values								Scale Metric Values								Final Score	Normalize Final Score	Rescaled Final Score
									Left Bank Stability		Right Bank Stability																							
Reach No.	Habitat Code	Watershed Area (acres)	% Embeddedness	Remoteness (meters)	%Shading	Epibenthic Substrate Score	Instream Habitat Score	Total No. Instream Woody Debris and Rootwads	Erosion Extent (meters)	Severity	Erosion Extent (meters)	Severity	Riffle Quality Score	Left	Right	EMBEDDED	REMOTE	RESTSHADING	EPISUB	RESINSTRHAB	WOOD	TBANKSTANB	RESRIFFQUAL	EMBEDDED	REMOTE	RESTSHADING	EPISUB	RESINSTRHAB	WOOD	TBANKSTANB	RESRIFFQUAL	Piedmont PHI	Normalized Piedmont PHI	Rescaled Piedmont PHI
7A	7Pb	9856	20	114.5	50	14	16	11	10	1	10	1	15	1	1	20	8.457	-0.17	14	-0.17	11	4.32	-0.46	0.889	0.529	0.69	0.765	0.803	0.917	1.024	0.804	**80.242**	**60.546**	**0.605**
7B	7Pe	10048	20	400.5	30	14	15	17	10	1	10	1	15	1	1	20	15.28	-0.38	14	-1.18	17	4.32	-0.48	0.889	0.955	0.545	0.765	0.738	1.417	1.024	0.803	**89.193**	**67.022**	**0.670**

Table 2-4: Coastal Plain Physiographic Province FWP PHI Metrics and Scores for design alternative 1																												
Stream		Metric Values Input										Transform Bank Severity		Prepare Metric Values						Scale Metric Values						Final Score	Normalize Final Score	Rescaled Final Score
								Left Bank Stability		Right Bank Stability																		
Reach Code	Habiat Code	Watershed Area (acres)	Remoteness (meters)	%Shading	Epibenthic Substrate Score	Instream Habitat Score	Total No. Instream Woody Debris and Rootwads	Erosion Extent (meters)	Severity	Erosion Extent (meters)	Severity	Left	Right	REMOTE	TSHADING	RESEPISUB	RESINSTRHAB	RESWOOD	TBANKSTAN	REMOTE	TSHADING	RESEPISUB	RESINSTRHAB	RESWOOD	TBANKSTAN	Coastal Plain PHI	Normalized Coastal Plain PHI	Rescaled Coastla Plain PHI
1A	1Cc	1210	211.8	15.00	15	15	11	10	1	10	1	1	1	11.28	0.398	3.517	1.356	-3.92	4.32	0.608	0.153	0.971	0.913	0.739	0.966	**72.497**	**56.498**	**0.565**
1B	1Cm	1235	1908.8	80.00	15	15	11	10	1	10	1	1	1	32.64	1.107	3.494	1.317	-4	4.32	1.758	0.787	0.97	0.911	0.737	0.966	**102.124**	**76.831**	**0.768**
3A	3Cce	22272	249.0	35.00	15	15	28	10	1	10	1	1	1	12.18	0.633	0.25	-4.02	1.928	4.32	0.656	0.363	0.781	0.615	0.912	0.966	**71.559**	**55.854**	**0.559**
3B	3Cm	22592	143.3	5.00	15	15	44	10	1	10	1	1	1	9.391	0.226	0.234	-4.04	17.87	4.32	0.506	-0	0.78	0.613	1.384	0.966	**70.812**	**55.341**	**0.553**
3C	*3Ccp*	22720	114.8	15.00	15	15	11	10	1	10	1	1	1	8.468	0.398	0.228	-4.05	-15.1	4.32	0.456	0.153	0.78	0.613	0.407	0.966	**56.249**	**45.347**	**0.453**
3D	*3Ccp*	22720	63.3	15.00	15	15	11	10	1	10	1	1	1	6.445	0.398	0.228	-4.05	-15.1	4.32	0.347	0.153	0.78	0.613	0.407	0.966	**54.433**	**44.101**	**0.441**
3E	*3Cce*	22272	26.1	35.00	15	15	28	10	1	10	1	1	1	4.359	0.633	0.25	-4.02	1.928	4.32	0.235	0.363	0.781	0.615	0.912	0.966	**64.538**	**51.036**	**0.510**
3F	*3Ccp*	22720	15.5	15.00	15	15	11	10	1	10	1	1	1	3.498	0.398	0.228	-4.05	-15.1	4.32	0.188	0.153	0.78	0.613	0.407	0.966	**51.788**	**42.285**	**0.423**
3G	*3Ccst*	31296	66.4	5.00	15	15	11	10	1	0	0	1	0	6.588	0.226	-0.13	-4.65	-16.4	4.397	0.355	-0	0.759	0.58	0.371	0.983	**50.786**	**41.597**	**0.416**
3H	None																											
3I	3Ccp	22720	419.0	15.00	15	15	11	10	1	10	1	1	1	15.62	0.398	0.228	-4.05	-15.1	4.32	0.841	0.153	0.78	0.613	0.407	0.966	**62.666**	**49.751**	**0.498**
3J	3Ccst	31296	139.0	5.00	15	15	11	10	1	0	0	1	0	9.258	0.226	-0.13	-4.65	-16.4	4.397	0.499	-0	0.759	0.58	0.371	0.983	**53.182**	**43.242**	**0.432**
3K	9Cs	7040	47.7	5.00	15	20	11	3	1	0	0	1	0	5.675	0.226	1.542	3.107	-10.7	4.45	0.306	-0	0.856	1.01	0.54	0.995	**61.767**	**49.134**	**0.491**
3L	3Ccst	31296	103.4	5.00	15	15	11	10	1	0	0	1	0	8.07	0.226	-0.13	-4.65	-16.4	4.397	0.435	-0	0.759	0.58	0.371	0.983	**52.115**	**42.510**	**0.425**
3M	9Cs	7040	61.9	5.00	15	20	11	3	1	0	0	1	0	6.381	0.226	1.542	3.107	-10.7	4.45	0.344	-0	0.856	1.01	0.54	0.995	**62.400**	**49.568**	**0.496**
3N	3Ccst	31296	52.1	5.00	15	15	11	10	1	0	0	1	0	5.908	0.226	-0.13	-4.65	-16.4	4.397	0.318	-0	0.759	0.58	0.371	0.983	**50.175**	**41.178**	**0.412**
3O	*3Ccu*	31488	29.0	15.00	15	15	11	10	1	10	1	1	1	4.563	0.398	-0.14	-4.66	-16.4	4.32	0.246	0.153	0.759	0.579	0.37	0.966	**51.217**	**41.893**	**0.419**
3P	3Ccu	31488	232.0	15.00	15	15	11	10	1	10	1	1	1	11.78	0.398	-0.14	-4.66	-16.4	4.32	0.634	0.153	0.759	0.579	0.37	0.966	**57.695**	**46.339**	**0.463**
3Q	3Ccpg	31616	386.4	25.00	15	15	14	10	1	10	1	1	1	15.02	0.524	-0.14	-4.66	-13.4	4.32	0.809	0.266	0.759	0.579	0.458	0.966	**63.939**	**50.624**	**0.506**
5A	5Ccst	19584	53.7	5.00	15	15	11	10	1	0	0	1	0	5.985	0.226	0.395	-3.78	-14.6	4.397	0.322	-0	0.79	0.628	0.424	0.983	**52.437**	**42.731**	**0.427**
5B	5Ccgu	19904	74.5	5.00	15	15	11	10	1	10	1	1	1	6.941	0.226	0.376	-3.81	-14.6	4.32	0.374	-0	0.789	0.626	0.422	0.966	**52.935**	**43.072**	**0.431**
5C	5Ccehu	19648	109.3	10.00	15	15	11	10	1	5	1	1	1	8.279	0.322	0.391	-3.79	-14.6	4.359	0.446	0.085	0.79	0.627	0.423	0.975	**55.771**	**45.019**	**0.450**
5D	5Cw	19904	39.1	10.00	15	15	29	10	1	10	1	1	1	5.2	0.322	0.376	-3.81	3.358	4.32	0.28	0.085	0.789	0.626	0.954	0.966	**61.680**	**49.074**	**0.491**
5E	5Ccgu	19904	120.8	5.00	15	15	11	10	1	10	1	1	1	8.67	0.226	0.376	-3.81	-14.6	4.32	0.467	-0	0.789	0.626	0.422	0.966	**54.486**	**44.137**	**0.441**
5F	5Ccehu	19648	162.6	10.00	15	15	11	10	1	5	1	1	1	9.963	0.322	0.391	-3.79	-14.6	4.359	0.536	0.085	0.79	0.627	0.423	0.975	**57.283**	**46.056**	**0.461**
5G	5Ccst	19584	49.9	5.00	15	15	11	10	1	0	0	1	0	5.794	0.226	0.395	-3.78	-14.6	4.397	0.312	-0	0.79	0.628	0.424	0.983	**52.266**	**42.613**	**0.426**
5H	5Ccehu	19648	117.7	10.00	15	15	11	10	1	5	1	1	1	8.569	0.322	0.391	-3.79	-14.6	4.359	0.461	0.085	0.79	0.627	0.423	0.975	**56.032**	**45.198**	**0.452**
5I	5Ccgu	19904	22.0	5.00	15	15	11	10	1	10	1	1	1	4.054	0.226	0.376	-3.81	-14.6	4.32	0.218	-0	0.789	0.626	0.422	0.966	**50.344**	**41.294**	**0.413**
5J	5Ccehu	19648	83.1	10.00	15	15	11	10	1	5	1	1	1	7.297	0.322	0.391	-3.79	-14.6	4.359	0.393	0.085	0.79	0.627	0.423	0.975	**54.890**	**44.414**	**0.444**
5K	5Ccle	19840	516.4	15.00	15	15	18	10	1	10	1	1	1	17.27	0.398	0.38	-3.8	-7.63	4.32	0.93	0.153	0.789	0.626	0.629	0.966	**68.235**	**53.573**	**0.536**
5L	5Cw	19904	151.5	10.00	15	15	29	10	1	10	1	1	1	9.639	0.322	0.376	-3.81	3.358	4.32	0.519	0.085	0.789	0.626	0.954	0.966	**65.663**	**51.808**	**0.518**
5M	5Ccst	19584	44.4	5.00	15	15	11	10	1	0	0	1	0	5.5	0.226	0.395	-3.78	-14.6	4.397	0.296	-0	0.79	0.628	0.424	0.983	**52.002**	**42.432**	**0.424**
5N	5Ccst	19584	38.4	5.00	15	15	11	10	1	0	0	1	0	5.156	0.226	0.395	-3.78	-14.6	4.397	0.278	-0	0.79	0.628	0.424	0.983	**51.693**	**42.220**	**0.422**
5O	9Cs	7040	28.5	5.00	15	20	11	3	1	0	0	1	0	4.531	0.226	1.542	3.107	-10.7	4.45	0.244	-0	0.856	1.01	0.54	0.995	**60.740**	**48.429**	**0.484**
5P	5Ccgu	19904	152.9	5.00	15	15	11	10	1	10	1	1	1	9.679	0.226	0.376	-3.81	-14.6	4.32	0.521	-0	0.789	0.626	0.422	0.966	**55.392**	**44.759**	**0.448**
5Q	5Ccgu	19904	41.2	5.00	15	15	11	10	1	10	1	1	1	5.32	0.226	0.376	-3.81	-14.6	4.32	0.286	-0	0.789	0.626	0.422	0.966	**51.480**	**42.074**	**0.421**
5R	5Ccst	19584	41.8	5.00	15	15	11	10	1	0	0	1	0	5.353	0.226	0.395	-3.78	-14.6	4.397	0.288	-0	0.79	0.628	0.424	0.983	**51.871**	**42.342**	**0.423**
5S	9Cs	7040	71.7	5.00	15	20	11	3	1	0	0	1	0	6.823	0.226	1.542	3.107	-10.7	4.45	0.367	-0	0.856	1.01	0.54	0.995	**62.797**	**49.840**	**0.498**

Table 2-4: Coastal Plain Physiographic Province FWP PHI Metrics and Scores for design alternative 1

Stream		Metric Values Input										Transform Bank Severity		Prepare Metric Values						Scale Metric Values						Final Score	Normalize Final Score	Rescaled Final Score
								Left Bank Stability		Right Bank Stability																		
Reach Code	Habiat Code	Watershed Area (acres)	Remoteness (meters)	%Shading	Epibenthic Substrate Score	Instream Habitat Score	Total No. Instream Woody Debris and Rootwads	Erosion Extent (meters)	Severity	Erosion Extent (meters)	Severity	Left	Right	REMOTE	TSHADING	RESEPISUB	RESINSTRHAB	RESWOOD	TBANKSTAN	REMOTE	TSHADING	RESEPISUB	RESINSTRHAB	RESWOOD	TBANKSTAN	Coastal Plain PHI	Normalized Coastal Plain PHI	Rescaled Coastla Plain PHI
5T	5Ccgu	19904	47.3	5.00	15	15	11	10	1	10	1	1	1	5.654	0.226	0.376	-3.81	-14.6	4.32	0.304	-0	0.789	0.626	0.422	0.966	**51.779**	**42.279**	**0.423**
7C	7Cc	10432	504.0	0.00	14	14	11	10	1	10	1	1	1	17.07	0	0.101	-3.62	-12.2	4.32	0.919	-0.2	0.773	0.637	0.495	0.966	**59.800**	**47.784**	**0.478**
7D	None																											
7E	7Cc	10432	682.3	0.00	14	14	11	10	1	10	1	1	1	19.76	0	0.101	-3.62	-12.2	4.32	1.064	-0.2	0.773	0.637	0.495	0.966	**62.216**	**49.442**	**0.494**
9A	9Cg	7168	173.2	15.00	14	14	11	10	1	10	1	1	1	10.26	0.398	0.522	-2.93	-10.7	4.32	0.553	0.153	0.797	0.675	0.538	0.966	**61.362**	**48.856**	**0.489**
9B	9Cs	7040	74.2	5.00	15	20	11	3	1	0	0	1	0	6.928	0.226	1.542	3.107	-10.7	4.45	0.373	-0	0.856	1.01	0.54	0.995	**62.891**	**49.905**	**0.499**
9C	9Cg	7168	435.8	15.00	14	14	11	10	1	10	1	1	1	15.92	0.398	0.522	-2.93	-10.7	4.32	0.857	0.153	0.797	0.675	0.538	0.966	**66.437**	**52.339**	**0.523**
10A	10Cs	1242	112.7	35.00	15	15	11	10	1	5	1	1	1	8.396	0.633	3.488	1.308	-4.02	4.359	0.452	0.363	0.969	0.91	0.736	0.975	**73.429**	**57.138**	**0.571**
10B	10Cg	1254	134.5	15.00	15	15	15	10	1	10	1	1	1	9.117	0.398	3.476	1.289	-0.06	4.32	0.491	0.153	0.969	0.909	0.853	0.966	**72.355**	**56.401**	**0.564**
10C	10Ce	1286	243.4	5.00	15	15	11	10	1	10	1	1	1	12.05	0.226	3.448	1.242	-4.16	4.32	0.649	-0	0.967	0.906	0.732	0.966	**70.335**	**55.014**	**0.550**
10D	10Cg	1254	148.2	15.00	15	15	15	10	1	10	1	1	1	9.537	0.398	3.476	1.289	-0.06	4.32	0.514	0.153	0.969	0.909	0.853	0.966	**72.732**	**56.659**	**0.567**
11A	11Ccp	17536	1820.2	10.00	15	15	11	10	1	10	1	1	1	31.89	0.322	0.518	-3.58	-14.2	4.32	1.717	0.085	0.797	0.639	0.436	0.966	**77.349**	**59.828**	**0.598**
11B	11Ccp	17536	269.9	10.00	15	15	11	10	1	10	1	1	1	12.66	0.322	0.518	-3.58	-14.2	4.32	0.682	0.085	0.797	0.639	0.436	0.966	**60.090**	**47.983**	**0.480**
11C	11Ccp	17536	107.1	10.00	15	15	11	10	1	10	1	1	1	8.202	0.322	0.518	-3.58	-14.2	4.32	0.442	0.085	0.797	0.639	0.436	0.966	**56.091**	**45.238**	**0.452**
11D	11Ccp	17536	30.0	10.00	15	15	11	10	1	10	1	1	1	4.627	0.322	0.518	-3.58	-14.2	4.32	0.249	0.085	0.797	0.639	0.436	0.966	**52.883**	**43.037**	**0.430**
11E	None																											
11F	None																											
11G	11Ccg	18176	42.4	5.00	15	15	11	0	0	10	1	0	1	5.389	0.226	0.478	-3.64	-14.3	4.397	0.29	-0	0.795	0.635	0.432	0.983	**52.251**	**42.603**	**0.426**
11H	11Ccg	18176	75.1	5.00	15	15	11	0	0	10	1	0	1	6.969	0.226	0.478	-3.64	-14.3	4.397	0.375	-0	0.795	0.635	0.432	0.983	**53.669**	**43.576**	**0.436**
11I	11Ccg	18176	21.5	5.00	15	15	11	0	0	10	1	0	1	4.01	0.226	0.478	-3.64	-14.3	4.397	0.216	-0	0.795	0.635	0.432	0.983	**51.014**	**41.754**	**0.418**
11J	11Cc	18176	53.6	5.00	15	15	11	10	1	10	1	1	1	5.98	0.226	0.478	-3.64	-14.3	4.32	0.322	-0	0.795	0.635	0.432	0.966	**52.497**	**42.772**	**0.428**
11K	11Ccg	18176	17.5	5.00	15	15	11	0	0	10	1	0	1	3.685	0.226	0.478	-3.64	-14.3	4.397	0.198	-0	0.795	0.635	0.432	0.983	**50.723**	**41.554**	**0.416**
11L	11Cc	18176	99.1	5.00	15	15	11	10	1	10	1	1	1	7.912	0.226	0.478	-3.64	-14.3	4.32	0.426	-0	0.795	0.635	0.432	0.966	**54.231**	**43.962**	**0.440**
11M	11Ccg	18176	74.7	5.00	15	15	11	0	0	10	1	0	1	6.95	0.226	0.478	-3.64	-14.3	4.397	0.374	-0	0.795	0.635	0.432	0.983	**53.653**	**43.565**	**0.436**
11N	11Cc	18176	120.0	5.00	15	15	11	10	1	10	1	1	1	8.645	0.226	0.478	-3.64	-14.3	4.32	0.466	-0	0.795	0.635	0.432	0.966	**54.889**	**44.414**	**0.444**
11O	11Ccg	18176	62.3	5.00	15	15	11	0	0	10	1	0	1	6.398	0.226	0.478	-3.64	-14.3	4.397	0.345	-0	0.795	0.635	0.432	0.983	**53.158**	**43.225**	**0.432**
11P	11Ccg	18176	96.4	5.00	15	15	11	0	0	10	1	0	1	7.811	0.226	0.478	-3.64	-14.3	4.397	0.421	-0	0.795	0.635	0.432	0.983	**54.425**	**44.095**	**0.441**
11Q	11Cc	18176	167.4	5.00	15	15	11	10	1	10	1	1	1	10.1	0.226	0.478	-3.64	-14.3	4.32	0.544	-0	0.795	0.635	0.432	0.966	**56.194**	**45.309**	**0.453**
12A	12Cc	6720	273.2	5.00	14	14	11	4	1	10	1	1	1	12.73	0.226	0.594	-2.81	-10.5	4.367	0.686	-0	0.801	0.682	0.545	0.976	**61.490**	**48.943**	**0.489**
12B	12Cm	6720	601.6	5.00	14	14	11	10	1	10	1	1	1	18.59	0.226	0.594	-2.81	-10.5	4.32	1.001	-0	0.801	0.682	0.545	0.966	**66.580**	**52.437**	**0.524**
12C	12Cc	6720	506.0	5.00	14	14	11	4	1	10	1	1	1	17.1	0.226	0.594	-2.81	-10.5	4.367	0.921	-0	0.801	0.682	0.545	0.976	**65.414**	**51.637**	**0.516**
13A	13Cmhe	21312	688.4	10.00	15	15	14	10	1	10	1	1	1	19.85	0.322	0.3	-3.94	-11.9	4.32	1.069	0.085	0.784	0.619	0.503	0.966	**67.109**	**52.800**	**0.528**
13B	13Cml	21504	459.0	10.00	15	15	31	10	1	10	1	1	1	16.32	0.322	0.29	-3.95	5.062	4.32	0.879	0.085	0.784	0.618	1.005	0.966	**72.283**	**56.351**	**0.564**
13C	13Cct	52.74	241.3	75.00	15	15	17	10	1	10	1	1	1	12	1.047	7.03	7.135	14.06	4.32	0.646	0.733	1.175	1.233	1.271	0.966	**100.422**	**75.663**	**0.757**
13D	13Ccsr	21760	257.1	5.00	17	15	11	10	1	10	1	1	1	12.37	0.226	2.276	-3.97	-15	4.32	0.666	-0	0.899	0.617	0.412	0.966	**59.326**	**47.459**	**0.475**
13E	13Cc	21760	395.2	10.00	15	15	17	10	1	10	1	1	1	15.19	0.322	0.276	-3.97	-8.98	4.32	0.818	0.085	0.783	0.617	0.589	0.966	**64.308**	**50.878**	**0.509**
13F	13Ccsr	21760	149.2	5.00	17	15	11	10	1	10	1	1	1	9.567	0.226	2.276	-3.97	-15	4.32	0.515	-0	0.899	0.617	0.412	0.966	**56.811**	**45.733**	**0.457**

Table 2-4: Coastal Plain Physiographic Province FWP PHI Metrics and Scores for design alternative 1																												
Stream		Metric Values Input										Transform Bank Severity		Prepare Metric Values						Scale Metric Values						Final Score	Normalize Final Score	Rescaled Final Score
								Left Bank Stability		Right Bank Stability																		
Reach Code	Habiat Code	Watershed Area (acres)	Remoteness (meters)	%Shading	Epibenthic Substrate Score	Instream Habitat Score	Total No. Instream Woody Debris and Rootwads	Erosion Extent (meters)	Severity	Erosion Extent (meters)	Severity	Left	Right	REMOTE	TSHADING	RESEPISUB	RESINSTRHAB	RESWOOD	TBANKSTAN	REMOTE	TSHADING	RESEPISUB	RESINSTRHAB	RESWOOD	TBANKSTAN	Coastal Plain PHI	Normalized Coastal Plain PHI	Rescaled Coastla Plain PHI
13G	13Ccsr	21760	153.9	5.00	17	15	11	10	1	10	1	1	1	9.709	0.226	2.276	-3.97	-15	4.32	0.523	-0	0.899	0.617	0.412	0.966	**56.938**	**45.820**	**0.458**
15A	15Ccor	192	100.0	10.00	14	14	19	10	1	10	1	1	1	7.945	0.322	4.581	3.751	11.12	4.32	0.428	0.085	1.033	1.046	1.184	0.966	**79.034**	**60.984**	**0.610**
15B	15Ccgt	115.2	354.4	25.00	14	14	11	10	1	10	1	1	1	14.41	0.524	5.154	4.693	5.074	4.32	0.776	0.266	1.066	1.098	1.005	0.966	**86.288**	**65.963**	**0.660**
15C	None																											
15D	15Ccor	192	229.8	10.00	14	14	19	10	1	10	1	1	1	11.73	0.322	4.581	3.751	11.12	4.32	0.631	0.085	1.033	1.046	1.184	0.966	**82.427**	**63.313**	**0.633**
15E	15Cce	44288	26.4	15.00	14	14	11	10	1	10	1	1	1	4.378	0.398	-1.52	-6.29	-17.7	4.32	0.236	0.153	0.678	0.489	0.331	0.966	**47.562**	**39.385**	**0.394**
15F	15Ccp	684.8	225.8	10.00	14	14	18	10	1	10	1	1	1	11.63	0.322	3.155	1.405	5.253	4.32	0.626	0.085	0.95	0.915	1.01	0.966	**75.897**	**58.831**	**0.588**
15G	15Cce	44288	180.8	15.00	14	14	11	10	1	10	1	1	1	10.47	0.398	-1.52	-6.29	-17.7	4.32	0.564	0.153	0.678	0.489	0.331	0.966	**53.030**	**43.138**	**0.431**
15H	15TCm	486.4	498.2	35.00	15	15	11	10	1	10	1	1	1	16.98	0.633	4.539	3.036	-0.44	4.32	0.914	0.363	1.03	1.006	0.842	0.966	**85.371**	**65.333**	**0.653**

Table 2-5: Piedmont Physiographic Province FWP PHI Metrics and Scores for design alternative 2																																		
		Metric Values Input												Transform Bank Severity		Prepare Metric Values								Scale Metric Values								Final Score	Normalize Final Score	Rescaled Final Score
									Left Bank Stability		Right Bank Stability																							
Reach No.	Habitat Code	Watershed Area (acres)	% Embeddedness	Remoteness (meters)	%Shading	Epibenthic Substrate Score	Instream Habitat Score	Total No. Instream Woody Debris and Rootwads	Erosion Extent (meters)	Severity	Erosion Extent (meters)	Severity	Riffle Quality Score	Left	Right	EMBEDDED	REMOTE	RESTSHADING	EPISUB	RESINSTRHAB	WOOD	TBANKSTANB	RESRIFFQUAL	EMBEDDED	REMOTE	RESTSHADING	EPISUB	RESINSTRHAB	WOOD	TBANKSTANB	RESRIFFQUAL	Piedmont PHI	Normalized Piedmont PHI	Rescaled Piedmont PHI
7A	7Pb	9856	20	114.5	50	15	16	11	10	1	10	1	15	1	1	20	8.46	-0.17	15	-0.17	11	4.32	-0.46	0.89	0.53	0.69	0.82	0.8	0.92	1.02	0.8	**80.977**	**61.078**	**0.611**
7B	7Pe	10048	20	400.5	30	15	15	17	10	1	10	1	15	1	1	20	15.3	-0.38	15	-1.18	17	4.32	-0.48	0.89	0.96	0.54	0.82	0.74	1.42	1.02	0.8	**89.928**	**67.554**	**0.676**

Table 2-6: Coastal Plain Physiographic Province FWP PHI Metrics and Scores for design alternative 2

Reach Code	Habiat Code	Metric Values Input: Watershed Area (acres)	Remoteness (meters)	%Shading	Epibenthic Substrate Score	Instream Habitat Score	Total No. Instream Woody Debris and Rootwads	Left Bank Stability: Erosion Extent (meters)	Severity	Right Bank Stability: Erosion Extent (meters)	Severity	Transform Bank Severity: Left	Right	Prepare Metric Values: REMOTE	TSHADING	RESEPISUB	RESINSTRHAB	RESWOOD	TBANKSTAN	Scale Metric Values: REMOTE	TSHADING	RESEPISUB	RESINSTRHAB	RESWOOD	TBANKSTAN	Final Score: Coastal Plain PHI	Normalize Final Score: Normalized Coastal Plain PHI	Rescaled Final Score: Rescaled Coastla Plain PHI
1A	1Cc	1210	211.8	15.00	15	15	11	10	1	10	1	1	1	11.28	0.398	3.517	1.356	-3.92	4.32	0.608	0.153	0.971	0.913	0.739	0.966	**72.497**	**56.498**	**0.565**
1B	1Cm	1235	1908.8	80.00	15	15	11	10	1	10	1	1	1	32.64	1.107	3.494	1.317	-4	4.32	1.758	0.787	0.97	0.911	0.737	0.966	**102.124**	**76.831**	**0.768**
3A	3Cce	22272	249.0	35.00	15	15	28	10	1	10	1	1	1	12.18	0.633	0.25	-4.02	1.928	4.32	0.656	0.363	0.781	0.615	0.912	0.966	**71.559**	**55.854**	**0.559**
3B	3Cm	22592	143.3	5.00	15	15	44	10	1	10	1	1	1	9.391	0.226	0.234	-4.04	17.87	4.32	0.506	-0	0.78	0.613	1.384	0.966	**70.812**	**55.341**	**0.553**
3C	3Ccp	22720	114.8	15.00	15	15	11	10	1	10	1	1	1	8.468	0.398	0.228	-4.05	-15.1	4.32	0.456	0.153	0.78	0.613	0.407	0.966	**56.249**	**45.347**	**0.453**
3D	3Ccp	22720	63.3	15.00	15	15	11	10	1	10	1	1	1	6.445	0.398	0.228	-4.05	-15.1	4.32	0.347	0.153	0.78	0.613	0.407	0.966	**54.433**	**44.101**	**0.441**
3E	3Cce	22272	26.1	35.00	15	15	28	10	1	10	1	1	1	4.359	0.633	0.25	-4.02	1.928	4.32	0.235	0.363	0.781	0.615	0.912	0.966	**64.538**	**51.036**	**0.510**
3F	3Ccp	22720	15.5	15.00	15	15	11	10	1	10	1	1	1	3.498	0.398	0.228	-4.05	-15.1	4.32	0.188	0.153	0.78	0.613	0.407	0.966	**51.788**	**42.285**	**0.423**
3G	3Ccst	31296	66.4	5.00	15	15	11	10	1	0	0	1	0	6.588	0.226	-0.13	-4.65	-16.4	4.397	0.355	-0	0.759	0.58	0.371	0.983	**50.786**	**41.597**	**0.416**
3H	None	#N/A	71.5	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	6.813	#N/A	#N/A	#N/A	#N/A	#N/A	0.367	#N/A	#N/A	#N/A	#N/A	#N/A	**#N/A**	**#N/A**	**#N/A**
3I	3Ccp	22720	419.0	15.00	15	15	11	10	1	10	1	1	1	15.62	0.398	0.228	-4.05	-15.1	4.32	0.841	0.153	0.78	0.613	0.407	0.966	**62.666**	**49.751**	**0.498**
3J	3Ccst	31296	139.0	5.00	15	15	11	10	1	0	0	1	0	9.258	0.226	-0.13	-4.65	-16.4	4.397	0.499	-0	0.759	0.58	0.371	0.983	**53.182**	**43.242**	**0.432**
3K	9Cs	7040	47.7	5.00	15	20	11	3	1	0	0	1	0	5.675	0.226	1.542	3.107	-10.7	4.45	0.306	-0	0.856	1.01	0.54	0.995	**61.767**	**49.134**	**0.491**
3L	3Ccst	31296	103.4	5.00	15	15	11	10	1	0	0	1	0	8.07	0.226	-0.13	-4.65	-16.4	4.397	0.435	-0	0.759	0.58	0.371	0.983	**52.115**	**42.510**	**0.425**
3M	9Cs	7040	61.9	5.00	15	20	11	3	1	0	0	1	0	6.381	0.226	1.542	3.107	-10.7	4.45	0.344	-0	0.856	1.01	0.54	0.995	**62.400**	**49.568**	**0.496**
3N	3Ccst	31296	52.1	5.00	15	15	11	10	1	0	0	1	0	5.908	0.226	-0.13	-4.65	-16.4	4.397	0.318	-0	0.759	0.58	0.371	0.983	**50.175**	**41.178**	**0.412**
3O	3Ccu	31488	29.0	15.00	15	15	11	10	1	10	1	1	1	4.563	0.398	-0.14	-4.66	-16.4	4.32	0.246	0.153	0.759	0.579	0.37	0.966	**51.217**	**41.893**	**0.419**
3P	3Ccu	31488	232.0	15.00	15	15	11	10	1	10	1	1	1	11.78	0.398	-0.14	-4.66	-16.4	4.32	0.634	0.153	0.759	0.579	0.37	0.966	**57.695**	**46.339**	**0.463**
3Q	3Ccpg	31616	386.4	25.00	15	15	14	10	1	10	1	1	1	15.02	0.524	-0.14	-4.66	-13.4	4.32	0.809	0.266	0.759	0.579	0.458	0.966	**63.939**	**50.624**	**0.506**
5A	5Ccst	19584	53.7	5.00	15	15	11	10	1	0	0	1	0	5.985	0.226	0.395	-3.78	-14.6	4.397	0.322	-0	0.79	0.628	0.424	0.983	**52.437**	**42.731**	**0.427**
5B	5Ccgu	19904	74.5	5.00	15	15	11	10	1	10	1	1	1	6.941	0.226	0.376	-3.81	-14.6	4.32	0.374	-0	0.789	0.626	0.422	0.966	**52.935**	**43.072**	**0.431**
5C	5Ccehu	19648	109.3	10.00	15	15	11	10	1	5	1	1	1	8.279	0.322	0.391	-3.79	-14.6	4.359	0.446	0.085	0.79	0.627	0.423	0.975	**55.771**	**45.019**	**0.450**
5D	5Cw	19904	39.1	10.00	15	15	29	10	1	10	1	1	1	5.2	0.322	0.376	-3.81	3.358	4.32	0.28	0.085	0.789	0.626	0.954	0.966	**61.680**	**49.074**	**0.491**
5E	5Ccgu	19904	120.8	5.00	15	15	11	10	1	10	1	1	1	8.67	0.226	0.376	-3.81	-14.6	4.32	0.467	-0	0.789	0.626	0.422	0.966	**54.486**	**44.137**	**0.441**
5F	5Ccehu	19648	162.6	10.00	15	15	11	10	1	5	1	1	1	9.963	0.322	0.391	-3.79	-14.6	4.359	0.536	0.085	0.79	0.627	0.423	0.975	**57.283**	**46.056**	**0.461**
5G	5Ccst	19584	49.9	5.00	15	15	11	10	1	0	0	1	0	5.794	0.226	0.395	-3.78	-14.6	4.397	0.312	-0	0.79	0.628	0.424	0.983	**52.266**	**42.613**	**0.426**
5H	5Ccehu	19648	117.7	10.00	15	15	11	10	1	5	1	1	1	8.569	0.322	0.391	-3.79	-14.6	4.359	0.461	0.085	0.79	0.627	0.423	0.975	**56.032**	**45.198**	**0.452**
5I	5Ccgu	19904	22.0	5.00	15	15	11	10	1	10	1	1	1	4.054	0.226	0.376	-3.81	-14.6	4.32	0.218	-0	0.789	0.626	0.422	0.966	**50.344**	**41.294**	**0.413**
5J	5Ccehu	19648	83.1	10.00	15	15	11	10	1	5	1	1	1	7.297	0.322	0.391	-3.79	-14.6	4.359	0.393	0.085	0.79	0.627	0.423	0.975	**54.890**	**44.414**	**0.444**
5K	5Ccle	19840	516.4	15.00	15	15	18	10	1	10	1	1	1	17.27	0.398	0.38	-3.8	-7.63	4.32	0.93	0.153	0.789	0.626	0.629	0.966	**68.235**	**53.573**	**0.536**
5L	5Cw	19904	151.5	10.00	15	15	29	10	1	10	1	1	1	9.639	0.322	0.376	-3.81	3.358	4.32	0.519	0.085	0.789	0.626	0.954	0.966	**65.663**	**51.808**	**0.518**
5M	5Ccst	19584	44.4	5.00	15	15	11	10	1	0	0	1	0	5.5	0.226	0.395	-3.78	-14.6	4.397	0.296	-0	0.79	0.628	0.424	0.983	**52.002**	**42.432**	**0.424**
5N	5Ccst	19584	38.4	5.00	15	15	11	10	1	0	0	1	0	5.156	0.226	0.395	-3.78	-14.6	4.397	0.278	-0	0.79	0.628	0.424	0.983	**51.693**	**42.220**	**0.422**
5O	9Cs	7040	28.5	5.00	15	20	11	3	1	0	0	1	0	4.531	0.226	1.542	3.107	-10.7	4.45	0.244	-0	0.856	1.01	0.54	0.995	**60.740**	**48.429**	**0.484**
5P	5Ccgu	19904	152.9	5.00	15	15	11	10	1	10	1	1	1	9.679	0.226	0.376	-3.81	-14.6	4.32	0.521	-0	0.789	0.626	0.422	0.966	**55.392**	**44.759**	**0.448**
5Q	5Ccgu	19904	41.2	5.00	15	15	11	10	1	10	1	1	1	5.32	0.226	0.376	-3.81	-14.6	4.32	0.286	-0	0.789	0.626	0.422	0.966	**51.480**	**42.074**	**0.421**
5R	5Ccst	19584	41.8	5.00	15	15	11	10	1	0	0	1	0	5.353	0.226	0.395	-3.78	-14.6	4.397	0.288	-0	0.79	0.628	0.424	0.983	**51.871**	**42.342**	**0.423**
5S	9Cs	7040	71.7	5.00	15	20	11	3	1	0	0	1	0	6.823	0.226	1.542	3.107	-10.7	4.45	0.367	-0	0.856	1.01	0.54	0.995	**62.797**	**49.840**	**0.498**

Table 2-6: Coastal Plain Physiographic Province FWP PHI Metrics and Scores for design alternative 2																												
		Metric Values Input										Transform Bank Severity		Prepare Metric Values						Scale Metric Values						Final Score	Normalize Final Score	Rescaled Final Score
								Left Bank Stability		Right Bank Stability																		
Reach Code	Habiat Code	Watershed Area (acres)	Remoteness (meters)	%Shading	Epibenthic Substrate Score	Instream Habitat Score	Total No. Instream Woody Debris and Rootwads	Erosion Extent (meters)	Severity	Erosion Extent (meters)	Severity	Left	Right	REMOTE	TSHADING	RESEPISUB	RESINSTRHAB	RESWOOD	TBANKSTAN	REMOTE	TSHADING	RESEPISUB	RESINSTRHAB	RESWOOD	TBANKSTAN	Coastal Plain PHI	Normalized Coastal Plain PHI	Rescaled Coastla Plain PHI
5T	5Ccgu	19904	47.3	5.00	15	15	11	10	1	10	1	1	1	5.654	0.226	0.376	-3.81	-14.6	4.32	0.304	-0	0.789	0.626	0.422	0.966	**51.779**	**42.279**	**0.423**
7C	7Cc	10432	504.0	0.00	15	15	11	10	1	10	1	1	1	17.07	0	1.101	-2.62	-12.2	4.32	0.919	-0.2	0.831	0.692	0.495	0.966	**61.693**	**49.083**	**0.491**
7D	None	#N/A	89.9	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	7.563	#N/A	#N/A	#N/A	#N/A	#N/A	0.407	#N/A	#N/A	#N/A	#N/A	#N/A	**#N/A**	**#N/A**	**#N/A**
7E	7Cc	10432	682.3	0.00	15	15	11	10	1	10	1	1	1	19.76	0	1.101	-2.62	-12.2	4.32	1.064	-0.2	0.831	0.692	0.495	0.966	**64.109**	**50.741**	**0.507**
9A	9Cg	7168	173.2	15.00	15	15	11	10	1	10	1	1	1	10.26	0.398	1.522	-1.93	-10.7	4.32	0.553	0.153	0.855	0.731	0.538	0.966	**63.255**	**50.155**	**0.502**
9B	9Cs	7040	74.2	5.00	15	20	11	3	1	0	0	1	0	6.928	0.226	1.542	3.107	-10.7	4.45	0.373	-0	0.856	1.01	0.54	0.995	**62.891**	**49.905**	**0.499**
9C	9Cg	7168	435.8	15.00	15	15	11	10	1	10	1	1	1	15.92	0.398	1.522	-1.93	-10.7	4.32	0.857	0.153	0.855	0.731	0.538	0.966	**68.330**	**53.638**	**0.536**
10A	10Cs	1242	112.7	35.00	13	13	9	10	1	5	1	1	1	8.396	0.633	1.488	-0.69	-6.02	4.359	0.452	0.363	0.853	0.799	0.677	0.975	**68.657**	**53.862**	**0.539**
10B	10Cg	1254	134.5	15.00	13	13	15	10	1	10	1	1	1	9.117	0.398	1.476	-0.71	-0.06	4.32	0.491	0.153	0.853	0.798	0.853	0.966	**68.569**	**53.802**	**0.538**
10C	10Ce	1286	243.4	5.00	13	13	10	10	1	10	1	1	1	12.05	0.226	1.448	-0.76	-5.16	4.32	0.649	-0	0.851	0.795	0.702	0.966	**66.056**	**52.077**	**0.521**
10D	10Cg	1254	148.2	15.00	13	13	15	10	1	10	1	1	1	9.537	0.398	1.476	-0.71	-0.06	4.32	0.514	0.153	0.853	0.798	0.853	0.966	**68.946**	**54.061**	**0.541**
11A	11Ccp	17536	1820.2	10.00	13	13	11	10	1	10	1	1	1	31.89	0.322	-1.48	-5.58	-14.2	4.32	1.717	0.085	0.681	0.528	0.436	0.966	**73.563**	**57.230**	**0.572**
11B	11Ccp	17536	269.9	10.00	13	13	11	10	1	10	1	1	1	12.66	0.322	-1.48	-5.58	-14.2	4.32	0.682	0.085	0.681	0.528	0.436	0.966	**56.304**	**45.384**	**0.454**
11C	11Ccp	17536	107.1	10.00	13	13	11	10	1	10	1	1	1	8.202	0.322	-1.48	-5.58	-14.2	4.32	0.442	0.085	0.681	0.528	0.436	0.966	**52.305**	**42.640**	**0.426**
11D	11Ccp	17536	30.0	10.00	13	13	11	10	1	10	1	1	1	4.627	0.322	-1.48	-5.58	-14.2	4.32	0.249	0.085	0.681	0.528	0.436	0.966	**49.097**	**40.438**	**0.404**
11E	None	#N/A	98.9	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	7.905	#N/A	#N/A	#N/A	#N/A	#N/A	0.426	#N/A	#N/A	#N/A	#N/A	#N/A	**#N/A**	**#N/A**	**#N/A**
11F	None	#N/A	34.0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	4.889	#N/A	#N/A	#N/A	#N/A	#N/A	0.263	#N/A	#N/A	#N/A	#N/A	#N/A	**#N/A**	**#N/A**	**#N/A**
11G	11Ccg	18176	42.4	5.00	14	14	11	0	0	10	1	0	1	5.389	0.226	-0.52	-4.64	-14.3	4.397	0.29	-0	0.736	0.58	0.432	0.983	**50.358**	**41.304**	**0.413**
11H	11Ccg	18176	75.1	5.00	14	14	11	0	0	10	1	0	1	6.969	0.226	-0.52	-4.64	-14.3	4.397	0.375	-0	0.736	0.58	0.432	0.983	**51.776**	**42.277**	**0.423**
11I	11Ccg	18176	21.5	5.00	14	14	11	0	0	10	1	0	1	4.01	0.226	-0.52	-4.64	-14.3	4.397	0.216	-0	0.736	0.58	0.432	0.983	**49.121**	**40.455**	**0.405**
11J	11Cc	18176	53.6	5.00	14	14	11	10	1	10	1	1	1	5.98	0.226	-0.52	-4.64	-14.3	4.32	0.322	-0	0.736	0.58	0.432	0.966	**50.604**	**41.473**	**0.415**
11K	11Ccg	18176	17.5	5.00	14	14	11	0	0	10	1	0	1	3.685	0.226	-0.52	-4.64	-14.3	4.397	0.198	-0	0.736	0.58	0.432	0.983	**48.830**	**40.255**	**0.403**
11L	11Cc	18176	99.1	5.00	14	14	11	10	1	10	1	1	1	7.912	0.226	-0.52	-4.64	-14.3	4.32	0.426	-0	0.736	0.58	0.432	0.966	**52.338**	**42.663**	**0.427**
11M	11Ccg	18176	74.7	5.00	14	14	11	0	0	10	1	0	1	6.95	0.226	-0.52	-4.64	-14.3	4.397	0.374	-0	0.736	0.58	0.432	0.983	**51.760**	**42.266**	**0.423**
11N	11Cc	18176	120.0	5.00	14	14	11	10	1	10	1	1	1	8.645	0.226	-0.52	-4.64	-14.3	4.32	0.466	-0	0.736	0.58	0.432	0.966	**52.996**	**43.115**	**0.431**
11O	11Ccg	18176	62.3	5.00	14	14	11	0	0	10	1	0	1	6.398	0.226	-0.52	-4.64	-14.3	4.397	0.345	-0	0.736	0.58	0.432	0.983	**51.265**	**41.926**	**0.419**
11P	11Ccg	18176	96.4	5.00	14	14	11	0	0	10	1	0	1	7.811	0.226	-0.52	-4.64	-14.3	4.397	0.421	-0	0.736	0.58	0.432	0.983	**52.532**	**42.796**	**0.428**
11Q	11Cc	18176	167.4	5.00	14	14	11	10	1	10	1	1	1	10.1	0.226	-0.52	-4.64	-14.3	4.32	0.544	-0	0.736	0.58	0.432	0.966	**54.301**	**44.010**	**0.440**
12A	12Cc	6720	273.2	5.00	15	15	11	4	1	10	1	1	1	12.73	0.226	1.594	-1.81	-10.5	4.367	0.686	-0	0.859	0.737	0.545	0.976	**63.383**	**50.243**	**0.502**
12B	12Cm	6720	601.6	5.00	15	15	11	10	1	10	1	1	1	18.59	0.226	1.594	-1.81	-10.5	4.32	1.001	-0	0.859	0.737	0.545	0.966	**68.473**	**53.736**	**0.537**
12C	12Cc	6720	506.0	5.00	15	15	11	4	1	10	1	1	1	17.1	0.226	1.594	-1.81	-10.5	4.367	0.921	-0	0.859	0.737	0.545	0.976	**67.307**	**52.936**	**0.529**
13A	13Cmhe	21312	688.4	10.00	14	14	14	10	1	10	1	1	1	19.85	0.322	-0.7	-4.94	-11.9	4.32	1.069	0.085	0.726	0.564	0.503	0.966	**65.216**	**51.501**	**0.515**
13B	13Cml	21504	459.0	10.00	14	14	31	10	1	10	1	1	1	16.32	0.322	-0.71	-4.95	5.062	4.32	0.879	0.085	0.726	0.563	1.005	0.966	**70.390**	**55.052**	**0.551**
13C	13Cct	52.74	241.3	75.00	14	14	17	10	1	10	1	1	1	12	1.047	6.03	6.135	14.06	4.32	0.646	0.733	1.117	1.178	1.271	0.966	**98.529**	**74.364**	**0.744**
13D	13Ccsr	21760	257.1	5.00	17	14	11	10	1	10	1	1	1	12.37	0.226	2.276	-4.97	-15	4.32	0.666	-0	0.899	0.561	0.412	0.966	**58.401**	**46.824**	**0.468**
13E	13Cc	21760	395.2	10.00	14	14	17	10	1	10	1	1	1	15.19	0.322	-0.72	-4.97	-8.98	4.32	0.818	0.085	0.725	0.561	0.589	0.966	**62.415**	**49.579**	**0.496**
13F	13Ccsr	21760	149.2	5.00	17	14	11	10	1	10	1	1	1	9.567	0.226	2.276	-4.97	-15	4.32	0.515	-0	0.899	0.561	0.412	0.966	**55.887**	**45.098**	**0.451**
13G	13Ccsr	21760	153.9	5.00	17	14	11	10	1	10	1	1	1	9.709	0.226	2.276	-4.97	-15	4.32	0.523	-0	0.899	0.561	0.412	0.966	**56.013**	**45.185**	**0.452**

Table 2-6: Coastal Plain Physiographic Province FWP PHI Metrics and Scores for design alternative 2																												
		Metric Values Input										Transform Bank Severity		Prepare Metric Values						Scale Metric Values						Final Score	Normalize Final Score	Rescaled Final Score
								Left Bank Stability		Right Bank Stability																		
Reach Code	Habiat Code	Watershed Area (acres)	Remoteness (meters)	%Shading	Epibenthic Substrate Score	Instream Habitat Score	Total No. Instream Woody Debris and Rootwads	Erosion Extent (meters)	Severity	Erosion Extent (meters)	Severity	Left	Right	REMOTE	TSHADING	RESEPISUB	RESINSTRHAB	RESWOOD	TBANKSTAN	REMOTE	TSHADING	RESEPISUB	RESINSTRHAB	RESWOOD	TBANKSTAN	Coastal Plain PHI	Normalized Coastal Plain PHI	Rescaled Coastla Plain PHI
15A	15Ccor	192	100.0	10.00	15	15	19	10	1	10	1	1	1	7.945	0.322	5.581	4.751	11.12	4.32	0.428	0.085	1.091	1.101	1.184	0.966	**80.927**	**62.283**	**0.623**
15B	15Ccgt	115.2	354.4	25.00	15	15	11	10	1	10	1	1	1	14.41	0.524	6.154	5.693	5.074	4.32	0.776	0.266	1.124	1.153	1.005	0.966	**88.181**	**67.262**	**0.673**
15C	None	#N/A	66.9	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	6.611	#N/A	#N/A	#N/A	#N/A	#N/A	0.356	#N/A	#N/A	#N/A	#N/A	#N/A	**#N/A**	**#N/A**	**#N/A**
15D	15Ccor	192	229.8	10.00	15	15	19	10	1	10	1	1	1	11.73	0.322	5.581	4.751	11.12	4.32	0.631	0.085	1.091	1.101	1.184	0.966	**84.320**	**64.612**	**0.646**
15E	15Cce	44288	26.4	15.00	15	15	11	10	1	10	1	1	1	4.378	0.398	-0.52	-5.29	-17.7	4.32	0.236	0.153	0.737	0.544	0.331	0.966	**49.455**	**40.684**	**0.407**
15F	15Ccp	684.8	225.8	10.00	15	15	18	10	1	10	1	1	1	11.63	0.322	4.155	2.405	5.253	4.32	0.626	0.085	1.008	0.971	1.01	0.966	**77.790**	**60.131**	**0.601**
15G	15Cce	44288	180.8	15.00	15	15	11	10	1	10	1	1	1	10.47	0.398	-0.52	-5.29	-17.7	4.32	0.564	0.153	0.737	0.544	0.331	0.966	**54.923**	**44.437**	**0.444**
15H	15TCm	486.4	498.2	35.00	15	15	11	10	1	10	1	1	1	16.98	0.633	4.539	3.036	-0.44	4.32	0.914	0.363	1.03	1.006	0.842	0.966	**85.371**	**65.333**	**0.653**

Table 2-7: Piedmont Physiographic Province BAC PHI Metrics and Scores

Stream		Metric Values Input												Transform Bank Severity		Prepare Metric Values								Scale Metric Values								Final Score	Normalize Final Score	Rescaled Final Score
									Left Bank Stability		Right Bank Stability																							
Reach No.	Habitat Code	Watershed Area (acres)	% Embeddedness	Remoteness (meters)	%Shading	Epibenthic Substrate Score	Instream Habitat Score	Total No. Instream Woody Debris and Rootwads	Erosion Extent (meters)	Severity	Erosion Extent (meters)	Severity	Riffle Quality Score	Left	Right	EMBEDDED	REMOTE	RESTSHADING	EPISUB	RESINSTRHAB	WOOD	TBANKSTANB	RESRIFFQUAL	EMBEDDED	REMOTE	RESTSHADING	EPISUB	RESINSTRHAB	WOOD	TBANKSTANB	RESRIFFQUAL	Piedmont PHI	Normalized Piedmont PHI	Rescaled Piedmont PHI
7A	7Pb	9856	20	114.5	50	20	20	32	0	0	0	0	20	0	0	20	8.46	-0.17	20	3.83	32	4.47	4.54	0.89	0.53	0.69	1.12	1.06	2.67	1.07	1.06	**113.471**	**84.589**	**0.846**
7B	7Pe	10048	20	400.5	30	20	20	32	0	0	0	0	20	0	0	20	15.3	-0.38	20	3.82	32	4.47	4.52	0.89	0.96	0.54	1.12	1.06	2.67	1.07	1.06	**116.966**	**87.117**	**0.871**

Table 2-8: Coastal Plain Physiographic Province BAC PHI Metrics and Scores

Stream: Reach Code	Stream: Habitat Code	Metric Values Input: Watershed Area (acres)	Metric Values Input: Remoteness (meters)	Metric Values Input: %Shading	Metric Values Input: Epibenthic Substrate Score	Metric Values Input: Instream Habitat Score	Metric Values Input: Total No. Instream Woody Debris and Rootwads	Left Bank Stability: Erosion Extent (meters)	Left Bank Stability: Severity	Right Bank Stability: Erosion Extent (meters)	Right Bank Stability: Severity	Transform Bank Severity: Left	Transform Bank Severity: Right	Prepare Metric Values: REMOTE	Prepare Metric Values: TSHADING	Prepare Metric Values: RESEPISUB	Prepare Metric Values: RESINSTRHAB	Prepare Metric Values: RESWOOD	Prepare Metric Values: TBANKSTAN	Scale Metric Values: REMOTE	Scale Metric Values: TSHADING	Scale Metric Values: RESEPISUB	Scale Metric Values: RESINSTRHAB	Scale Metric Values: RESWOOD	Scale Metric Values: TBANKSTAN	Final Score: Coastal Plain PHI	Normalize Final Score: Normalized Coastal Plain PHI	Rescaled Final Score: Rescaled Coastla Plain PHI
1A	1Cc	1209.6	211.8	15.00	20	20	32	0	0	0	0	0	0	11.28	0.398	8.517	6.356	17.08	4.472	0.608	0.153	1.262	1.19	1.36	1	**92.882**	**70.488**	**0.705**
1B	1Cm	1235.2	1908.8	80.00	20	20	32	0	0	0	0	0	0	32.64	1.107	8.494	6.317	17	4.472	1.758	0.787	1.26	1.188	1.358	1	**122.509**	**90.821**	**0.908**
3A	3Cce	22272	249.0	35.00	20	20	32	0	0	0	0	0	0	12.18	0.633	5.25	0.982	5.928	4.472	0.656	0.363	1.072	0.892	1.03	1	**83.562**	**64.092**	**0.641**
3B	3Cm	22592	143.3	5.00	20	20	32	0	0	0	0	0	0	9.391	0.226	5.234	0.956	5.873	4.472	0.506	-0	1.071	0.891	1.029	1	**74.925**	**58.164**	**0.582**
3C	3Ccp	22720	114.8	15.00	20	20	32	0	0	0	0	0	0	8.468	0.398	5.228	0.946	5.851	4.472	0.456	0.153	1.071	0.89	1.028	1	**76.633**	**59.336**	**0.593**
3D	3Ccp	22720	63.3	15.00	20	20	32	0	0	0	0	0	0	6.445	0.398	5.228	0.946	5.851	4.472	0.347	0.153	1.071	0.89	1.028	1	**74.817**	**58.090**	**0.581**
3E	3Cce	22272	26.1	35.00	20	20	32	0	0	0	0	0	0	4.359	0.633	5.25	0.982	5.928	4.472	0.235	0.363	1.072	0.892	1.03	1	**76.540**	**59.273**	**0.593**
3F	3Ccp	22720	15.5	15.00	20	20	32	0	0	0	0	0	0	3.498	0.398	5.228	0.946	5.851	4.472	0.188	0.153	1.071	0.89	1.028	1	**72.172**	**56.275**	**0.563**
3G	3Ccst	31296	66.4	5.00	20	20	32	0	0	0	0	0	0	6.588	0.226	4.869	0.355	4.626	4.472	0.355	-0	1.05	0.857	0.992	1	**70.885**	**55.391**	**0.554**
3H	None	#N/A	71.5	#N/A	20	20	32	0	0	0	0	0	0	6.813	#N/A	#N/A	#N/A	#N/A	4.472	0.367	#N/A	#N/A	#N/A	#N/A	1	**#N/A**	**#N/A**	**#N/A**
3I	3Ccp	22720	419.0	15.00	20	20	32	0	0	0	0	0	0	15.62	0.398	5.228	0.946	5.851	4.472	0.841	0.153	1.071	0.89	1.028	1	**83.051**	**63.741**	**0.637**
3J	3Ccst	31296	139.0	5.00	20	20	32	0	0	0	0	0	0	9.258	0.226	4.869	0.355	4.626	4.472	0.499	-0	1.05	0.857	0.992	1	**73.281**	**57.036**	**0.570**
3K	9Cs	7040	47.7	5.00	20	20	32	0	0	0	0	0	0	5.675	0.226	6.542	3.107	10.34	4.472	0.306	-0	1.147	1.01	1.161	1	**77.046**	**59.620**	**0.596**
3L	3Ccst	31296	103.4	5.00	20	20	32	0	0	0	0	0	0	8.07	0.226	4.869	0.355	4.626	4.472	0.435	-0	1.05	0.857	0.992	1	**72.215**	**56.304**	**0.563**
3M	9Cs	7040	61.9	5.00	20	20	32	0	0	0	0	0	0	6.381	0.226	6.542	3.107	10.34	4.472	0.344	-0	1.147	1.01	1.161	1	**77.679**	**60.054**	**0.601**
3N	3Ccst	31296	52.1	5.00	20	20	32	0	0	0	0	0	0	5.908	0.226	4.869	0.355	4.626	4.472	0.318	-0	1.05	0.857	0.992	1	**70.275**	**54.973**	**0.550**
3O	3Ccu	31488	29.0	15.00	20	20	32	0	0	0	0	0	0	4.563	0.398	4.862	0.344	4.602	4.472	0.246	0.153	1.049	0.857	0.991	1	**71.601**	**55.883**	**0.559**
3P	3Ccu	31488	232.0	15.00	20	20	32	0	0	0	0	0	0	11.78	0.398	4.862	0.344	4.602	4.472	0.634	0.153	1.049	0.857	0.991	1	**78.079**	**60.329**	**0.603**
3Q	3Ccpg	31616	386.4	25.00	20	20	32	0	0	0	0	0	0	15.02	0.524	4.857	0.336	4.587	4.472	0.809	0.266	1.049	0.856	0.991	1	**82.844**	**63.599**	**0.636**
5A	5Ccst	19584	53.7	5.00	20	20	32	0	0	0	0	0	0	5.985	0.226	5.395	1.22	6.42	4.472	0.322	-0	1.08	0.905	1.045	1	**72.536**	**56.525**	**0.565**
5B	5Ccgu	19904	74.5	5.00	20	20	32	0	0	0	0	0	0	6.941	0.226	5.376	1.19	6.358	4.472	0.374	-0	1.079	0.903	1.043	1	**73.319**	**57.062**	**0.571**
5C	5Ccehu	19648	109.3	10.00	20	20	32	0	0	0	0	0	0	8.279	0.322	5.391	1.214	6.407	4.472	0.446	0.085	1.08	0.905	1.045	1	**76.012**	**58.910**	**0.589**
5D	5Cw	19904	39.1	10.00	20	20	32	0	0	0	0	0	0	5.2	0.322	5.376	1.19	6.358	4.472	0.28	0.085	1.079	0.903	1.043	1	**73.189**	**56.973**	**0.570**
5E	5Ccgu	19904	120.8	5.00	20	20	32	0	0	0	0	0	0	8.67	0.226	5.376	1.19	6.358	4.472	0.467	-0	1.079	0.903	1.043	1	**74.871**	**58.127**	**0.581**
5F	5Ccehu	19648	162.6	10.00	20	20	32	0	0	0	0	0	0	9.963	0.322	5.391	1.214	6.407	4.472	0.536	0.085	1.08	0.905	1.045	1	**77.524**	**59.948**	**0.599**
5G	5Ccst	19584	49.9	5.00	20	20	32	0	0	0	0	0	0	5.794	0.226	5.395	1.22	6.42	4.472	0.312	-0	1.08	0.905	1.045	1	**72.365**	**56.408**	**0.564**
5H	5Ccehu	19648	117.7	10.00	20	20	32	0	0	0	0	0	0	8.569	0.322	5.391	1.214	6.407	4.472	0.461	0.085	1.08	0.905	1.045	1	**76.273**	**59.089**	**0.591**
5I	5Ccgu	19904	22.0	5.00	20	20	32	0	0	0	0	0	0	4.054	0.226	5.376	1.19	6.358	4.472	0.218	-0	1.079	0.903	1.043	1	**70.728**	**55.284**	**0.553**
5J	5Ccehu	19648	83.1	10.00	20	20	32	0	0	0	0	0	0	7.297	0.322	5.391	1.214	6.407	4.472	0.393	0.085	1.08	0.905	1.045	1	**75.131**	**58.306**	**0.583**
5K	5Ccle	19840	516.4	15.00	20	20	32	0	0	0	0	0	0	17.27	0.398	5.38	1.196	6.37	4.472	0.93	0.153	1.079	0.904	1.043	1	**85.168**	**65.194**	**0.652**
5L	5Cw	19904	151.5	10.00	20	20	32	0	0	0	0	0	0	9.639	0.322	5.376	1.19	6.358	4.472	0.519	0.085	1.079	0.903	1.043	1	**77.172**	**59.707**	**0.597**
5M	5Ccst	19584	44.4	5.00	20	20	32	0	0	0	0	0	0	5.5	0.226	5.395	1.22	6.42	4.472	0.296	-0	1.08	0.905	1.045	1	**72.101**	**56.226**	**0.562**
5N	5Ccst	19584	38.4	5.00	20	20	32	0	0	0	0	0	0	5.156	0.226	5.395	1.22	6.42	4.472	0.278	-0	1.08	0.905	1.045	1	**71.792**	**56.014**	**0.560**
5O	9Cs	7040	28.5	5.00	20	20	32	0	0	0	0	0	0	4.531	0.226	6.542	3.107	10.34	4.472	0.244	-0	1.147	1.01	1.161	1	**76.019**	**58.915**	**0.589**
5P	5Ccgu	19904	152.9	5.00	20	20	32	0	0	0	0	0	0	9.679	0.226	5.376	1.19	6.358	4.472	0.521	-0	1.079	0.903	1.043	1	**75.777**	**58.749**	**0.587**
5Q	5Ccgu	19904	41.2	5.00	20	20	32	0	0	0	0	0	0	5.32	0.226	5.376	1.19	6.358	4.472	0.286	-0	1.079	0.903	1.043	1	**71.864**	**56.064**	**0.561**
5R	5Ccst	19584	41.8	5.00	20	20	32	0	0	0	0	0	0	5.353	0.226	5.395	1.22	6.42	4.472	0.288	-0	1.08	0.905	1.045	1	**71.970**	**56.136**	**0.561**
5S	9Cs	7040	71.7	5.00	20	20	32	0	0	0	0	0	0	6.823	0.226	6.542	3.107	10.34	4.472	0.367	-0	1.147	1.01	1.161	1	**78.075**	**60.326**	**0.603**
5T	5Ccgu	19904	47.3	5.00	20	20	32	0	0	0	0	0	0	5.654	0.226	5.376	1.19	6.358	4.472	0.304	-0	1.079	0.903	1.043	1	**72.164**	**56.269**	**0.563**
7C	7Cc	10432	504.0	0.00	20	20	32	0	0	0	0	0	0	17.07	0	6.101	2.381	8.83	4.472	0.919	-0.2	1.121	0.97	1.116	1	**82.077**	**63.073**	**0.631**
7D	None	#N/A	89.9	#N/A	20	20	32	0	0	0	0	0	0	7.563	#N/A	#N/A	#N/A	#N/A	4.472	0.407	#N/A	#N/A	#N/A	#N/A	1	**#N/A**	**#N/A**	**#N/A**

Table 2-8: Coastal Plain Physiographic Province BAC PHI Metrics and Scores

Stream: Reach Code	Stream: Habitat Code	Metric Values Input: Watershed Area (acres)	Remoteness (meters)	%Shading	Epibenthic Substrate Score	Instream Habitat Score	Total No. Instream Woody Debris and Rootwads	Left Bank Stability: Erosion Extent (meters)	Left Bank Stability: Severity	Right Bank Stability: Erosion Extent (meters)	Right Bank Stability: Severity	Transform Bank Severity: Left	Transform Bank Severity: Right	Prepare Metric Values: REMOTE	TSHADING	RESEPISUB	RESINSTRHAB	RESWOOD	TBANKSTAN	Scale Metric Values: REMOTE	TSHADING	RESEPISUB	RESINSTRHAB	RESWOOD	TBANKSTAN	Final Score: Coastal Plain PHI	Normalize Final Score: Normalized Coastal Plain PHI	Rescaled Final Score: Rescaled Coastla Plain PHI
7E	7Cc	10432	682.3	0.00	20	20	32	0	0	0	0	0	0	19.76	0	6.101	2.381	8.83	4.472	1.064	-0.2	1.121	0.97	1.116	1	**84.493**	**64.731**	**0.647**
9A	9Cg	7168	173.2	15.00	20	20	32	0	0	0	0	0	0	10.26	0.398	6.522	3.074	10.27	4.472	0.553	0.153	1.146	1.008	1.159	1	**83.639**	**64.145**	**0.641**
9B	9Cs	7040	74.2	5.00	20	20	32	0	0	0	0	0	0	6.928	0.226	6.542	3.107	10.34	4.472	0.373	-0	1.147	1.01	1.161	1	**78.170**	**60.391**	**0.604**
9C	9Cg	7168	435.8	15.00	20	20	32	0	0	0	0	0	0	15.92	0.398	6.522	3.074	10.27	4.472	0.857	0.153	1.146	1.008	1.159	1	**88.715**	**67.628**	**0.676**
10A	10Cs	1241.6	112.7	35.00	20	20	32	0	0	0	0	0	0	8.396	0.633	8.488	6.308	16.98	4.472	0.452	0.363	1.26	1.187	1.357	1	**93.670**	**71.029**	**0.710**
10B	10Cg	1254.4	134.5	15.00	20	20	32	0	0	0	0	0	0	9.117	0.398	8.476	6.289	16.94	4.472	0.491	0.153	1.259	1.186	1.356	1	**90.767**	**69.037**	**0.690**
10C	10Ce	1286.4	243.4	5.00	20	20	32	0	0	0	0	0	0	12.05	0.226	8.448	6.242	16.84	4.472	0.649	-0	1.258	1.184	1.353	1	**90.719**	**69.004**	**0.690**
10D	10Cg	1254.4	148.2	15.00	20	20	32	0	0	0	0	0	0	9.537	0.398	8.476	6.289	16.94	4.472	0.514	0.153	1.259	1.186	1.356	1	**91.144**	**69.296**	**0.693**
11A	11Ccp	17536	1820.2	10.00	20	20	32	0	0	0	0	0	0	31.89	0.322	5.518	1.423	6.842	4.472	1.717	0.085	1.087	0.916	1.057	1	**97.734**	**73.818**	**0.738**
11B	11Ccp	17536	269.9	10.00	20	20	32	0	0	0	0	0	0	12.66	0.322	5.518	1.423	6.842	4.472	0.682	0.085	1.087	0.916	1.057	1	**80.474**	**61.973**	**0.620**
11C	11Ccp	17536	107.1	10.00	20	20	32	0	0	0	0	0	0	8.202	0.322	5.518	1.423	6.842	4.472	0.442	0.085	1.087	0.916	1.057	1	**76.475**	**59.228**	**0.592**
11D	11Ccp	17536	30.0	10.00	20	20	32	0	0	0	0	0	0	4.627	0.322	5.518	1.423	6.842	4.472	0.249	0.085	1.087	0.916	1.057	1	**73.267**	**57.026**	**0.570**
11E	None	#N/A	98.9	#N/A	20	20	32	0	0	0	0	0	0	7.905	#N/A	#N/A	#N/A	#N/A	4.472	0.426	#N/A	#N/A	#N/A	#N/A	1	**#N/A**	**#N/A**	**#N/A**
11F	None	#N/A	34.0	#N/A	20	20	32	0	0	0	0	0	0	4.889	#N/A	#N/A	#N/A	#N/A	4.472	0.263	#N/A	#N/A	#N/A	#N/A	1	**#N/A**	**#N/A**	**#N/A**
11G	11Ccg	18176	42.4	5.00	20	20	32	0	0	0	0	0	0	5.389	0.226	5.478	1.357	6.705	4.472	0.29	-0	1.085	0.913	1.053	1	**72.351**	**56.398**	**0.564**
11H	11Ccg	18176	75.1	5.00	20	20	32	0	0	0	0	0	0	6.969	0.226	5.478	1.357	6.705	4.472	0.375	-0	1.085	0.913	1.053	1	**73.769**	**57.371**	**0.574**
11I	11Ccg	18176	21.5	5.00	20	20	32	0	0	0	0	0	0	4.01	0.226	5.478	1.357	6.705	4.472	0.216	-0	1.085	0.913	1.053	1	**71.113**	**55.548**	**0.555**
11J	11Cc	18176	53.6	5.00	20	20	32	0	0	0	0	0	0	5.98	0.226	5.478	1.357	6.705	4.472	0.322	-0	1.085	0.913	1.053	1	**72.881**	**56.762**	**0.568**
11K	11Ccg	18176	17.5	5.00	20	20	32	0	0	0	0	0	0	3.685	0.226	5.478	1.357	6.705	4.472	0.198	-0	1.085	0.913	1.053	1	**70.822**	**55.348**	**0.553**
11L	11Cc	18176	99.1	5.00	20	20	32	0	0	0	0	0	0	7.912	0.226	5.478	1.357	6.705	4.472	0.426	-0	1.085	0.913	1.053	1	**74.616**	**57.952**	**0.580**
11M	11Ccg	18176	74.7	5.00	20	20	32	0	0	0	0	0	0	6.95	0.226	5.478	1.357	6.705	4.472	0.374	-0	1.085	0.913	1.053	1	**73.752**	**57.359**	**0.574**
11N	11Cc	18176	120.0	5.00	20	20	32	0	0	0	0	0	0	8.645	0.226	5.478	1.357	6.705	4.472	0.466	-0	1.085	0.913	1.053	1	**75.274**	**58.404**	**0.584**
11O	11Ccg	18176	62.3	5.00	20	20	32	0	0	0	0	0	0	6.398	0.226	5.478	1.357	6.705	4.472	0.345	-0	1.085	0.913	1.053	1	**73.257**	**57.019**	**0.570**
11P	11Ccg	18176	96.4	5.00	20	20	32	0	0	0	0	0	0	7.811	0.226	5.478	1.357	6.705	4.472	0.421	-0	1.085	0.913	1.053	1	**74.524**	**57.889**	**0.579**
11Q	11Cc	18176	167.4	5.00	20	20	32	0	0	0	0	0	0	10.1	0.226	5.478	1.357	6.705	4.472	0.544	-0	1.085	0.913	1.053	1	**76.579**	**59.299**	**0.593**
12A	12Cc	6720	273.2	5.00	20	20	32	0	0	0	0	0	0	12.73	0.226	6.594	3.193	10.51	4.472	0.686	-0	1.15	1.015	1.166	1	**83.595**	**64.115**	**0.641**
12B	12Cm	6720	601.6	5.00	20	20	32	0	0	0	0	0	0	18.59	0.226	6.594	3.193	10.51	4.472	1.001	-0	1.15	1.015	1.166	1	**88.858**	**67.726**	**0.677**
12C	12Cc	6720	506.0	5.00	20	20	32	0	0	0	0	0	0	17.1	0.226	6.594	3.193	10.51	4.472	0.921	-0	1.15	1.015	1.166	1	**87.519**	**66.808**	**0.668**
13A	13Cmhe	21312	688.4	10.00	20	20	32	0	0	0	0	0	0	19.85	0.322	5.3	1.064	6.096	4.472	1.069	0.085	1.075	0.897	1.035	1	**86.014**	**65.775**	**0.658**
13B	13Cml	21504	459.0	10.00	20	20	32	0	0	0	0	0	0	16.32	0.322	5.29	1.047	6.062	4.472	0.879	0.085	1.074	0.896	1.034	1	**82.806**	**63.573**	**0.636**
13C	13Cct	52.736	241.3	75.00	20	20	32	0	0	0	0	0	0	12	1.047	12.03	12.13	29.06	4.472	0.646	0.733	1.466	1.511	1.715	1	**117.848**	**87.622**	**0.876**
13D	13Ccsr	21760	257.1	5.00	20	20	32	0	0	0	0	0	0	12.37	0.226	5.276	1.025	6.017	4.472	0.666	-0	1.073	0.894	1.033	1	**77.774**	**60.119**	**0.601**
13E	13Cc	21760	395.2	10.00	20	20	32	0	0	0	0	0	0	15.19	0.322	5.276	1.025	6.017	4.472	0.818	0.085	1.073	0.894	1.033	1	**81.734**	**62.837**	**0.628**
13F	13Ccsr	21760	149.2	5.00	20	20	32	0	0	0	0	0	0	9.567	0.226	5.276	1.025	6.017	4.472	0.515	-0	1.073	0.894	1.033	1	**75.259**	**58.394**	**0.584**
13G	13Ccsr	21760	153.9	5.00	20	20	32	0	0	0	0	0	0	9.709	0.226	5.276	1.025	6.017	4.472	0.523	-0	1.073	0.894	1.033	1	**75.386**	**58.481**	**0.585**
15A	15Ccor	192	100.0	10.00	20	20	32	0	0	0	0	0	0	7.945	0.322	10.58	9.751	24.12	4.472	0.428	0.085	1.382	1.379	1.569	1	**97.366**	**73.566**	**0.736**
15B	15Ccgt	115.2	354.4	25.00	20	20	32	0	0	0	0	0	0	14.41	0.524	11.15	10.69	26.07	4.472	0.776	0.266	1.415	1.431	1.626	1	**108.565**	**81.252**	**0.813**
15C	None	#N/A	66.9	#N/A	20	20	32	0	0	0	0	0	0	6.611	#N/A	#N/A	#N/A	#N/A	4.472	0.356	#N/A	#N/A	#N/A	#N/A	1	**#N/A**	**#N/A**	**#N/A**
15D	15Ccor	192	229.8	10.00	20	20	32	0	0	0	0	0	0	11.73	0.322	10.58	9.751	24.12	4.472	0.631	0.085	1.382	1.379	1.569	1	**100.760**	**75.895**	**0.759**
15E	15Cce	44288	26.4	15.00	20	20	32	0	0	0	0	0	0	4.378	0.398	4.48	-0.29	3.297	4.472	0.236	0.153	1.027	0.822	0.953	1	**69.839**	**54.674**	**0.547**
15F	15Ccp	684.8	225.8	10.00	20	20	32	0	0	0	0	0	0	11.63	0.322	9.155	7.405	19.25	4.472	0.626	0.085	1.299	1.248	1.425	1	**94.723**	**71.752**	**0.718**

Table 2-8: Coastal Plain Physiographic Province BAC PHI Metrics and Scores																													
Stream		Metric Values Input						Left Bank Stability		Right Bank Stability		Transform Bank Severity		Prepare Metric Values						Scale Metric Values						Final Score	Normalize Final Score	Rescaled Final Score
Reach Code	Habiat Code	Watershed Area (acres)	Remoteness (meters)	%Shading	Epibenthic Substrate Score	Instream Habitat Score	Total No. Instream Woody Debris and Rootwads	Erosion Extent (meters)	Severity	Erosion Extent (meters)	Severity	Left	Right	REMOTE	TSHADING	RESEPISUB	RESINSTRHAB	RESWOOD	TBANKSTAN	REMOTE	TSHADING	RESEPISUB	RESINSTRHAB	RESWOOD	TBANKSTAN	Coastal Plain PHI	Normalized Coastal Plain PHI	Rescaled Coastla Plain PHI
15G	15Cce	44288	180.8	15.00	20	20	32	0	0	0	0	0	0	10.47	0.398	4.48	-0.29	3.297	4.472	0.564	0.153	1.027	0.822	0.953	1	**75.308**	**58.427**	**0.584**
15H	15TCm	486.4	498.2	35.00	20	20	32	0	0	0	0	0	0	16.98	0.633	9.539	8.036	20.56	4.472	0.914	0.363	1.321	1.283	1.463	1	**105.755**	**79.323**	**0.793**

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Attachment 3: Aggregate Benefits Tables

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ATTACHMENT 3: AGGREGATE BENEFITS

Table 3-1. Aggregate Benefits for Northwest Branch and Tributaries

Site	Length (ft)	Order	Project	Owner	Project Type	Completed	PHI	SHUs	PHI used	Data Source
3	626	3	NW6&7 - Woodrow Wilson bridge mitigation	SHA	Riffle/grade	2005	69.60	1306	PHI=Ave 2004 data for 09-005 (Tetra Tech; surrogate for PHI)	Tetra Tech monitoring data
3	221	3	NW8 - Woodrow Wilson Bridge mitigation	SHA	Riffle/grade	2004	74.50	495	PHI =2005 PHI for NW-8B and 8A average	Post Construction Monitoring Report, 2006
3	4291	3	Site 3 - Non-FRM impacted reach	USACE	Stream restoration	Design	54.06	6959	PHI=FWP Site 3	FWP
3	5597	3	Fish passage benefits upstream of site 13	N/A	N/A	N/A	72.62	12194	Feet in excess (not overlapping) site 3 length and connectivity = 16283, minus site 13 (7690) = 8593; PHI = average of 2010 data for 09-009 (Tetra Tech; surrogate for PHI); not selected by team due to high quality habitat	Tetra Tech monitoring data
3	2996	3	Fish passage benefits between sites 3 and 13	N/A	N/A	N/A	56.30	5060	PHI=average FWP for sites 3 and 13; not selected by team due to good quality habit	FWP Site 3 and 13
3	7690	3	Fish passage benefits for length of site 13*	USACE	Stream restoration	Design	40.57	9359	FWOP PHI for Site 13	FWOP for site 13 (so benefits not dependent on construction of site 13)
3	903	3	NW3-Woodrow Wilson Bridge mitigation	SHA	Riffle/grade	2004	67.00	1814	PHI = 2005 PHI for NW-3A and 3B average	Post Construction Monitoring Report, 2006
3	874	3	NW2-Woodrow Wilson Bridge mitigation	SHA	Riffle/grade	2003	60.50	1586	PHI = 2005 PHI for NW-2A and 2B average	Post Construction Monitoring Report, 2006
3	497	3	NWB1 - Woodrow Wilson Bridge mitigation	SHA	Riffle/grade	2003	58.50	871	PHI =2005 PHI for NW-1A and 1B average	Post Construction Monitoring Report, 2006
3	389	3	NW4, NW5 - Woodrow Wilson Bridge mitigation	SHA	Riffle/grade	2005	67.00	783	PHI=2005 PHI for NW-4B	Post Construction Monitoring Report, 2006
3	3523	3	USACE 1135 - Connects to downstream end of NWB1	USACE	Stream restoration, fish passage, riffle grade	1999	66.00	6976	PHI=2005 PHI for NW-0A	Post Construction Monitoring Report, 2006
3	2994	3	Site 3 - FRM Impacted Reach	USACE	Stream restoration	Design	55.00	4940	PHI=FWP	FWP
3	680	3	Gap Between NWB1 and NW2	N/A	N/A	N/A	40.08	818	PHI=ANAC-302-X-2000 (MDNR MBSS)	Maryland Biological Stream Survey
3	430	3	Gap Between NW2 and NW3	N/A	N/A	N/A	40.08	517	PHI=ANAC-302-X-2000 (MDNR MBSS)	Maryland Biological Stream Survey
9	319	2	Sligo Creek - SC - Woodrow Wilson Br mitigation	SHA	Fish passage	2004	58.33	372	PHI=average of 2010 data for 14-001 (Tetra Tech; surrogate for PHI); PHI is same as 2006 WW Br Mitigation data	Tetra Tech monitoring data; WW Br Mitigation Post Construction Monitoring Report, 2006
9	324	2	SC2 - Woodrow Wilson Br mitigation	SHA	Fish passage	2004	58.33	378	PHI=average of 2010 data for 14-001 (Tetra Tech; surrogate for PHI); PHI is same as 2006 WW Br Mitigation data	Tetra Tech monitoring data; WW Br Mitigation Post Construction Monitoring Report, 2006
9	107	2	SC3 - Woodrow Wilson Br mitigation	SHA	Fish passage	2004	58.33	125	PHI=average of 2010 data for 14-001 (Tetra Tech; surrogate for PHI); PHI is same as 2006 WW Br Mitigation data	Tetra Tech monitoring data; WW Br Mitigation Post Construction Monitoring Report, 2006
9	209	2	SC4 - Woodrow Wilson Br mitigation	SHA	Fish passage	2004	58.33	243	PHI=average of 2010 data for 14-001 (Tetra Tech; surrogate for PHI); PHI is same as 2006 WW Br Mitigation data	Tetra Tech monitoring data; WW Br Mitigation Post Construction Monitoring Report, 2006
9	2241	2	Site 9	USACE	Stream restoration	Design	60.40	2707	Site 9 fish passage benefits overlap with site 9 and connectivity, so include benefits for fish passage	FWP
9	515	2	GAP Between SC and SC2	N/A	N/A	N/A	48.21	497	PHI=Oct 1999 data for 14-001 (Tetra Tech; surrogate for PHI)	Tetra Tech monitoring data
9	240	2	GAP Between SC2 and SC3	N/A	N/A	N/A	48.21	231	PHI=Oct 1999 data for 14-001 (Tetra Tech; surrogate for PHI)	Tetra Tech monitoring data

Site	Length (ft)	Order	Project	Owner	Project Type	Completed	PHI	SHUs	PHI used	Data Source
9	100	2	GAP Between SC3 and SC4	N/A	N/A	N/A	48.21	96	PHI=Oct 1999 data for 14-001 (Tetra Tech; surrogate for PHI)	Tetra Tech monitoring data
10	2096	1	Site 10	USACE	Stream restoration	Design	62.51	1310	PHI = FWP Site 10	

Table 3-2. Aggregate Benefits for Northeast Branch and Tributaries

Site	Length (ft)	Order	Project	Owner	Project Type	Completed	PHI	SHUs	PHI used	Data Source
1	3257	1	Site 1 fish passage benefits upstream of Ammendale Rd	USACE	Stream restoration	Design	73.08	2380	Overlaps with upper portion of site 1	FWP
5	5040	3	USACE Paint Branch 206	USACE	Stream restoration	2015	55.36	8370	PHI = same as average for site 5.	Site 5 FWP
5	6453	3	Site 5	USACE	Stream restoration	Design	55.36	10717	Site 5 benefits	FWP
5	808	3	GAP between Paint CAP and Paint ICC	N/A	N/A	N/A	35.42	859	PHI = FWOP average Site 12 and Site 5	FWOP Sites 12 and 5
5	3488	2	Paint Branch/Little Paint Branch ICC	SHA	Stream restoration	2012/2013	66.67	4650	PHI = 08/30/2010 data for 05-208 (Tetra Tech; surrogate for PHI)	Tetra Tech monitoring data
5	215	3	Paint Branch WSSC Sewer Line Riffle	WSSC	Fish passage	2005	55.36	357	Restored section in the middle of site 5; PHI = FWP site 5	Average FWP Sites 5 and 15
7	5876	2	Site 7 counted for Fish passage benefits	USACE	Stream restoration	Design	54.25	6376	Site 7 along entire length for fish passage; PHI-FWP Site 7	FWP Site 7
11	1944	4	Indian Creek WSSC	WSSC	Fish passage, riffle/grade	2011	36.50	2838	PHI = ave FWOP and FWP Site 11 (improved habitat, but not to point of FWP since riffle grade by WSSC)	Extrapolated
11	419	4	Indian Creek 2002 - Woodrow Wilson Br mitigation	SHA	Stream restoration	2002	56.50	946	PHI= average of 2005 PHI for IC-1B and IC-1A	Post Construction Monitoring Report, 2006
11	400	4	GAP between IC2002 and Site 11	N/A	N/A	N/A	24.34	389	PHI=FWOP Site 11	FWOP Site 11
11	2723	4	Site 11 (lower portion - FRM)	USACE	Stream restoration	Design	46.24	5036	PHI = FWP Site 11 lower portion	FWP Site 11
11	7443	4	Site 11 (upper portion - non-FRM)	USACE	Stream restoration	Design	45.32	13493	PHI = FWP Site 11 upper portion	FWP Site 11
12	3488	2	Paint Branch/Little Paint Branch ICC	SHA	Stream restoration	2012/2013	66.67	4650	PHI = 08/30/2010 data for 05-208 (Tetra Tech; surrogate for PHI)	Tetra Tech monitoring data
12	4530	2	Site 12	USACE	Stream restoration	Design	52.04	4715	PHI = FWP Site 12	FWP Site 12
12	808	3	GAP between Paint CAP and Paint ICC	N/A	N/A	N/A	35.42	859	PHI = FWOP average Site 12 and Site 5	FWOP Sites 12 and 5
12	5040	3	USACE Paint Branch 206	USACE	Stream restoration	2015	55.36	8370	PHI = same as average for site 5.	FWP Site 5
15	1069	4	Site 15 (upper portion - FRM)	USACE	Stream restoration	Design	78.32	3349	PHI = FWP Site 15 upper portion	FWP Site 15
15	4450	4	Site 15 (lower portion - non-FRM)	USACE	Stream restoration	Design	68.12	12125	PHI = FWP Site 15 lower portion	FWP Site 15

Attachment 4: Physical Habitat Index Model Documentation

A. Model Recommendation Memo from Ecosystem Restoration Center of Expertise

B. Physical Habitat Assessment, Sampling Manual: Field Protocols, Revision January 2013

Maryland Department of Natural Resources
Maryland Biological Stream Survey

Selected Document Sections:
Section 3.5.9 Physical Habitat (in part)

C. A Physical Habitat Index For Freshwater Wadeable Streams in Maryland, May 2003

Maryland Department of Natural Resources

Selected Document Sections:
Methods: Sections 2.1 and 2.3
Results and Discussion: Sections 3.1, 3-1 to 3-20
Appendix B: 7-1 to 7-3

D. Physical Habitat Index- Maryland Biological Stream Survey

Data Sheets and Assessment Guidance

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DEPARTMENT OF THE ARMY
MISSISSIPPI VALLEY DIVISION, CORPS OF ENGINEERS
P.O. BOX 80
VICKSBURG, MISSISSIPPI 39181-0080

REPLY TO
ATTENTION OF:

CEMVD-PD-N 22 January, 2015

MEMORANDUM FOR CECW-NAD (Shuman)

SUBJECT: Recommendation for Single Use Approval of the MBSS Physical Habitat Index and MCDEP Rapid Habitat Assessment for the Montgomery County and Prince George's County Anacostia Watershed Ecosystem Restoration Feasibility Studies.

1. References:
   a. Engineering Circular 1105-2-412: Assuring Quality of Planning Models, dated 31 March 2010.

   b. US Army Corps of Engineers. Assuring Quality of Planning Models - Model Certification/Approval Process: Standard Operating Procedures. February 2012

   c. Model Approval Plan, Maryland Biological Stream Survey Habitat Assessment and Physical Habitat Index and Montgomery County Water Quality Monitoring Program Rapid Habitat Assessment, dated 11 April 2014 (Enclosure 1)

   d. Anacostia Watershed Assessment Model Documentation, October 2014 (Enclosure 2).

   e. Physical Habitat Assessment spreadsheet (Enclosure 3)

   f. Model Review Comment Response Record (Enclosure 4).

   g. Maryland Department of Natural Resources. 2003. A Physical Habitat Index for Freshwater Wadeable Streams in Maryland. Final Report. Chesapeake Bay and Watershed Programs. Monitoring and Non-tidal Assessment. CBWP-MANTA-EA-03-4.

   h. Maryland Department of Natural Resources. 2013. Sampling Manual: Field Protocols. Rev. Jan. 2013. Maryland Biological Stream Survey. Chesapeake Bay and Watershed Programs. Monitoring and Non-tidal Assessment. CBWP-MANTA-EA-07-01. 63 pages.

   i. Montgomery County Department of Environmental Protection. 1997. Montgomery County Water Quality Monitoring Program: Stream Monitoring Protocols.

   j. Montgomery County Department of Environmental Protection. Online. Accessed 23 October 2013. *Biological Monitoring Program* Design.

2. The National Ecosystem Restoration Planning Center of Expertise (ECO-PCX) evaluated the Maryland Biological Stream Survey Habitat Assessment and Physical Habitat Index (PHI) and Montgomery County Water Quality Monitoring Program Rapid Habitat Assessment (RHA) in accordance with References 1.a., 1.b., and the Model Approval Plan (Encl. 1). Based on the results of the evaluation, the ECO-PCX recommends single use approval of the PHI and RHA for the Anacostia Watershed Assessment Studies in Montgomery and Prince George's Counties, Maryland. Please log in this recommendation with the Office of Water Project Review for consideration by the Model Certification Team.

3. The Maryland Biological Stream Survey (MBSS) assesses the status and trends in the water chemistry, physical habitat, and biological condition of wadeable, non-tidal streams in Maryland. The MBSS has been collecting a variety of physical habitat measures for streams in the State since 1994. In 1999, the MBSS developed a provisional Physical Habitat Index (PHI) to synthesize those parameters into a single multimetric indicator of physical habitat quality. MBSS revised, updated, and finalized the PHI in 2003 (Reference. 1.g.), the latest field manual was published in 2013 (Reference 1.h.).

   Montgomery County Department of Environmental Protection (MCDEP) employs similar methods to assess local water quality conditions in the Rapid Habitat Assessment (RHA; References 1.i. and 1.j.) at more locations, and is therefore able to contribute finer-scale data to the State, which can be used to protect statewide water resources and the Chesapeake Bay. Within Montgomery County, the combined MBSS and MCDEP dataset is utilized in permitting and planning decisions. The data have been used to characterize the importance of numerous stressors upon aquatic life, and has identified thresholds of urban land use, percent impervious cover, acid pH, conductivity, and other variables applicable to streams in Maryland, including by County.

4. The ECO-PCX reviewed the technical quality, system quality and usability of the PHI for use in Prince George's County and the RHA for use in Montgomery County following procedures described by the Anacostia Watershed Assessment Procedures (Encl. 2 and 3). The review was conducted by Elliott Stefanik (MVP) and Dr. Bruce Pruitt (ERDC), and was managed by Dr. Charles Theiling (MVD). There were 14 comments including 3 critical comments (Enclosure 4). The comments addressed model documentation, scoring, normalization, reference sites, model sensitivity, and inclusion of appropriate parameters.

5. Model review comments were addressed to the satisfaction of the ECO-PCX. Model documentation was integrated into a single, project-specific procedures manual to help clarify methodology (Encl 2). Scores for the separate metrics were calculated using the State of Maryland methods and were then normalized and indexed on a 0 to 1 scale to provide a common scale for comparison. Reference sites and recommendations for using water quality parameters were addressed by more clearly identifying supporting background information. Scoring is sensitive to embeddedness and remoteness parameters. Sensitivity of model

outputs to these parameters should be considered during model application and reviewed during ATR.

6. The models facilitate forecasting of the future with- and without-project conditions due to their focus on physical parameters, and the assumptions used in creating the model are valid and supported in the literature. The underlying theory and relationships in the models reflect fundamental fluvial geomorphological principles which hold true and are valid in piedmont and coastal plains streams. The PHI and RHA provide indicators of habitat quality by measuring those physical factors which are known to affect fish communities. The RHA and PHI have been applied within the county and state, respectively, and were subsequently validated by empirical studies, showing a consistent relationship between model parameters and stream quality in the Anacostia River Watershed. The metric scoring criteria, formulas, and aggregations used to calculate final PHI and RHA scores are scientifically and mathematically valid within the range of conditions expected in the Anacostia River Watershed. Finally, the models comply with USACE policies, guidance, and procedures. The outputs can be readily used within our alternative evaluation, comparison, and selection process, and the model does not calculate non-ecological outputs.

7. The PHI has sufficient technical and system quality and usability. The PHI relies on field data sheets and quantitative formulae derived by Maryland DNR following common bio-assessment protocols. A spreadsheet incorporating best spreadsheet practices was developed by USACE Baltimore District to calculate the PHI score. The formulas used to calculate index scores are biologically accurate, computed in a straightforward manner, and computationally correct within the expected range encountered in the Anacostia River Watershed. Input scores, calculations, and output scores should be documented and ATR teams should be charged with reviewing the inputs, outputs, and checking computational correctness of model application. The remoteness parameter can have particularly strong influence on the model, but is not appreciably affected by project alternatives. Embeddedness also exerts a strong influence on the model and should be considered carefully by PDTs and ATR teams. Scores beyond the expected range can be encountered and should be reported to Maryland DNR as unique conditions.

   The PHI, which can be implemented statewide in Maryland piedmont streams, has acceptable usability in that the scoring of metrics and calculating an overall score is simple, and output interpretation is straightforward. Data required for input is available through field collection surveys. Model output is normalized to a score from 0-100, which is easily understandable. Scoring is rescaled on a 0 to 1 index to provide uniform and useful information in determining habitat quality to support habitat benefit evaluations.

8. The RHA has sufficient technical quality and usability. The RHA relies on field data sheets and hand calculations (i.e., no software currently exists) to produce an index score. However, the method used to calculate index scores is biologically accurate, computed in a straightforward manner, and computationally correct. Input scores, calculations, and output

scores should be documented and ATR teams charged with reviewing the inputs, outputs, and ensuring computational correctness during application of the model.

The RHA, which can be implemented in Montgomery County only, has acceptable usability in that the scoring of metrics and calculating an overall score is simple, and output interpretation is straightforward. Data required for input is available through field collection surveys. Model output is a score from 0-200, which is understandable. Scoring is rescaled on a 0 to 1 score to provide uniform and useful information in determining habitat quality to support habitat benefit evaluations.

9. The PHI and RHA are comparable metrics when transformed to habitat suitability scores fitting a 0 – 1 scale. Changes in habitat suitability due to restoration would be expected to increase habitat suitability index scores and provide higher habitat unit benefits in restoration project areas.

10. MBSS and Montgomery County require training or certification to implement PHI and RHA.

11. In summary, the ECO-PCX finds the Maryland Biological Stream Survey Habitat Assessment and Physical Habitat Index and Montgomery County Water Quality Monitoring Program Rapid Habitat Assessment meet the technical and system quality criteria, meet usability criteria for Anacostia Watershed Assessment following the procedures developed for the project, and complies with USACE policy and guidance. It is the recommendation of the ECO-PCX that the models be approved for single use on the Anacostia Watershed Restoration Studies. ATR teams assigned to projects using the RHA and PHI should be charged with reviewing the application of the model and checking computational correctness of outputs. Please notify the ECO-PCX of the findings of the Model Certification Panel.

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Encl (4)

Marshall Plumley
Operating Director, Ecosystem Restoration
Planning Center of Expertise

CF (w/ enclosures):
CECW-PC (Coleman, Matusiak, Trulick, Ware, Bee)
CECW-PB (Carlson)
CECW-CP (Hughes)
CECW-NAD (Hannon, Wimbrough)
CENAD-PD (Vietri, Weichenberg, Henn, Jones)
CENAB-PL (Bierly, Guise, Roach, Spaur, Sowers)
CENAB-PP-C (Nolta, Gross)
CEMVD-PD-N (Wilbanks, Lachney, Young, Plumley)
CEMVP-PD-P (Richards, Theiling)

Attachment 4-B

Physical Habitat Assessment
Sampling Manual: Field Protocols
Revision January 2013

Maryland Department of Natural Resources
Maryland Biological Stream Survey

Selected Document Sections

A. Section 3.5.9 Physical Habitat (in part)

A. Physical Habitat Assessment, Sampling Manual: Field Protocols, Revision January 2013
Maryland Department of Natural Resources Maryland Biological Stream Survey
Selected Document Sections: Section 3.5.9 Physical Habitat (in part)

3.5.9 Physical Habitat

Physical habitat assessments conducted by MBSS are intended to represent the habitat conditions available to the organisms living in the streams and to report on the extent to which certain anthropogenic factors may be affecting Maryland's streams. MBSS Habitat assessment protocols are based on a combination of metrics modified and adapted from USEPA's Rapid Bioassessment Protocols (RBP) and Ohio EPA's Qualitative Habitat Evaluation Index (QHEI). Although EPA's RBP habitat assessment protocols differentiate between riffle-run and pool-glide stream types, all metrics selected for the MBSS are scored at all MBSS sample sites to allow direct comparisons across physiographic regions and summaries of conditions on a statewide basis.

Certain MBSS physical habitat variables are recorded based on counts, measurements, or estimates made in the field. These variables include distance from nearest road to site, width of riparian buffer, stream gradient, width, depth, velocity, culvert width and length, extent and height of eroded bank, numbers of woody debris and root wads, extent of channelization, percent embeddedness, and percent shading. The quality of five habitat assessment metric variables along with the severity of bank erosion, buffer breaks, and bar formation are rated using standardized MBSS rating methods. The collection of data on certain other habitat variables are based on the observation (or not) of certain conditions such as buffer breaks, land use types, and evidence of channelization. Based on observations at sites, the absence, presence or extensive presence of stream character and bar substrate is recorded. The type and relative size of riparian vegetation and the type of land cover adjacent to the buffer are reported using standard MBSS codes. The method used for collecting data in the field for each variable differs based on the expected use of each variable as well as optimizing the time required to collect useable information.

Data sheet entries for all physical habitat variables are based on observations within or from the 75 m site only, unless otherwise stated below.

In all cases where it is necessary to differentiate the left bank of the stream from the right bank, the left and right are determined while facing upstream.

Only persons who have attended MBSS training and have demonstrated proficiency with performing MBSS physical habitat assessments should conduct MBSS physical habitat assessments.

Most MBSS physical habitat assessment information is collected during the Summer Index Period.

3.5.9.2 Summer Index Period Physical Habitat Assessment

The physical habitat assessment variables recorded during the Summer Index Period can be found on the MBSS Summer Habitat Data Sheet and should be recorded on this sheet. The methods used to determine exactly what should be recorded for each variable are described, by variable, below. Data sheet entries for all Summer Index Period physical habitat variables are based on observations within or from the 75 m site only, unless otherwise specified.

In all cases where it is necessary to differentiate the left bank of the stream from the right bank, the left and right are determined while facing upstream.

Many of the summer physical habitat assessment measures require sufficiently clear water to observe the stream bottom throughout the majority of the 75 m site. If conditions do not allow sufficient visibility to see all of the features that must be observed, or if conditions are unsafe for wading, the site should be considered unsampleable for physical habitat. In many cases, the stream may be sampleable during a return visit when the water level is lower. However, if the stream cannot be sampled for summer physical habitat assessment, this should be noted on the Summer Index Period Data Sheet. Codes designating reasons that a stream could not be sampled are provided on page 43.

1. **Habitat Assessment Metrics.** Five metrics: instream habitat, epifaunal substrate, pool quality, riffle quality, and velocity depth diversity are rated on a scale of 0-20 using criteria provided on the Habitat Assessment Guidance Sheet (pages 44 and 45). The scores for each of these metrics are meant to characterize a distinct aspect of stream habitat. The instream habitat metric primarily addresses habitat for fishes and epifaunal substrate is meant to rate the suitability of habitat for benthic macroinvertebrates. The general quality of riffle and pool habitats are rated based primarily on the prevalence of sufficient depth and extent of these habitats. Velocity/depth/diversity provides a measure of the how well fast, slow, deep, and shallow areas are represented in the stream.

2. **Embeddedness.** The percent of riffle substrates surrounded by fine substrates, such as sand and silt, is recorded based on visual observation. Riffle substrates that are examined should include the area with the fastest flow within riffle or run habitats. If no riffle is present within the 75 m site, embeddedness can be rated based on the closest available riffle located in the same reach as the site (but should not be more than 75 m away from the upstream or downstream end of the site). Several substrates should be examined within the riffle to determine the approximate average condition within the fast part of the riffle. Substrates should be examined for embeddedness prior to disturbances (such as walking or netting) that are likely to dislodge fine materials from around larger substrate.

3. **Shading.** The percent of the wetted area of the 75 m site that is shaded by overhanging vegetation or other structures is approximated based on a visual assessment. If clearing of vegetation was conducted to facilitate electrofishing, or for any other reason, shading should be rated based on the condition prior to clearing.

4. **Woody Debris.** For the MBSS, large woody debris are defined as any natural woody structures (e.g. logs, snags, dead tree trunks), with the exception of live trees that are at least 10 cm in diameter and more than 1.5 m long. The number of large woody debris, located in the wetted portion of the 75 m stream site (instream woody debris), is counted. The number of large woody debris in the stream channel or immediate riparian area, but not in the wetted portion of the stream (dewatered woody debris) are counted separately from instream woody

debris. Only those dewatered woody debris from the immediate riparian area that (in the opinion of the evaluator) are likely to become wetted during high flows, or fall into the stream channel should be counted.

5. **Root Wads.** For the MBSS, root wads that are on live trees with a chest high trunk diameter (DBH) of at least 15 cm should be counted. These should be counted along both banks of the stream within the 75 m site. Those root wads that are in the water (instream) are counted separately from those not in the stream (dewatered). However, only those dewatered root wads that provide stability to the stream bank or that are likely to become wetted during high flows should be counted.

6. **Stream Character.** The Stream Character portion of the MBSS Summer Habitat Data Sheet lists 15 stream features. For each feature, an A, P, or E should be recorded in the box next to the feature indicating whether the feature is absent, present, or extensive respectively in the 75 m stream site.

7. **Maximum Depth.** The maximum depth of the MBSS site is considered the deepest area found anywhere within the 75 m. Maximum depth is recorded to the nearest cm.

8. **Wetted Width, Thalweg Depth, and Thalweg Velocity.** The wetted width, thalweg depth and thalweg velocity are measured at four transects within the 75 m MBSS site. The four transects are located at the 0 m, 25 m, 50 m, and 75 m portions of the MBSS site (beginning with 0m at the downstream-most end of the site). Wetted width is measured from bank to bank (perpendicular to the direction of the stream flow) to the nearest 0.1 m and includes only the wetted portion of the stream. Islands or other large features in the stream that would not be covered by water during higher base-flow should not be included in the measurement of wetted width. Features that would be covered by water (during higher base-flow should be included in the wetted width measurement. Thalweg depth is the depth (in cm) of the deepest part of the stream at each transect. Thalweg velocity is the stream current velocity (in m/sec) in the deepest part of the stream at each transect.

9. **Flow.** Measurements that can be used to calculate flow (often referred to as discharge) are recorded on the MBSS Summer Habitat Data Sheet. A transect that is suitable for taking these measurements should be located. A suitable transect approximates a "U" shaped channel to the extent possible. The most useful measurements are acquired by avoiding transects with boulders or other irregularities that create backflows and cross flows. The stream channel can be modified to more closely approximate a "U" shaped channel and provide laminar flow with adequate depth for taking velocity measurements. Unless the stream is very small (less than 0.5 m wide), a minimum of 10 measurements should be taken. As many as 25 measurements can be recorded on the MBSS Summer Habitat Data Sheet. In general, more measurements are required in larger streams. The measurements consist of depth (to the nearest 0.5 cm) and velocity (to the nearest 0.001 m/sec) and should be recorded at regular intervals. Velocity measurements should be taken at 0.6 of the distance from the water surface to the bottom (measured from the surface), making sure to orient the sensor to face upstream and taking care to stand well downstream to avoid deflection of flows. Depth and velocity measurements should be taken at the exact same locations. The Lat Loc on the MBSS Summer Habitat Data Sheet refers to the distance from one stream bank (either left or right) where each depth and velocity measurement is taken.

10. **Alternative Flow**. If flows are so low that they can not be measured with a flow meter,

the stream should be constricted as much as possible in a 1 meter section of uniform width and depth. The speed of a floated object should be recorded three times as a substitute for velocity measured with the flow meter. Record on the data sheet the depth, width, and time (3 trials) for the floated object.

11. **Bank Erosion.** The length and average height of erosion on both banks of the stream, within the 75 m site should be recorded along with the severity of erosion, on the MBSS Summer Habitat Data Sheet. In braided streams it is possible to have the total extent of eroded bank add up to more than 75 m. Since the objective of this measure is to determine the total area of erosion present at the site, this is acceptable.

12. **Bar Formation and Substrate**. Boxes in this portion of the MBSS Summer Habitat Data Sheet should be filled in completely to indicate if the bar formation is absent (fill in the box next to "None"), minor, moderate, or extensive; and the dominant substrate type(s) that make up the bars in the site. More than one substrate can be selected. However substrates comprising only a minor part of the substrate should not be selected.

Attachment 4-C

A Physical Habitat Index For Freshwater Wadeable Streams in Maryland

Maryland Department of Natural Resources

May 2003
Selected Document Sections

A. **Methods: Sections 2.1 and 2.3**
B. **Results and Discussion: Sections 3.1, 3-1 to 3-20**
C. **Appendix B: 7-1 to 7-3**

2 METHODS

2.1 Physical Habitat Index Revision

Revising the PHI consisted of classifying streams in the state, developing a new set of reference criteria that did not include any biological variables, analyzing the physical habitat metrics statistically for normality and transforming as necessary, selecting discriminatory habitat metrics that were free of watershed area effects, assembling the metrics into a new multimetric physical habitat index, testing the new index for discrimination efficiency and association with biological indices, and comparing it to the provisional PHI. Physical habitat data were collected by the MBSS from 1994-2000 and methods for the collection of these data have been extensively described elsewhere (Roth et al. 1999). A list of the physical habitat data collected for each site by sampling periods is shown in Table 1. Habitat variables are shown along with the nature of the data (character or numeric) and what aspect of habitat is reflected by each variable.

We used general level III ecoregions as the main classification of streams, consistent with the MBSS program (Omernik 1987, Roth et al. 1999). We used the Piedmont and Coastal Plain regions and combined all other ecoregions in the state into a Highlands class.

After streams were classified, we developed new reference criteria for establishing reference habitat characteristics. We relied on land use/land cover values to develop reference and degraded stream criteria for selecting reference streams. Land use/land cover analysis and data are described in Roth et al. (1999).

Table 1 – Habitat variables collected during the three MBSS study periods. The types of data as well as the habitat feature represented by each measure are also indicated. (LCLU = land cover/land use, Data Types: Char = character, Num = numeric)

Variable	Feature	1994	1995-1997	2000	Data Type
1	Site Info	SITE	SITE	SITEYR	Char
2	Site Info	LAT	LAT	LAT_DD	Num
3	Site Info	LONG	LONG	LONG_DD	Num
4	Site Info	NORTHING	NORTHING	NORTHING	Num
5	Site Info	EASTING	EASTING	EASTING	Num
6	Catchment Size	ACREAGE	ACREAGE	ACRES	Num
7	LCLU-Catchment	URBAN	URBAN	URBAN	Num
8	LCLU-Catchment	AGRI	AGRI	AGRI	Num
9	LCLU-Catchment	FOREST	FOREST	FOREST	Num
10	LCLU-Catchment		WETLANDS	WETLANDS	Num
11	LCLU-Catchment		BARREN	BARREN	Num
12	LCLU-Catchment		WATER	WATER	Num
13	LCLU-Catchment		HIGHURB		Num
14	LCLU-Catchment		LOWURB	LOW_URB	Num
15	LCLU-Catchment		PASTUR	HAYPAST	Num
16	LCLU-Catchment		PROBCROP		Num
17	LCLU-Catchment		ROWCROP	ROWCROP	Num
18	LCLU-Catchment		CONIFER	CONIFOR	Num
19	LCLU-Catchment		DECIDFOR	DECIDFOR	Num
20	LCLU-Catchment		MIXEDFOR	MIXEDFOR	Num
21	LCLU-Catchment		EMERGWET	EMERWET	Num
22	LCLU-Catchment		WOODYWET	WOODWET	Num
23	LCLU-Catchment		COALMINE		Num
24	LCLU-Catchment		TRANS	TRANS	Num
25	LCLU-Catchment			OTHGRASS	Num
26	LCLU-Catchment			HIGH_RES	Num
27	LCLU-Catchment			HIGH_COM	Num
28	LCLU-Catchment			BAREROCK	Num
29	LCLU-Catchment			QUARRY	Num
30	LCLU-Reach	OLD_FLD	OLD_FLD	OLD_FLD	Char
31	LCLU-Reach	DEC_FOR	DEC_FOR	DEC_FOR	Char
32	LCLU-Reach	CONI_FOR	CONI_FOR	CONI_FOR	Char
33	LCLU-Reach	WETLAND	WETLAND	WETLAND	Char
34	LCLU-Reach	SURFMINE	SURFMINE	SURFMINE	Char
35	LCLU-Reach	LANDFILL	LANDFILL	LANDFILL	Char
36	LCLU-Reach	RESIDENT	RESIDENT	RESIDENT	Char
37	LCLU-Reach	COMM_IND	COMM_IND	COMM_IND	Char
38	LCLU-Reach	CROPLAND	CROPLAND	CROPLAND	Char
39	LCLU-Reach	PASTURE	PASTURE	PASTURE	Char
40	LCLU-Reach	ORCH_VIN	ORCH_VIN	ORCH_VIN	Char
41	LCLU-Reach			GOLF	Char
42	Hydrology		THAVEL0	THALVE0	Num

Table 1 (continued).

Variable	Feature	1994	1995-1997	2000	Data Type
43	Hydrology		THAVEL25	THALVE25	Num
44	Hydrology		THAVEL50	THALVE50	Num
45	Hydrology		THAVEL75	THALVE75	Num
46	Hydrology		DISCHARG	DISC_CFS	Num
47	Geomorphology			GRAD	Num
48	Geomorphology	SEG_LEN		SEG_LEN	Num
49	Geomorphology	MAXDEPTH	MAXDEPTH	MAXDEPTH	Num
50	Geomorphology			STWID_0	Num
51	Geomorphology			STWID_75	Num
52	Geomorphology	WETWID0	WETWID0	WETWID0	Num
53	Geomorphology	WETWID25	WETWID25	WETWID25	Num
54	Geomorphology	WETWID50	WETWID50	WETWID50	Num
55	Geomorphology	WETWID75	WETWID75	WETWID75	Num
56	Geomorphology	THADEP0	THADEP0	THALDE0	Num
57	Geomorphology	THADEP25	THADEP25	THALDE25	Num
58	Geomorphology	THADEP50	THADEP50	THALDE50	Num
59	Geomorphology	THADEP75	THADEP75	THALDE75	Num
60	Geomorphology	FLOODHT			Num
61	Geomorphology			TURB_FLD	Num
62	Geomorphology	VEL_DPTH	VEL_DPTH	VEL_DEPT	Num
63	Geomorphology	POOLQUAL	POOLQUAL		Num
64	Geomorphology			POOLGLID	Num
65	Geomorphology			EXPOOL	Num
66	Geomorphology	RIFFQUAL	RIFFQUAL		Num
67	Geomorphology			RIFFLRUN	Num
68	Geomorphology			EXRIFRUN	Num
69	Geomorphology	EMBEDDED	EMBEDDED	EMBED	Num
70	Geomorphology			CONCR_L	Num
71	Geomorphology			CONCR_B	Num
72	Geomorphology			CONCR_R	Num
73	Geomorphology			GABIO_L	Num
74	Geomorphology			GABIO_B	Num
75	Geomorphology			GABIO_R	Num
76	Geomorphology			RIPRP_L	Num
77	Geomorphology			RIPRP_B	Num
78	Geomorphology			RIPRP_R	Num
79	Geomorphology			BERM_L	Num
80	Geomorphology			BERM_B	Num
81	Geomorphology			BERM_R	Num
82	Geomorphology			DREG_L	Num
83	Geomorphology			DREG_B	Num
84	Geomorphology			DREG_R	Num
85	Geomorphology			PIPE_L	Num
86	Geomorphology			PIPE_B	Num

Table 1 (continued).

Variable	Feature	1994	1995-1997	2000	Data Type
87	Geomorphology			PIPE_R	Num
88	Geomorphology			CULVPRES	Num
89	Geomorphology			CULVSAMP	Num
90	Geomorphology			CULVWID	Num
91	Geomorphology	CHAN_ALT	CHAN_ALT		Num
92	Geomorphology	CH_FLOW	CH_FLOW		Num
93	Geomorphology	BANKSTAB	BANKSTAB		Num
94	Geomorphology		BANKHTFH		Num
95	Geomorphology		BANKANGL		Num
96	Geomorphology		BANKROOT		Num
97	Geomorphology		BANKSOIL		Num
98	Geomorphology		PARTSIZE		Num
99	Geomorphology		ERODIND5		Num
100	Geomorphology		ERODIND3		Num
101	Geomorphology			ERODEXLT	Num
102	Geomorphology			ERODEXRT	Num
103	Geomorphology			ERODSVLT	Num
104	Geomorphology			ERODSVRT	Num
105	Geomorphology			ERODARLT	Num
106	Geomorphology			ERODARRT	Num
107	Geomorphology			BAR_NONE	Num
108	Geomorphology			BAR_MIN	Num
109	Geomorphology			BAR_MOD	Num
110	Geomorphology			BAR_EXT	Num
111	Geomorphology			COB_BAR	Num
112	Geomorphology			GRAV_BAR	Num
113	Geomorphology			SAND_BAR	Num
114	Geomorphology			SC_BAR	Num
115	Wood	WOOD_DEB	WOOD_DEB	WOODINST	Num
116	Wood			WOODDEWA	Num
117	Wood		NUMROOT	ROOTINST	Num
118	Wood			ROOTDEWA	Num
119	Visual Habitat	INSTRHAB	INSTRHAB	INSTRHAB	Num
120	Visual Habitat	EPI_SUB	EPI_SUB	EPI_SUB	Num
121	Stream Character	MEANDER	MEANDER		Char
122	Stream Character	BRAIDED	BRAIDED	BRAIDED	Char
123	Stream Character	CHANNEL	CHANNEL	CHAN_YN	Char
124	Stream Character	STRAIGHT	STRAIGHT		Char
125	Stream Character	RIFFLE	RIFFLE	RIFFLE	Char
126	Stream Character	RUN_GLID	RUN_GLID	RUNGLIDE	Char
127	Stream Character	DEEPPOOL	DEEPPOOL	DEEPOOL	Char
128	Stream Character	SHALPOOL	SHALPOOL	SHALPOOL	Char
129	Stream Character	BOULDGT2	BOULDGT2	LRGBOULD	Char
130	Stream Character	BOULDLT2	BOULDLT2	SMLBOULD	Char

Table 1 (continued).

Variable	Feature	1994	1995-1997	2000	Data Type
131	Stream Character	COBBLE	COBBLE	COBBLE	Char
132	Stream Character	BEDROCK	BEDROCK	BEDROCK	Char
133	Stream Character	GRAVEL	GRAVEL	GRAVEL	Char
134	Stream Character	SAND	SAND	SAND	Char
135	Stream Character	SILTCLAY	SILTCLAY	SILTCLAY	Char
136	Stream Character	CONCRETE	CONCRETE		Char
137	Stream Character	ROOTWAD	ROOTWAD		Char
138	Stream Character	UNDCTBNK	UNDCTBNK	UNDERCUT	Char
139	Stream Character	OH_COVER	OH_COVER	OH_COVER	Char
140	Stream Character	H_REFUSE	H_REFUSE		Char
141	Stream Character	EMER_VEG	EMER_VEG	EMRPLANT	Char
142	Stream Character	SUBM_VEG	SUBM_VEG		Char
143	Stream Character	FLOATVEG	FLOATVEG	FLTPLANT	Char
144	Stream Character	STORMDRN	STORMDRN		Char
145	Stream Character	EFF_DIS	EFF_DIS		Char
146	Stream Character	BEAVPOND	BEAVPOND	BEAVPND	Char
147	Stream Blockage	ST_BLKHT	ST_BLKHT	ST_BLKHT	Num
148	Stream Blockage	ST_BLKTP	ST_BLKTP	ST_BLKTP	Char
149	Riparian Condition	SHADING	SHADING	SHADING	Num
150	Riparian Condition	RIP_WID	RIP_WID	RV_WID_L	Num
151	Riparian Condition			RV_WID_R	Num
152	Riparian Condition	BUFF_TYP	BUFF_TYP		Char
153	Riparian Condition	ADJ_COVR	ADJ_COVR	ADJ_CV_L	Char
154	Riparian Condition			ADJ_CV_R	Char
155	Riparian Condition			RV_BU_BL	Char
156	Riparian Condition			RV_BU_BR	Char
157	Riparian Condition			VEG_T_1L	Char
158	Riparian Condition			VEG_T_2L	Char
159	Riparian Condition			VEG_T_3L	Char
160	Riparian Condition			VEG_T_4L	Char
161	Riparian Condition			VEG_T_1R	Char
162	Riparian Condition			VEG_T_2R	Char
163	Riparian Condition			VEG_T_3R	Char
164	Riparian Condition			VEG_T_4R	Char
165	Riparian Condition			BRKTYPE	Char
166	Riparian Condition			BRK_SIDE	Char
167	Riparian Condition			BRK_SEV	Char
168	Riparian Condition			MULTFLOR	Char
169	Riparian Condition			MILEMIN	Char
170	Riparian Condition			JHONEY	Char
171	Riparian Condition			RCANGRAS	Char
172	Riparian Condition			THISTLE	Char
173	Riparian Condition			EXO_OTHE	Char
174	Remoteness	REMOTE	REMOTE		Num

Table 1 (continued).

Variable	Feature	1994	1995-1997	2000	Data Type
175	Remoteness			DIST_RD	Num
176	Aesthetics	AESTHET	AESTHET	AESTHET	Num

Once streams were classified and new reference criteria developed, we examined and transformed the physical habitat metrics for use in the multimetric habitat index. The databases from the three sampling periods (1994, 1995-1997, and 2000) were merged and numerically and visually examined for statistical distributions (central tendency and variance) and adherence to assumptions of normality and equal error variance. Several metrics required transformations to meet those assumptions (Table 2). In addition, there were some differences in the way habitat metrics were measured among the 3 collection periods. We calibrated two metrics (erosion index and remoteness) to make them comparable among sampling periods. Lastly, some riparian land use, habitat, and substrate data consisted of discrete presence/absence values. These were difficult to model using a parametric statistical approach and were combined into a percentage of the different land use, habitat, and substrate types present at a site to approximate more continuous variable behavior (Table 2).

We looked at the spatial dependence of metrics using standard pearson correlation analysis of each metric with watershed area. Watershed areas had been calculated by the MBSS (e.g. Roth et al. 1999) and areas were plotted against each metric for reference sites. For metrics exhibiting spatial dependence, a regression model was built to predict the metric value for each site based on watershed area. The residuals from this prediction were then used as the value for that metric. Conceptually, degraded sites would have larger or smaller residuals than reference sites, whose mean residuals should be equal to zero. Table 2 lists metrics requiring spatial modeling. Metrics not showing spatial dependence were not modeled this way.

Once reference sites for each stream class were identified, the data prepared, transformed, and corrected for spatial dependence, individual metrics were rescaled from 0 to 100 (Barbour et al. 1999). For metrics decreasing with degradation, we calculated the scaled metric value using the formula:

$$\text{Metric}_{\text{scale}} = \frac{(\text{value}) - (\text{min})}{(95^{\text{th}}\ \text{Percentile}) - (\text{min})} \times 100$$

where min = minimum value for that metric and the 95^{th} percentile is the 95^{th} percentile of the metric values. For metrics that increased in value with degradation, we used the formula:

$$\text{Metric}_{\text{scaled}} = \frac{(\text{max}) - (\text{value})}{(\text{max}) - (5^{\text{th}}\ \text{percentile})} \times 100$$

where max = maximum value for that metric and 5^{th} percentile is the 5^{th} percentile of metric values.

Once the metrics were properly scored, we evaluated their ability to discriminate between reference and degraded sites in each stream class. We used box and whisker plots to analyze the distributions of scores in reference and degraded streams and calculated discrimination efficiencies for each metric (discrimination efficiency = percent of degraded site scores below the 25^{th} percentile of reference site scores)(Barbour et al. 1999).

Table 2 - Variables used for building metrics. The variables listed are the ones that could be normalized. Transformations used for transformed variables are shown, along with the formulae for calculating new variables and variables transformed for comparability among years.

Variable	Description (Transformation)
TACRE	Watershed area (common log)
FORLU	Adjacent forested land use
SINUOUS	Sinuosity
MAXDEPTH	Maximum depth
WETWID	Wetted width
THADEP	Thalweg depth
WIDDEP	Wetted width/Thalweg depth
VELDEP	Velocity/depth quality
POOLQUAL	Pool quality
RIFFQUAL	Riffle quality
EMBEDDED	Embeddedness
TBANKSTAB	Transformed bank stability (square root)
WOOD	Instream Wood
INSTRHAB	Instream Habitat
EPISUB	Epibenthic substrate
SUBSTR	Substrate
HAB	Habitat
TSHAD	Transformed percent shading (arc-sine square-root)
RIPWID	Riparian width
REMOTE	Remoteness
AESTHET	Aesthetics

FORLU = percent of adjacent forest types present (old field, deciduous forest, coniferous forest, wetland).
SINUOUS = Straight line distance of upstream to downstream ÷ 75m.
BANKSTAB = MBSS 2000 erosion extent was converted to 0-20 score bank stability using the formula:

$$= \left[\frac{\text{(Erosion Extent)}}{-15} \times \text{(Severity)} \right]_{\text{left bank}} + \left[\frac{\text{(Erosion Extent)}}{-15} \times \text{(Severity)} \right]_{\text{right bank}} + 20$$

SUBSTR = Percent of substrate types present in Coastal Plain (cobble, gravel, sand, and silt/clay), Piedmont (small boulder, cobble, gravel, sand, silt/clay), and Highland (bedrock, large boulders, small boulders, cobble, gravel, sand, and silt/clay) streams.
HAB = percent of habitat types present (riffle, run/glide, deep pools, shallow pools, undercut banks, overhanging cover).
REMOTE = MBSS 2000 distance to road was converted to a 0-20 remoteness score using the equation:

$$= 0.615 + 0.733\sqrt{\text{meters from road}}$$

Of the most discriminating metrics, we selected the set that was least redundant (avoiding an abundance of highly correlated metrics) and reflected the largest diversity of habitat characteristics. The scores for these metrics were averaged to calculate a final physical habitat index (PHI) score for each site within each stream class.

Once the final PHI was calculated for each site, we looked for watershed area effects in final scores among the reference sites by measuring correlation between watershed area and the final PHI scores. Variables exhibiting watershed area effects were corrected using regression analysis. After investigating for area effects, we looked at the discrimination efficiency of the overall PHI scores by looking at both box and whisker distribution plots of scores in reference and degraded sites and calculating the percent discrimination efficiency as the percentage of degraded sites scoring below the 25^{th} percentile of the reference scores.

We investigated the relationship between the new PHI developed here and the provisional PHI (Hall et al. 2000) using regression analysis. We developed and equation for converting between the different PHI values as well and we measured the root mean square error of the regression to estimate the error involved in predicting the provisional PHI value from the revised value. We also compared correlations between each of the habitat indices and the fish and benthic indices to compare the indices.

We looked at the relationship between the PHI and the fish index of biological integrity (FIBI, Roth et al. 1997, 1998, 2000) and the benthic index of biological integrity (BIBI, Stribling et al. 1998) using correlation analysis. We looked at these relationships statewide, within each stream class, and then by major river basin. Finally, we constructed multiple regression models to predict FIBI and BIBI scores using a variety of chemical measures (pH, acid neutralizing capacity, nitrate and sulfate concentration, conductivity, dissolved oxygen, and mean temperature) and the PHI. Chemistry data were collected by MBSS (Roth et al. 1999). We used the forward-stepwise selection method, and limited the models to 4 final variables.

2.3 Statistical Analysis

Statistical analyses were made using standard visual and numeric analysis techniques along with correlation analysis, simple linear regression, and multiple linear regression with Statistica 5.0 software (Statsoft 1995, Zar 1999).

3 RESULTS AND DISCUSSION

3.1 Physical Habitat Index Revision

We investigated a number of different stream classifications for the state. We originally split study sites into Coastal Plain and Non-Coastal Plain sites, consistent with the original PHI approach. Non-Coastal Plain sites consisted of the Piedmont, Blue Ridge, Valley and Ridge, and Appalachian Plateau (Figure 1). Seeing as the Piedmont represents nearly a third of the state and has markedly different soils and land use history, we added the Piedmont region as a third class of streams and combined the remaining non-Coastal Plain sites into a Highlands class in our final classification. An additional reason for distinguishing the Piedmont class was that original reference criteria for the non-Coastal Plain sites led to a predominance of Highland streams serving as reference sites for the whole non-Coastal Plain class. Because Piedmont streams were so underrepresented, we were concerned that the two class approach would be biased against Piedmont streams.

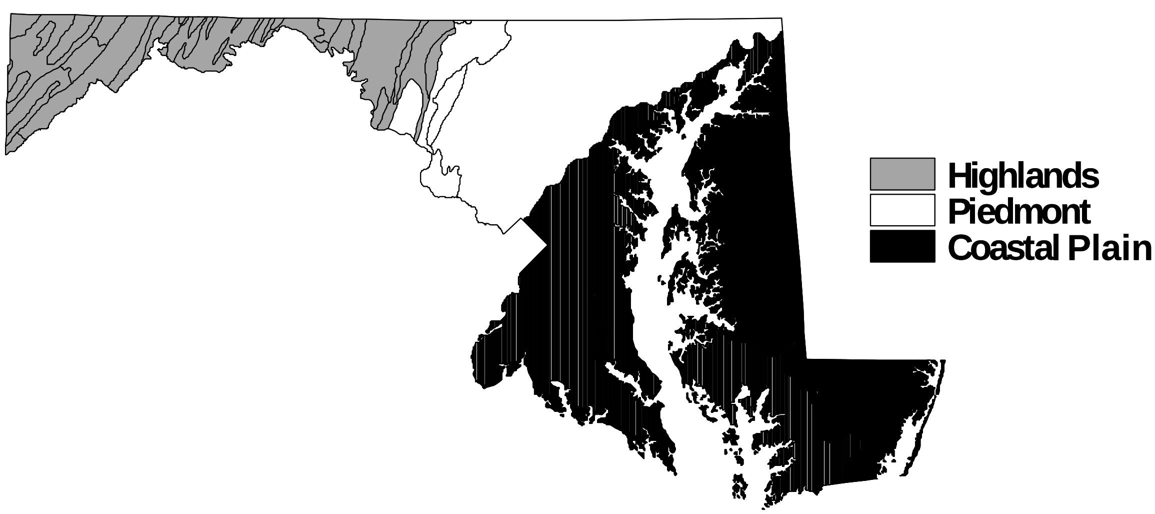

Figure 1 – Map of Maryland indicating ecoregions of the state. The Highland stream class was formed by joining the Blue Ridge, Valley and Ridge, and Appalachian Plateau ecoregions.

Once we had classified the streams of the state, we proceeded to define reference criteria. Our objective while selecting reference and degraded criteria was to refrain from using biological or chemical variables. We wanted to avoid the circularity affecting the original PHI reference criteria, which included FIBI scores. In addition, we wanted to avoid using chemical variables because one function of the PHI is to be used to diagnose biological stream degradation separately from chemical degradation. By keeping the criteria separate, we hoped to isolate their effects. For this reason, we selected land use/land cover values as our reference criteria, with the implicit assumption that greater landscape disturbance alters channel morphology, the template upon which physical habitat is based. Relationships between agricultural and urban transformations of the landscape and stream condition are well established (see Wiley et al. 1990, Roth et al. 1996, Wang et al. 1997, Paul and Meyer 2002). We excluded any channelized streams from consideration as reference sites.

We used different criteria for each of the three stream classes. We sought criteria that maximized the contrast in land cover between reference and degraded conditions (reflecting the least disturbed reference and most degraded land use conditions possible), while at the same time providing enough sites for statistical comparison (Table 3). For Coastal Plain areas, reference criteria were greater than 70% forest and less than 3% urban land cover, while degraded sites were less than 15% forest and/or greater than 85% agriculture and/or greater than 50% urban. This resulted in 40 reference sites and 49 degraded sites in the Coastal Plain class (7 and 9 % of the sites in the class respectively). For the Piedmont class, reference criteria were set lower to provide enough sites for adequate comparison. We set reference criteria at greater than 55% forest and less than

2% urban. Due to the amount of disturbed landscape, however, we were able to set stricter criteria for degraded sites: less than 10% forest, and/or greater than 85% agriculture and/or 70% urban. These criteria resulted in 30 reference sites and 66 degraded sites (5 and 12% of Piedmont sites respectively). The Highlands class contained the most forested watersheds. For this reason, criteria could be set much higher. Reference criteria were set at greater than 95% forest and less than 0.5% urban. Degraded criteria were set at less than 25% forest and/or greater than 75% agriculture and/or greater than 30% urban. This gave 36 reference sites and 28 degraded sites (11 and 8% of Highland sites respectively).

Table 3 – Reference and degraded stream criteria for each of the three stream classes used for constructing physical habitat indices for Maryland. Below this is shown the number of sites in each stream class and the distribution of those sites in reference, degraded, and non-categorized groups. (F=forest, A=agriculture, U=urban).

Stream Class	*Reference Criteria*	*Degraded Criteria*
Coastal Plain	F>70% and U<3%	F<15% and/or A>85% and/or U>50%
Piedmont	F>55% and U<2%	F<10% and/or A>85% and/or U>70%
Highlands	F>95% and U<0.5%	F<25% and/or A>75% and/or U>30%

	Reference	*Non-categorized*	*Degraded*
Coastal Plain (544)	40 (7%)	455 (84%)	49 (9%)
Piedmont (561)	30 (5%)	465 (83%)	66 (12%)
Highlands (343)	36 (10%)	279 (82%)	28 (8%)

There was equal representation of reference sites across the state and no east to west bias (Figure 2). This was a result, in part, of relaxing the reference criteria for Piedmont streams as compared to other areas so we could identify ample reference sites within the Piedmont. This needs to be considered when comparing results from

Piedmont sites with the two other regions as the Piedmont criteria set a lower reference standard, resulting in greater habitat degradation in reference sites. As a result, there are lower expectations for the reference condition within this class and the calculation of impairment thresholds for physical habitat in the Piedmont may have to be different from the other two stream classes. For example, the 25th percentile of reference PHI could be used for Coastal Plain and Highland streams, while the 75th percentile of reference PHI is used for Piedmont streams.

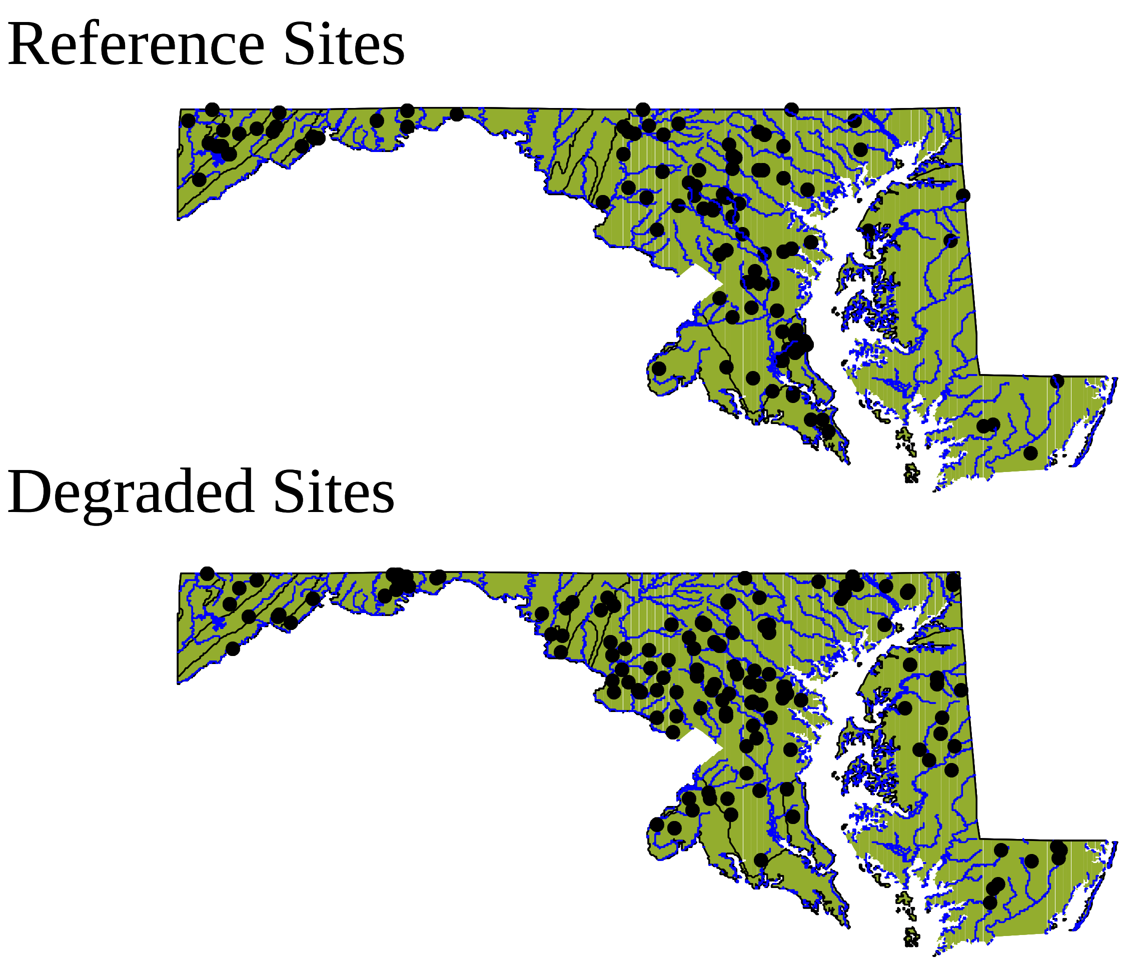

Figure 2 – Map of the location of physical habitat reference and degraded sites across the state.

Reference streams did tend to be smaller than degraded streams in the Coastal Plain and Highland stream classes, but were actually larger, on average, than degraded streams in the Piedmont region (Figure 3). It is generally difficult to find large sized reference streams, because the patchy nature of land use disturbance tends to disrupt large contiguous patches of forested land. While this situation may affect this analysis, the box-and-whisker plots clearly indicate overlap in stream sizes among the reference and degraded conditions in each stream class. In addition, we corrected for area effects to isolate the effects of area on several potential metrics (see below).

Once we established stream classes and reference and degraded criteria, we began to analyze potential metrics. Metrics were transformed as necessary (Table 2). We also had to modify a few variables. Adjacent forested land use was constructed from the percent of four land use types (old field, deciduous forest, coniferous forest, and wetland) observed adjacent to the study reach. The substrate variables were constructed from the percent of sediment types present at a site, with the assumption that a variety of sediment types is preferable to more homogeneous substrate conditions. We determined which sediment classes to consider by considering only those present in at least 50% of the reference sites (Table 4). For Coastal Plain streams, we calculated the percent in cobble, gravel, sand, and silt/clay; for Piedmont streams, the percent of small boulder, cobble, gravel, sand, and silt/clay; and, lastly, for Highland streams, the percent bedrock, large and small boulders, cobble, gravel, sand, and silt/clay.

We modified the habitat metric in a similar way. We calculated the percent of habitat types present at each site, again assuming that a variety of habitat types was preferable to only a few types. In this case, all three classes used the same set of habitat

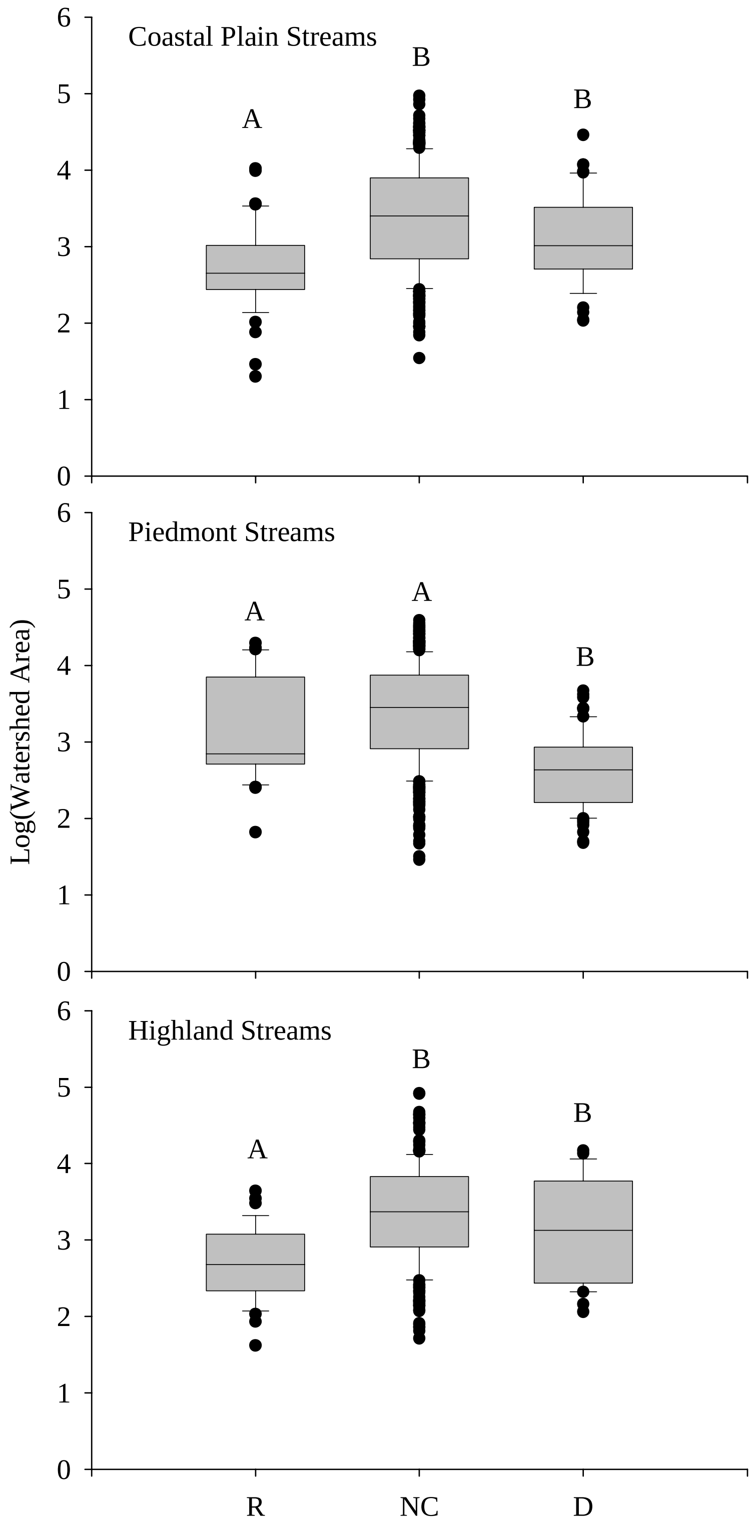

Figure 3 – Box and whisker plots of watershed area by reference category (R=reference, NC=non-categorized, D=degraded) and by stream class. Boxes indicate the median, 10^{th}, 25^{th}, 75^{th}, and 90^{th} percentiles. Within a stream class, categories with different letters above the boxes are significantly different ($p<0.05$, one-way ANOVA, Tukey's HSD multiple comparisons test).

types, which were present in at least 50% of the reference sites in each class. These habitat types were riffle, run/glide, deep pools, shallow pools, undercut banks, and overhanging cover. Emergent and floating vegetation were excluded, as they were only present in, at most, 30% of the reference sites.

Table 4 – The percent of reference sites having each substrate types in each of the three stream classes. Substrate types in bold were used in calculating the SUBSTR metric for each stream class (>50% reference sites).

	Stream Class		
Substrate Type	*Coastal Plain*	*Piedmont*	*Highlands*
Large Boulder	7.1	40.0	**54.5**
Small Boulder	28.6	**93.1**	**93.9**
Cobble	**51.5**	**97.2**	**94.3**
Bedrock	3.6	28.6	**56.5**
Gravel	**78.9**	**97.3**	**97.1**
Sand	**91.5**	**100.0**	**100.0**
Silt/clay	**97.9**	**100.0**	**96.8**

Two other new variables were considered. The width:depth ratio was calculated as the ratio of wetted width to average stream thalweg depth calculated for each site. Bankfull or channel widths would have been more comparable than wetted widths, which are subject to flow conditions, but these data were not available for the MBSS sites. Sinuosity was also estimated as the ratio of the straight line distance between the upstream and downstream segment endpoints and 75 m, the stream reach length assessed and measured along the thalweg.

Two other variables were collected in each period, but using different approaches. For each, we derived equations to make the measurements comparable among years. Bank stability was measured on a 0-20 scale from 1994-1997. During the 2000 sampling, the MBSS estimated bank stability as the linear extent of erosion along both banks (maximum of 75 m each bank) and also noted the severity of the erosion (from 0=minimal to 3=severe). We converted the year 2000 data to a 0-20 scale using the following formula:

$$= \left[\frac{(\text{Erosion Extent})}{-15} \times (\text{Severity}) \right]_{\text{left bank}} + \left[\frac{(\text{Erosion Extent})}{-15} \times (\text{Severity}) \right]_{\text{right bank}} + 20$$

and we used severity values of 0,1,1.5, and 2. Thus, if all 75 m of stream were eroded severely on each bank, each bank would score –10, for a sum total of –20. Adding 20 to this score would result in a score of 0 for bank stability. Likewise, if there was no erosion, a site would get a score of 20.

The second variable we converted was remoteness, which had been scored on a scale of 0-20 from 1994-1997, wheras, during the 2000 sampling, instead of using this scale, the actual distance to a road was estimated. Because of this discrepancy, we converted the 1994-1997 values to make the measures comparable. The original method stated distance criteria for each scoring range: 0-5 scores had roads adjacent to the stream, 6-10 were where roads were within 0.25 miles of the stream but accessible by trail, scores of 11-15 for streams within 0.25 miles but not accessible by trail, and scores of 16-20 for sites more than 0.25 miles. We converted the miles to meters and created a gradient of distances corresponding to each metric score. We then regressed the 0-20 based scores for each site against the distance in meters to calculate new remoteness scores for the 2000 data. The formula for this conversion was

$$= 0.615 + 0.733\sqrt{\text{meters from road}}\ .$$

These values can be found in Appendix A where all the physical habitat data are shown for each site.

We found relationships between watershed area and several variables in reference sites in each of the three regions (Coastal Plain: pool quality, instream wood, instream habitat quality, and epibenthic substrate quality; Piedmont: velocity-depth quality, pool quality, riffle quality, instream habitat quality, and percent shading; Highlands: velocity-depth quality and percent of habitat present)(Table 5). The likely reason is the description of the different habitat metrics and their dependence on depth criteria for scoring. Since stream depth, like most channel dimensions, increases with stream size, it is not surprising that we found these relationships (e.g. Figure 4). We corrected these variables by regressing reference site values against the $\log_{10}$ of their watershed area. We used the regression formula, based on reference sites, to predict the metric value for any given site based on its watershed area. We took the residual of this value and used it as our metric score. We assumed increasing negative residuals were correlated with physical disturbance, which is demonstrated by the mean residual riffle quality in degraded Piedmont streams (Figure 5).

Once we finished the area corrections, we analyzed all the metrics for their ability to discriminate between reference and degraded sites. We calculated discrimination efficiencies for each metric and examined correlation coefficients among the metrics (Table 6). In general, we sought to combine metrics that exhibited some discrimination (>0.25) and we attempted to avoid having too many highly correlated variables together. Ultimately, it was the performance of the final multimetric that was our focus, rather than any one metric alone. Based on our analyses, we selected a set of discriminatory metrics for each of the three stream classes and these were combined into a final multimetric PHI (Table 7). In the Coastal Plain region, we found that bank stability, wood, instream

Table 5 – Regression equations used to correct spatial dependence for different variables in each of the three stream classes. The equations were derived from reference site catchment area versus metric value regressions. Watershed area values (acres) were then entered for each site and the residuals from the predicted values used as the response variable. (Abbreviations are explained in Table 2).

Stream Classes		
Coastal Plain	*Piedmont*	*Highlands*
POOLQUAL = -1.170+4.3125 (TACRE)	VELDEP = 1.2083+3.3096 (TACRE)	VELDEP = 1.4974+2.4473 (TACRE)
WOOD = -12.24+8.8120 (TACRE)	POOLQUAL = -1.751+4.4219 (TACRE)	HAB = -0.1591+0.28704 (TACRE)
INSTRHAB = 0.5505+4.2475 (TACRE)	RIFFQUAL = 5.8467+2.4075 (TACRE)	
EPISUB = 3.5233+2.5821 (TACRE)	INSTRHAB = 9.9876+1.5476 (TACRE)	
	TSHAD = 1.7528-0.1990 (TACRE)	

habitat, epibenthic substrate, shading, and remoteness were the best combination of metrics for discriminating degraded sites from reference. In Piedmont streams, riffle quality, bank stability, wood, instream habitat, epibenthic substrate, shading, remoteness, and embeddedness were the best metrics. Finally, in the Highlands streams, bank stability, epibenthic substrate, shading, riparian width, and remoteness were used. All the multimetrics originally had aesthetics included as a metric. This was a very discriminating metric but it was felt to reflect stressors that may be independent of instream habitat, so it was left out of the multimetric indicator. Detailed equations and procedures for calculating the final multimetric PHI in each region are given in Appendix B.

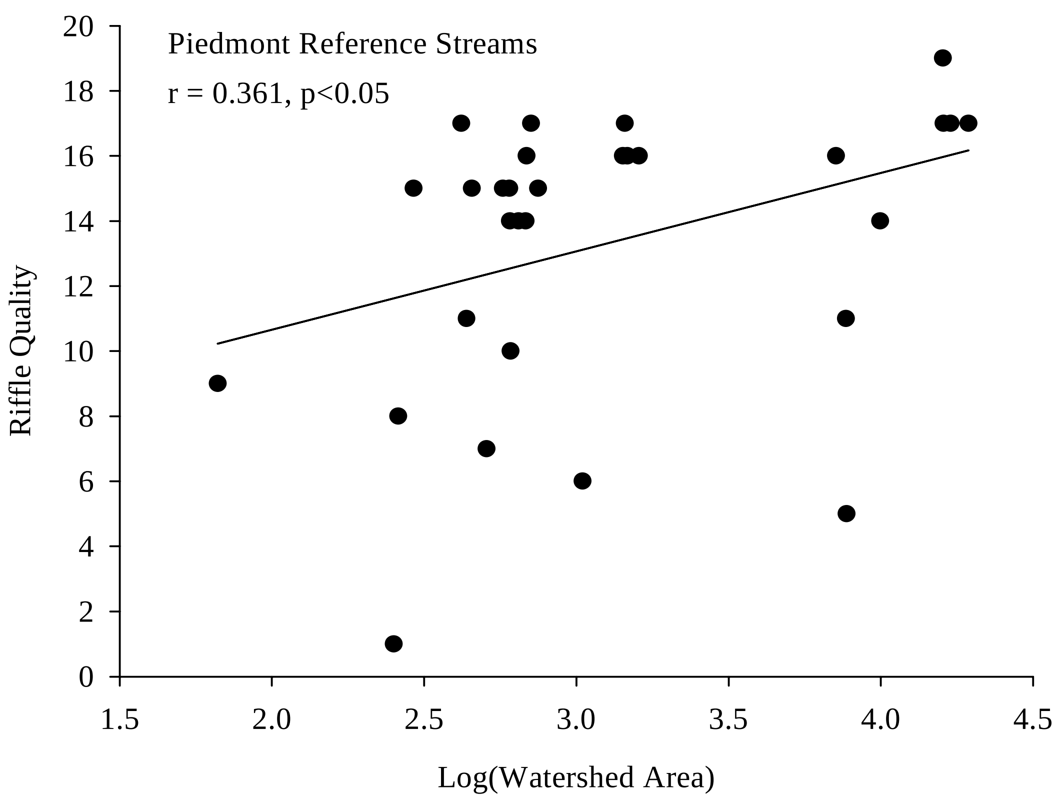

Figure 4 – Plot of watershed area against riffle quality scores in Piedmont reference streams. The pearson correlation coefficient is shown. Similar analyses were run for all metrics to check for watershed area effects.

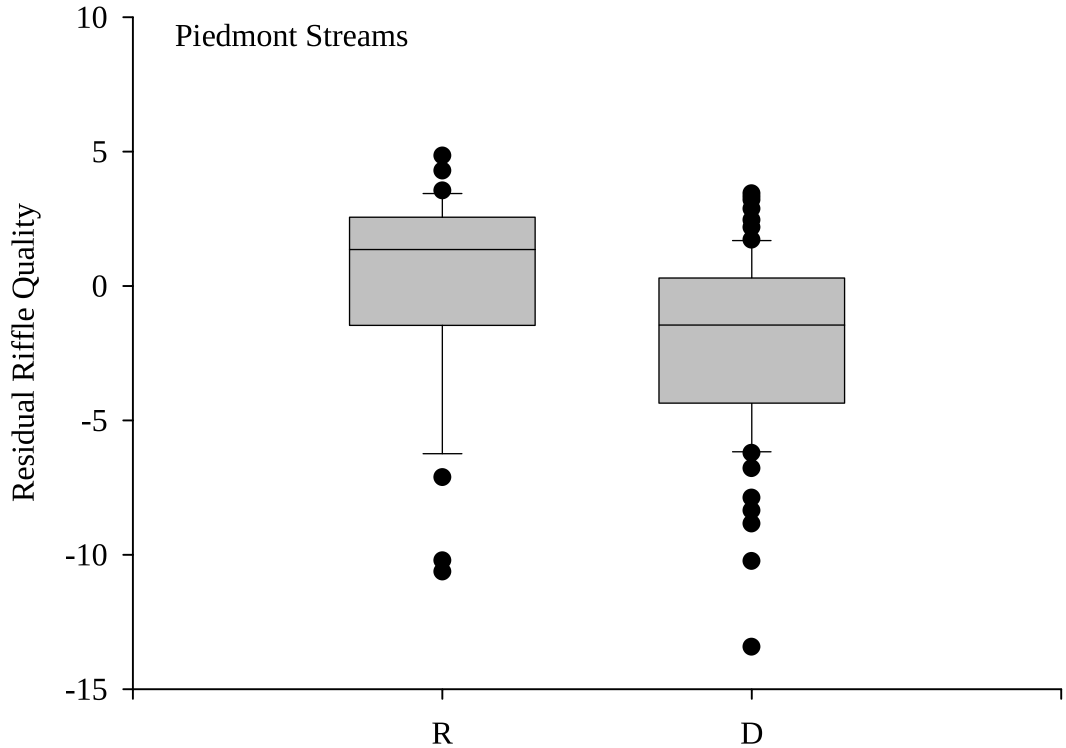

Figure 5 – Box and whisker plot of residual riffle quality in reference (R) and degraded (D) sites in Piedmont streams. Residual riffle quality was calculated by subtracting the riffle quality of a test site predicted based on the area of that watershed (estimated from the regression of area versus riffle quality in reference sites) from the observed riffle quality. Negative residuals indicate sites having worse riffle quality than that predicted for reference sites of similar watershed area. Boxes indicate the median, 10^{th}, 25^{th}, 75^{th}, and 90^{th} percentiles.

The final metrics selected reflected a mix of different habitat characteristics (e.g. reach land cover, geomorphology, wood, visual habitat, riparian condition, etc.), but we do not consider these to be the only metrics of importance in stream habitat assessment. Land use changes will continue to affect stream habitat and it may be that other metrics currently collected will need to be used in the future to better assess and diagnose habitat problems. While the current PHI can be used to assess habitat and calculate the number of habitat impaired streams across the state, variables not used likely will be important in diagnosing specific habitat problems at sites indicated as generally degraded by the PHI. In addition, it may be that future insights and modifications to the habitat assessment will result in revisions to the PHI. The program will be most flexible in terms of meeting any future changes by keeping the full suite of variables.

Table 6 – Discrimination efficiencies of each metric in each of the three stream classes in Maryland. Values in bold represent metrics selected for the PHI of each class. (Abbreviations are explained in Table 2).

Variable	**Discrimination Efficiency**		
	Coastal Plain	*Piedmont*	*Highlands*
FORLU	0.27	0.23	0.18
SINUOUS	0.08	0.23	0.21
MAXDEPTH	0.16	0.30	0.07
WETWID	0.10	0.59	0.18
THADEP	0.16	0.36	0.04
WIDDEP	0.16	0.52	0.46
VEL_DPTH	0.10	0.26	0.29
POOLQUAL	0.37	0.29	0.07
RIFFQUAL	0.18	**0.50**	0.14
EMBEDDED	0.22	**0.29**	0.00
TBANKSTAB	**0.53**	**0.32**	**0.57**
WOOD	**0.82**	**0.36**	0.25
INSTRHAB	**0.45**	**0.64**	0.25
EPI_SUB	**0.53**	**0.35**	**0.43**
SUBSTR	0.12	0.14	0.32
HABITAT	0.16	0.20	0.29
TSHADING	**0.51**	**0.70**	**0.46**
RIPWID	0.86	0.41	**0.75**
REMOTE	**0.71**	**0.36**	**0.64**
AESTHET	0.80	0.36	0.89

After assembling the multimetrics, we checked to see if there were any watershed area effects in the final multimetric by plotting watershed area versus the PHI for each region. There was no significant relationship between area and PHI score (Figure 6). This means there was no apparent dependence on area. This is not surprising, given the careful attention to controlling for stream size in the construction of the individual metrics. The lack of bias against small streams also means that habitat quality can be equally compared in streams of any size.

Table 7 – Metrics used in the PHI for each stream class, the direction of change with degradation, and the habitat feature reflected by each metric. Metrics denoted with an asterisk were watershed area corrected. (Abbreviations are explained in Table 2)

Region	Direction of Change	Feature
Coastal Plain		
TBANKSTAB	Decreases	Geomorphology
WOOD*	Decreases	Wood
INSTRHAB*	Decreases	Visual Habitat
EPISUB*	Decreases	Visual Habitat
TSHAD	Decreases	Riparian Condition
REMOTE	Decreases	Remoteness
Piedmont		
RIFFQUAL *	Decreases	Geomorphology
TBANKSTAB	Decreases	Geomorphology
WOOD	Decreases	Wood
INSTRHAB*	Decreases	Visual Habitat
EPISUB	Decreases	Visual Habitat
TSHAD*	Decreases	Riparian Condition
REMOTE	Decreases	Remoteness
EMBEDDED	Increases	Geomorphology
Highlands		
TBANKSTAB	Decreases	Geomorphology
EPISUB	Decreases	Visual Habitat
TSHAD	Decreases	Riparian Condition
RIPWID	Decreases	Riparian Condition
REMOTE	Decreases	Remoteness

After checking for watershed size dependence, we examined the ability of the overall multimetric indices to discriminate between reference and degraded streams in each stream class. Discrimination efficiency for the final PHI was highest for Highland streams (89%) and this was similar to the discrimination efficiency observed in the Coastal Plain region (84%). The discrimination in the Piedmont region was much lower

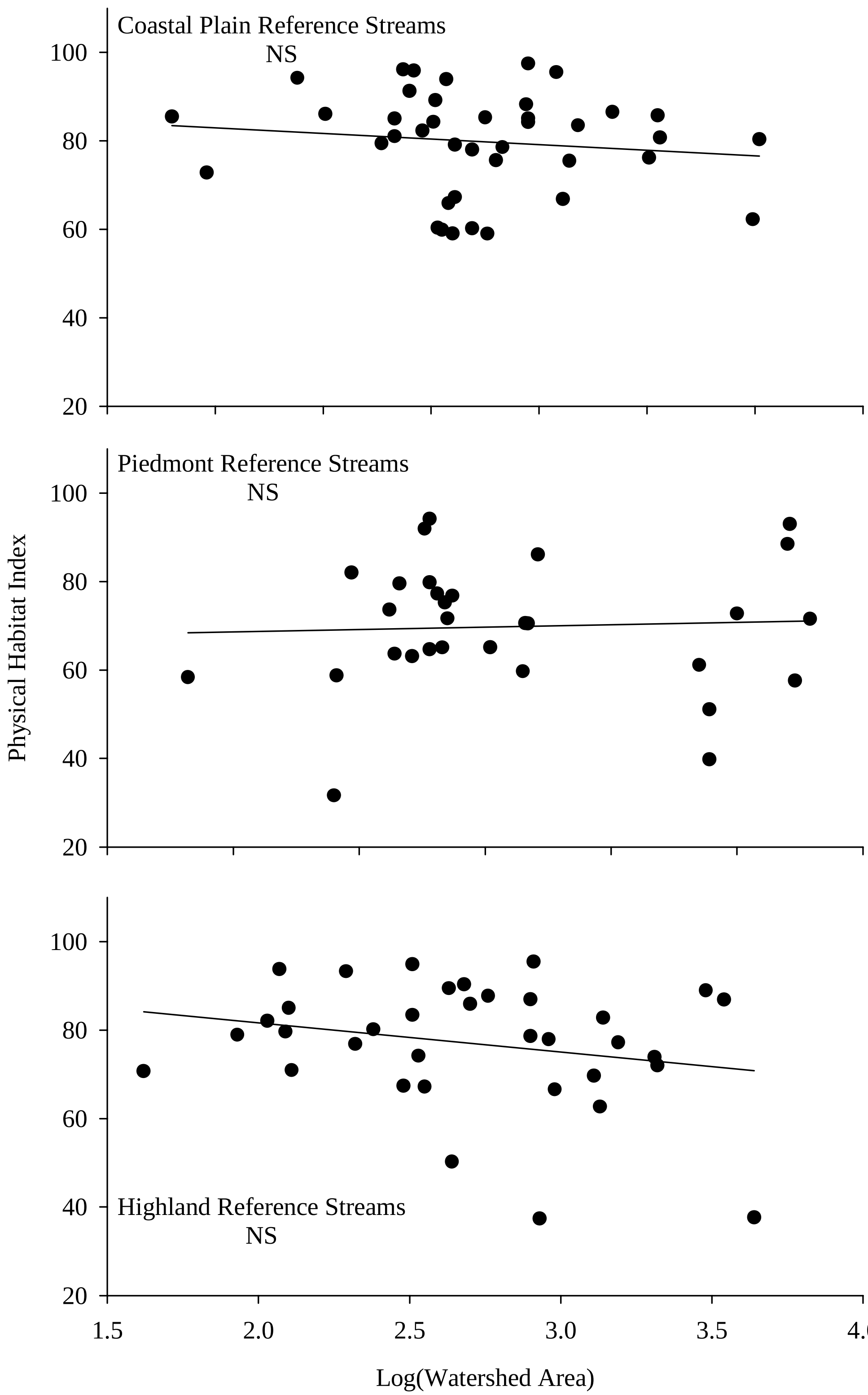

Figure 6 – Plots of watershed area versus the final PHI for reference streams in each stream class. None of the classes showed a significant correlation between area and PHI, indicating no watershed area effects. (NS = not significant).

(55%). This is likely a result of the lowered reference criteria used in the Piedmont region. We used streams with more land use disturbance in our reference set for this region to get a sufficient number of reference sites for identifying and scoring metrics. Scores are scaled to the reference distribution, which resulted in higher values for degraded sites in this region and the decreased observed discrimination efficiency. As mentioned above, any conclusions about the habitat quality in Piedmont streams must be tempered by these facts. Any threshold value should be based on the confidence with which the reference set reflects truly minimally disturbed conditions. For the Piedmont region, we are less confident reference sites reflect as minimally impacted a condition as in the other two regions and the impairment thresholds should reflect that uncertainty. In setting thresholds for establishing habitat impairment criteria, it may be necessary to use more conservative values (e.g., the 75^{th} percentile of reference scores) for this region as opposed to others (which might use, for example, the 25^{th} percentile of reference).

Having compiled new PHI scores, we related them to the FIBI and BIBI multimetric scores calculated for the same sites from the same study periods. We calculated correlation coefficients between the PHI and IBIs for each individual region (Table 8). We ran separate correlations between the PHI and IBIs for sites where the low pH (<5) and DO (<2 mg/L) sites had been removed in order to remove the potential interference of acid precipitation and low oxygen stressed sites (Table 8). These correlations are generally higher, largely because sites with these obvious chemical disturbances have been removed. Even without the low DO and low pH sites, the correlation coefficients are still quite low, but they are comparable to correlations observed with the provisional PHI (0.15 for the B-IBI and 0.46 with the FIBI)(Hall et al.

1999). The previous PHI was more strongly correlated with the FIBI, but FIBI scores were used for defining the reference condition, so that result is not surprising.

Table 8 – Results of correlation analyses among PHI and IBI values for each stream class. Values are Pearson product-moment correlation coefficients and significant coefficients ($p<0.05$) are indicated with an asterisk.

Stream Class	**All Sites**			**Low pH and DO Sites Removed**		
Coastal Plain	N	BIBI	FIBI	N	BIBI	FIBI
PHI versus	349	+0.300*	+0.070	331	+0.330*	+0.100
Piedmont						
PHI versus	415	+0.290*	+0.380*	414	+0.280*	+0.360*
Highlands						
PHI versus	263	+0.250*	+0.120*	254	+0.280*	+0.150*
Overall						
PHI versus	1027	+0.250*	+0.200*	999	+0.260*	+0.220*

Some studies have observed stronger relationships between physical habitat scores and multimetric biotic scores, while others show similar correlations to the ones we observed (Rankin 1995, Gerritsen et al. 1996, Dyer et al. 1998, Rankin et al. 1999, Rockdale County 2001). Habitat clearly constrains the biological integrity of streams. The degree to which it is statistically associated with biotic integrity will depend on the extent and nature of different stressors. Areas with numerous effluents would be expected to show stronger relationships between IBI scores and stream chemistry, those with extensive channelization and hydrologic modification may show stronger relationships with habitat, those with a mixture of stresses (e.g. urban land use) would likely show relationships with both chemistry and habitat.

Due to spatial differences in land use and therefore potential spatial differences in the types of habitat impacts, we expected to find various degrees of correlation between habitat and biological integrity in Maryland streams across the state. When we examined these relationships by river basin, we observed clear differences (Table 9). The BIBI was significantly correlated with the PHI in 12 of the 17 basins studied, most highly correlated with the habitat index in the North Branch Potomac, Chester, and Patapsco basins, but not correlated with the PHI in the Bush, Elk, Lower Potomac, Susquehanna, and Youghiogheny basins. The FIBI was significantly correlated with the PHI in fewer basins, 10 of 17, most highly correlated with the PHI in the Pocomoke, Nanticoke-Wicomico, and Middle Potomac basins, but not related to the PHI in the Choptank, Chester, Lower Potomac, Patuxent, Susquehanna, Upper Potomac, and West Chesapeake basins.

To examine the relative contribution of chemical and habitat variables in predicting biological integrity, we constructed very simple forward stepwise multiple linear regression models using a mixture of water chemistry variables (pH, acid neutralizing capacity, nitrate and sulfate concentration, conductivity, dissolved oxygen, and mean temperature) and the PHI. There were differences in the variables chosen in each region and between the BIBI and FIBI (Table 10). The PHI is a significant predictor in 5 of the 6 models, and is the first or second variable selected in 3 of those 5. The most common chemical predictors were conductivity and dissolved oxygen. These preliminary models predicted from 10 to 26 percent of the variance in IBI scores. The remaining variance may be due to other stressors, interactions among chemical and physical stressors, non-linear responses in biological responses to these stressors, and/or natural variability and sampling error. Because the PHI appears so frequently in the regression models, clearly the physical habitat index presents an important and significant predictor of biological integrity in Maryland streams.

Table 9 – Basin specific correlations between PHI and IBI values. For this analysis, all sites with pH<5 and dissolved oxygen < 2mg/L have been removed. Values are Pearson product-moment correlation coefficients and significant coefficients (p<0.05) are indicated with an asterisk.

	PHI versus		
Basin	**BIBI**	**FIBI**	**N**
Bush	-0.170	+0.380*	24
Choptank	+0.360*	-0.140	44
Chester	+0.510*	+0.150	41
Elk	+0.190	+0.440*	19
Gunpowder	+0.280*	+0.270*	48
Lower Potomac	-0.050	-0.010	65
Middle Potomac	+0.190*	+0.430*	125
North Branch Potomac	+0.500*	+0.310*	59
Nanticoke-Wicomico	+0.500*	+0.500*	22
Pocomoke	+0.400*	+0.590*	27
Patapsco	+0.420*	+0.330*	152
Potomac-Washington Metro	+0.230*	+0.250*	65
Patuxent	+0.230*	+0.060	92
Susquehanna	-0.150	+0.030	33
Upper Potomac	+0.260*	-0.140	74
West Chesapeake	+0.390*	-0.240	24
Youghiogheny	+0.130	+0.250*	85
Number Significant	**12 of 17**	**10 of 17**	

We compared our revised PHI to the provisional PHI (Hall et al. 1999)(Figure 7). The two were significantly correlated (r^2=0.23) and the regression equation between them is represented by the equation:

$$\text{Revised PHI} = 0.2368(\text{Provisional PHI}) + 53.331.$$

Using this score, previous values can be converted and compared with new PHI values, however, this will introduce error associated with the regression equation. The root mean square error of this regression was 12.9, which represents 20% of the mean revised PHI score, which is a fairly inaccurate estimate of the revised PHI. A much better approach is to calculate the revised PHI directly from the data. Appendix A contains revised PHI values calculated for each site using the habitat data directly, along with the provisional PHI values from the 1999 analysis.

Table 10 – Multiple linear regression model results. Models were built to predict BIBI and FIBI from a suite of chemical variables (pH, acid neutralizing capacity, nitrate and sulfate concentration, conductivity, dissolved oxygen, and mean temperature) and the PHI. Variables are shown in the order with which they entered the forward stepwise models. The signs in front of each variable represent the response of each IBI to that particular predictor. (DO=dissolved oxygen, Temp=temperature, NO_3=nitrate, ANC=acid neutralizing capacity).

	Response Variables			
Site Class	**BIBI**	**R^2**	**FIBI**	**R^2**
Coastal Plain	-Conductivity, +DO, +PHI, +Temp	0.20	+DO, -ANC, +Temp, +PHI	0.09
Piedmont	-Conductivity, +PHI, -NO_3, -Temp	0.19	+PHI, -Conductivity, +Temp, +DO	0.26
Highlands	+PHI, +pH, -Conductivity, -NO_3	0.16	+pH, -Conductivity, +DO, +PHI	0.12
Overall	-Conductivity, +DO, +PHI, +pH	0.15	+PHI, +DO, +Temp, -Conductivity	0.10

This revised PHI was not validated with an independent set of data. We recommend validation with data collected since 2000. The variables collected since 2000 can be entered into the models and PHI scores calculated. The reference and degraded criteria can be applied based on land use and the number of sites scoring in the correct category can be evaluated. Ideally, high percent classification rates are sought.

Attachment 4-D

Physical Habitat Index

Maryland Biological Stream Survey

Data Sheets and Assessment Guidance

v. 2012

MBSS SUMMER HABITAT DATA SHEET

Page ☐ Of ☐

SITE Watershed Code ☐☐☐☐ Segment ☐☐☐ Type ☐ Year ☐☐☐☐

Reviewer: First ______ / Second ______

BANK EROSION

	Left Bank	Right Bank
Extent (m)	☐☐	☐☐
Severity (0=none, 1=min, 2=mod, 3=severe)	☐	☐
Average Height (m)	☐☐.☐	☐☐.☐

BAR FORMATION & SUBSTRATE

Severity ___
0=none
1=min
2=mod
3=extensive

☐ Cobble
☐ Gravel
☐ Sand
☐ Silt/Clay

HABITAT ASSESSMENT

1. Instream Habitat (0-20) ☐☐
2. Epifaunal Substrate (0-20) ☐☐
3. Velocity/Depth Diversity (0-20) ☐☐
4. Pool/Glide/Eddy Quality (0-20) ☐☐
   Extent (m) ☐☐
5. Riffle/Run Quality (0-20) ☐☐
   Extent (m) ☐☐
6. Embeddedness (%) ☐☐☐
7. Shading (%) ☐☐☐

FLOW

Lat Loc (m)	Depth (cm)	Velocity (m/s)
0 0 . 0 0	0 0 . 0	0 . 0 0

STREAM CHARACTER

☐ Braided
☐ Riffle
☐ Run/Glide
☐ Deep Pool(>= .5m)
☐ Shallow Pool(< .5m)

☐ Gravel
☐ Sand
☐ Silt/Clay
☐ Cobble
☐ Bedrock

☐ Boulder >2m
☐ Boulder <2m
☐ Beaver Pond
☐ Overhead Cover
☐ Undercut Bank

A = Absent P = Present E = Extensive

☐☐ No. of Instream Woody Debris
☐☐ No. of Dewatered Woody Debris
☐☐ No. of Instream Rootwads
☐☐ No. of Dewatered Rootwads

Maximum Depth (cm) ☐☐☐

	Wetted Width (m)	Thalweg Depth (cm)	Thalweg Velocity (m/s)
0 m	☐☐.☐	☐☐☐	☐.☐☐
25 m	☐☐.☐	☐☐☐	☐.☐☐
50 m	☐☐.☐	☐☐☐	☐.☐☐
75 m	☐☐.☐	☐☐☐	☐.☐☐

Alternative Flow Measurements

Distance (cm) ☐☐☐
Depth (cm) ☐
Width (cm) ☐☐
Time (sec)
1. ☐☐☐
2. ☐☐☐
3. ☐☐☐

COMMENTS ______________________________

MBSS Stream Habitat Assessment Guidance Sheet

Habitat Parameter	Optimal 16-20	Sub-Optimal 11-15	Marginal 6-10	Poor 0-5
1. Instream Habitat[(a)]	Greater than 50% of a variety of cobble, boulder, submerged logs, undercut banks, snags, root wads, aquatic plants, or other stable habitat	30-50% of stable habitat. Adequate habitat	10-30% mix of stable habitat. Habitat availability less than desirable	Less than 10% stable habitat. Lack of habitat is obvious
2. Epifaunal Substrate[(b)]	Preferred substrate abundant, stable, and at full colonization potential (riffles well developed and dominated by cobble; and/or woody debris prevalent, not new, and not transient)	Abund. of cobble with gravel &/or boulders common; or woody debris, aquatic veg., undercut banks, or other productive surfaces common but not prevalent /suited for full colonization	Large boulders and/or bedrock prevalent; cobble, woody debris, or other preferred surfaces uncommon	Stable substrate lacking; or particles are over 75% surrounded by fine sediment or flocculent material
3. Velocity/Depth Diversity[(c)]	Slow (<0.3 m/s), deep (>0.5 m); slow, shallow (<0.5 m); fast (>0.3 m/s), deep; fast, shallow habitats all present	Only 3 of the 4 habitat categories present	Only 2 of the 4 habitat categories present	Dominated by 1 velocity/depth category (usually pools)
4. Pool/Glide/Eddy Quality[(d)]	Complex cover/&/or depth > 1.5 m; both deep (> .5 m)/shallows (< .2 m) present	Deep (>0.5 m) areas present; but only moderate cover	Shallows (<0.2 m) prevalent in pool/glide/eddy habitat; little cover	Max depth <0.2 m in pool/glide/eddy habitat; or absent completely
5. Riffle/Run Quality[(e)]	Riffle/run depth generally >10 cm, with maximum depth greater than 50 cm (maximum score); substrate stable (e.g. cobble, boulder) & variety of current velocities	Riffle/run depth generally 5-10 cm, variety of current velocities	Riffle/run depth generally 1-5 cm; primarily a single current velocity	Riffle/run depth < 1 cm; or riffle/run substrates concreted
6. Embeddedness[(f)]	Percentage that gravel, cobble, and boulder particles are surrounded by line sediment or flocculent material.			
7. Shading[(g)]	Percentage of segment that is shaded (duration is considered in scoring). 0% = fully exposed to sunlight all day in summer; 100% = fully and densely shaded all day in summer			
8. Trash Rating[(h)]	Little or no human refuse visible from stream channel or riparian zone	Refuse present in minor amounts	Refuse present in moderate amounts	Refuse abundant and unsightly

a) <u>Instream Habitat</u> Rated based on perceived value of habitat to the fish community. Within each category, higher scores should be assigned to sites with a variety of habitat types and particle sizes. In addition, higher scores should be assigned to sites with a high degree of hypsographic complexity (uneven bottom). In streams where ferric hydroxide is present, instream habitat scores are not lowered unless the precipitate has changed the gross physical nature of the substrate. In streams where substrate types are favorable but flows are so low that fish are essentially precluded from using the habitat, low scores are assigned. If none of the habitat within a segment is useable by fish, a score of zero is assigned.

b) <u>Epifaunal Substrate</u> Rated based on the amount and variety of hard, stable substrates usable by benthic macroinvertebrates. Because they inhibit colonization, floculent materials or fine sediments surrounding otherwise good substrates are assigned low scores. Scores are also reduced when substrates are less stable.

c) <u>Velocity/Depth Diversity</u> Rated based on the variety of velocity/depth regimes present at a site (slow-shallow, slow-deep, fast-shallow, and fast-deep). As with embeddedness, this metric may result in lower scores in low-gradient streams but will provide a statewide information on the physical habitat found in Maryland streams.

d) <u>Pool/Glide/Eddy Quality</u> Rated based on the variety and spatial complexity of slow- or still-water habitat within the sample segment. It should be noted that even in high-gradient segments, functionally important slow-water habitat may exist in the form of larger eddies. Within a category, higher scores are assigned to segments which have undercut banks, woody debris or other types of cover for fish.

e) <u>Riffle/Run Quality</u> Rated based on the depth, complexity, and functional importance of riffle/run habitat in the segment, with

highest scores assigned to segments dominated by deeper riffle/run areas, stable substrates, and a variety of current velocities.

f) Embeddedness Rated as a percentage based on the fraction of surface area of larger particles that is surrounded by fine sediments on the stream bottom. In low gradient streams with substantial natural deposition, the correlation between embeddedness and fishability or ecological health may be weak or non-existent, but this metric is rated in all streams to provide similar information from all sites statewide.

g) Shading Rated based on estimates of the degree and duration of shading at a site during summer, including any effects of shading caused by landforms.

h) Trash Rating The scoring of this metric is based on the amount of human refuse in the stream and along the banks of the sample segment.