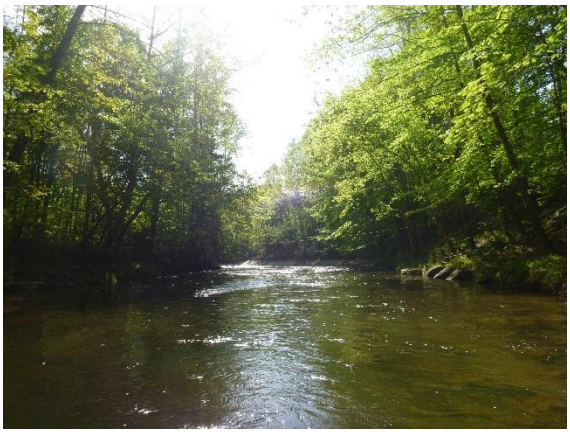

HOWARD COUNTY BIOLOGICAL MONITORING AND ASSESSMENT UPPER MIDDLE PATUXENT, MIDDLE MIDDLE PATUXENT, AND LOWER MIDDLE PATUXENT WATERSHEDS 2014

NPDES Permit Number 00-DP-3318 MD0068322

December 30, 2014

HOWARD COUNTY
BIOLOGICAL MONITORING
AND ASSESSMENT
UPPER MIDDLE PATUXENT,
MIDDLE MIDDLE PATUXENT, AND
LOWER MIDDLE PATUXENT WATERSHEDS
2014

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Prepared for

Department of Public Works
Bureau of Environmental Services
Stormwater Management Division
NPDES Watershed Management Programs

Prepared by

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EXECUTIVE SUMMARY

The Howard County Department of Public Works, Stormwater Management Division, initiated the Howard County Biological Monitoring and Assessment Program in the spring of 2001. The County initiated the monitoring program to establish a baseline ecological stream condition for all of the County's watersheds. The program involves monitoring the biological and physical condition of the County's water resources and is designed on a five-year rotating basis such that each of the County's 15 watersheds, or primary sampling units (PSUs), is sampled once every five years.

To allow for paired site comparisons with both Rounds 1 and 2, 30 sites from Round 1 and 30 sites from Round 2 were randomly selected for repeat sampling in Round 3. The remaining 90 sites in Round 3 will be new random sites. More specifically, 2 sites in each Round 3 watershed will be randomly chosen from the 10 Round 1 sites and 2 sites will be randomly chosen from the 10 Round 2 sites; the remaining 6 sites will be new random sites. In 2014, ten sites were chosen for sampling in each of three subwatersheds: Upper Middle Patuxent, Middle Middle Patuxent, and Lower Middle Patuxent. These subwatersheds were also sampled in Round 1 (2002) and Round 2 (2007) of the countywide assessment. The monitoring involved sampling instream water quality, collection and analysis of the biological community (benthic macroinvertebrates) using Maryland Biological Stream Sampling (MBSS) protocols, cross sectional analysis, particle size distribution, and assessment of the physical habitat using the United States Environmental Protection Agency's (EPA) Rapid Bioassessment Protocols (RBP) and the MBSS's Physical Habitat Index (PHI). The sampling methods used are compatible with those used in the first two rounds of the assessment, with updates where applicable.

All biological data collection occurred between April 9, 2014 and May 12, 2014, slightly past the sampling index period required by the MBSS protocols due to issues encountered during the permissions process. The positions of the sites were collected using a GPS unit accurate to within 2 meters.

Biological results for 2014 in the Upper Middle Patuxent, Middle Middle Patuxent, and Lower Middle Patuxent subwatersheds indicate streams that are in good to very poor condition. Sixteen of the sites sampled received overall BIBI ratings of "Good". Six sites received ratings of "Fair" and five sites received ratings of "Poor". Only three sites, one in the Upper Middle Patuxent subwatershed and two in the Lower Middle Patuxent subwatershed, received a rating of "Very Poor".

RBP habitat assessment results indicate average subwatershed physical habitat conditions that are "Partially Supporting" in all three subwatersheds. None of the sites sampled in any of the three subwatersheds were "Comparable to Reference" (as defined as > 90% of the maximum score). Eight sites were "Supporting", five of which were in the Lower Middle Patuxent subwatershed. Fourteen sites were "Partially Supporting" and eight were "Non-Supporting." The PHI results indicate average subwatershed physical habitat conditions that are "Degraded" in the Upper Middle Patuxent subwatershed and "Partially Degraded" in the Middle Middle Patuxent and Lower Middle Patuxent subwatersheds. No sites were "Minimally Degraded."

The geomorphic assessment indicates a variable system. Some of the channels sampled throughout the subwatersheds were classified as stable type C and E channels; however, two-thirds of the channels were classified as unstable, incised F and G channels. Gravel is the dominant substrate type in almost all of the sampled reaches; however, sand- and silt/clay-dominant streams also were present.

The average percentage of impervious area in the upstream catchments in the Upper Middle Patuxent subwatershed is 10%. Eight percent of the land in the upstream catchments in the Middle Middle Patuxent and 13% of the land in the Lower Middle Patuxent subwatershed is impervious surface. Imperviousness in the areas draining to each sampling site ranges from 2% to 29% (see Appendix A for impervious values). The benthic community in a freshwater stream can be adversely affected by impervious cover and associated runoff at values below 10% (CWP 2003).

There are significant positive relationships between the BIBI and both the RBP habitat assessment score and the PHI score ($R2= 0.36$, $p < 0.001$, $R2 = 0.34$, $p < 0.001$, respectively). As the habitat scores increase, so does the BIBI (see Figure 4-2). This suggests that physical habitat conditions directly affect the biological condition of a stream.

Comparisons to Rounds 1 and 2 of the assessment indicate fairly consistent conditions in all three subwatersheds. The Upper and Middle Middle Patuxent subwatersheds were in "Fair" biological condition in all three Rounds. The Lower Middle Patuxent subwatershed was in "Fair" condition in Rounds 1 and 3, but had fallen to "Poor" condition in Round 2. All three sub-watersheds had average RBP scores that were "Non-Supporting" in Round 1, but "Partially Supporting" in Rounds 2 and 3.

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1 BACKGROUND AND OBJECTIVES

The Howard County Department of Public Works, Stormwater Management Division, initiated the Howard County Biological Monitoring and Assessment Program in the spring of 2001. The program involves monitoring the biological and physical condition of the county's water resources to monitor status and detect trends at the stream level, the watershed level, and ultimately the county level. The Department of Public Works initiated the program to establish a baseline ecological stream condition for all of the county's watersheds. The program is designed on a 5-year, rotating basis such that each of the county's 15 watersheds, or primary sampling units (PSU), is sampled once every 5 years. In general three PSUs are sampled each year, and 10 sites are sampled in each PSU.

The first sampling rotation (Round 1) was completed in only 3 years (2001 to 2003; Table 1-1). Sampling conducted in PSUs 2, 5, and 3 in 2001 addressed requirements of the Patuxent Reservoir Watershed Group in addition to sampling conducted in the Little Patuxent watersheds (PSUs 11, 12, and 13) under a Watershed Restoration Action Strategy (WRAS) grant. In 2002, only the Middle Patuxent sites (PSUs 6, 7, and 8) were sampled. Additional WRAS funding in 2003 allowed sampling to be completed in the Patapsco River tributaries (PSUs 1, 4, and 10) in addition to Rocky Gorge, Hammond Branch, and Dorsey Run, which were sampled to supplement the data collected in 2001 for the Little Patuxent. Round 1 (2001-2003) was sampled and assessed by Tetra Tech.

Round 2 (2005 to 2009) focused on Upper and Lower Brighton Dam (PSUs 2 and 5, respectively) and Cattail Creek (PSU 3) during the first year of sampling. The Little Patuxent River subwatersheds (PSUs 11, 12, and 13) were sampled in 2006. The Middle Patuxent subwatersheds (PSUs 6, 7, and 8) and the Patapsco River subwatersheds (PSUs 1, 4, and 10) were re-sampled in 2007 and 2008, respectively. In 2009, 30 newly selected sites were sampled in the Rocky Gorge Dam (PSU 9), Hammond Branch (PSU 14), and Dorsey Run (PSU 15) subwatersheds to fulfill sampling requirements. Tetra Tech completed the first year of Round 2 sampling and assessment (2005), while KCI was responsible for the remainder of the second Round (2006-2009).

Round 3 (2012 to 2016) of county-wide sampling began with sampling at Upper Brighton Dam (PSU 2), Lower Brighton Dam (PSU 5), and Cattail Creek (PSU 3) during 2012 and with the Little Patuxent River watersheds in 2013 (PSUs 11, 12, and 13). During 2014, Round 3 sampling continued with the sampling of the Middle Patuxent River subwatersheds (PSUs 6, 7, and 8). Round 3 sampling will continue through 2016 and PSUs will be sampled in the same order as in Round 2. Round 3 sampling will include a combination of repeat site samples and new random site samples to improve trend detection. Figure 1-1 illustrates the progress made to date on the county-wide biological monitoring program.

Assessment methods follow those developed by Maryland Department of Natural Resources' (DNR) Maryland Biological Stream Survey (MBSS) and the standard operating procedures (SOPs) found in the Quality Assurance Project Plan (QAPP) for the Howard County Biological Monitoring and Assessment Program (Howard County 2001). The sampling methods

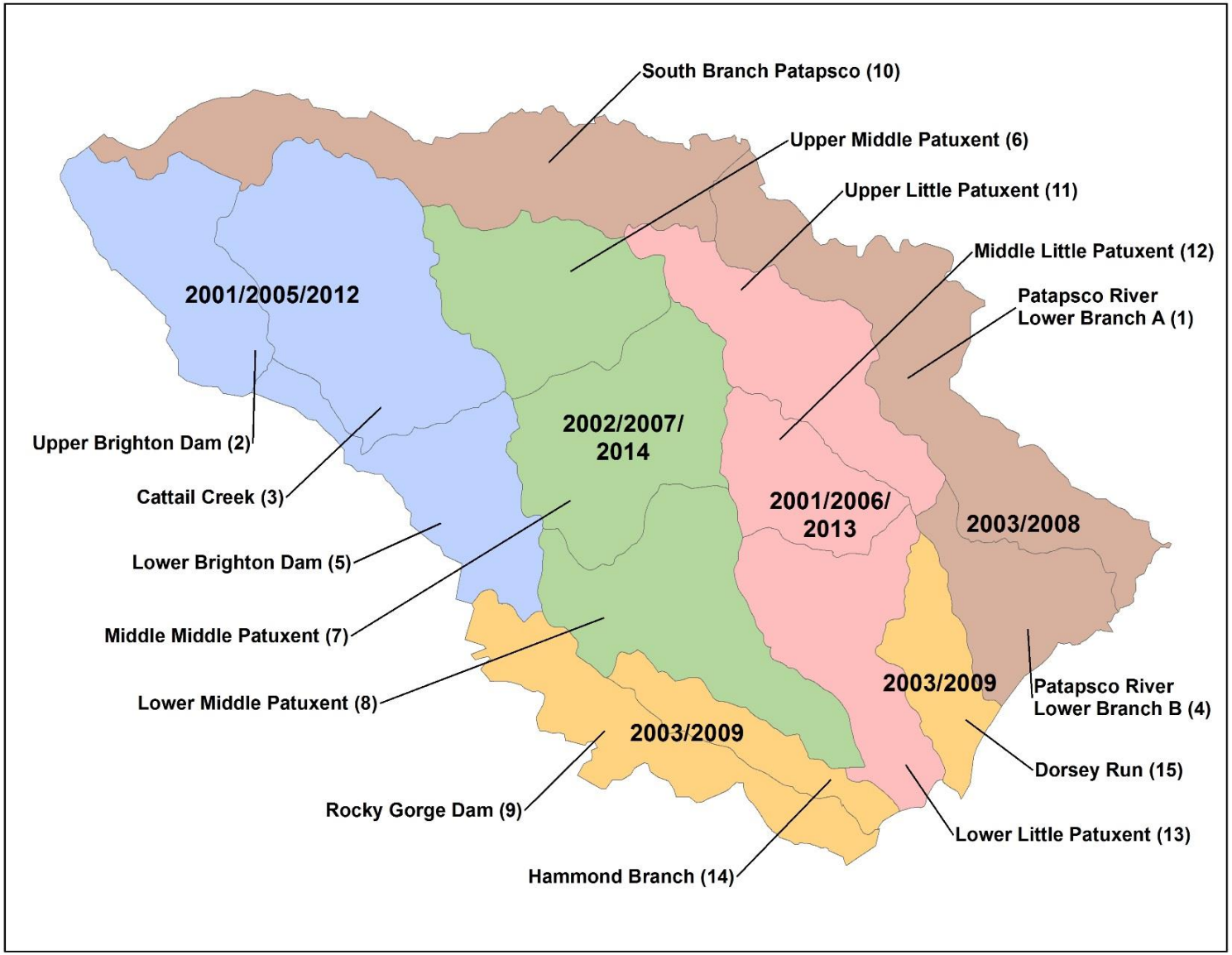

Figure 1-1. Summary of Howard County bioassessment progress (2001-2014)

used in Round 3 are compatible with those used in Rounds 1 and 2 and have been updated where applicable.

Table 1-1. Howard County bioassessment subwatersheds and schedule

Year	Number of Sites	Primary Sampling Unit (Code and Name)
Round 1		
2001	60	11 – Upper Little Patuxent 12 – Middle Little Patuxent 13 – Lower Little Patuxent 2 – Upper Brighton Dam 5 – Lower Brighton Dam 3 – Cattail Creek
2002	30	6 – Upper Middle Patuxent 7 – Middle Middle Patuxent 8 – Lower Middle Patuxent
2003	60	9 – Rocky Gorge Dam 14 – Hammond Branch 15 – Dorsey Run 10 – S Branch Patapsco River Tributaries 1 – Patapsco River L Branch A 4 – Patapsco River L Branch B
Round 2		
2005	30	2 – Upper Brighton Dam 5 – Lower Brighton Dam 3 – Cattail Creek
2006	30	11 – Upper Little Patuxent 12 – Middle Little Patuxent 13 – Lower Little Patuxent
2007	30	6 – Upper Middle Patuxent 7 – Middle Middle Patuxent 8 – Lower Middle Patuxent
2008	30	10 – S Branch Patapsco River Tributaries 1 – Patapsco River L Branch A 4 – Patapsco River L Branch B
2009	30	9 – Rocky Gorge Dam 14 – Hammond Branch 15 – Dorsey Run
Round 3		
2012	30	2 – Upper Brighton Dam 5 – Lower Brighton Dam 3 – Cattail Creek
2013	30	11 – Upper Little Patuxent 12 – Middle Little Patuxent 13 – Lower Little Patuxent
2014	30	6 – Upper Middle Patuxent 7 – Middle Middle Patuxent 8 – Lower Middle Patuxent

Table 1-1. (Continued)

Year	Number of Sites	Primary Sampling Unit (Code and Name)
2015	30	10 – S Branch Patapsco River Tributaries 1 – Patapsco River L Branch A 4 – Patapsco River L Branch B
2016	30	9 – Rocky Gorge Dam 14 – Hammond Branch 15 – Dorsey Run

All three subwatersheds sampled in 2014 are located in the central portion of the county and are crossed by several major transportation routes (Figure 1-2). Maryland Route 32 runs roughly north-south through a portion of each of the three subwatersheds. Interstate 70 and Frederick Road (Route 40) run roughly east-west through the Upper Middle Patuxent subwatershed. The western portion of that subwatershed is also bisected by Maryland Route 97. Frederick Road bisects the very northern portion of the Middle Middle Patuxent subwatershed. The Lower Middle Patuxent subwatershed is traversed by Maryland Route 108 (Clarksville Pike) and Maryland Route 29. Interstate 95 and Washington Boulevard (Route 1) bisect the southern portion of the Lower Middle Patuxent subwatershed.

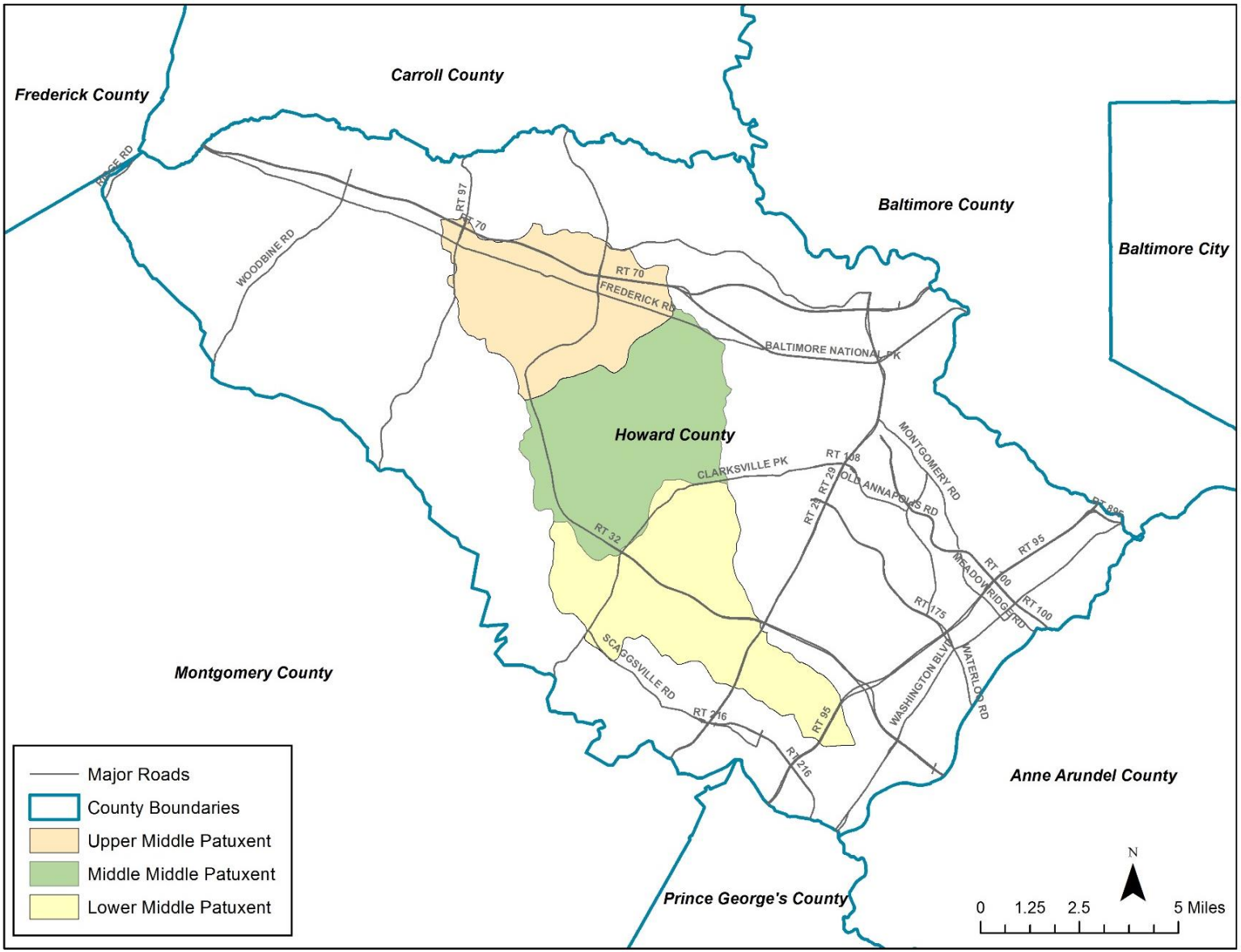

Figure 1-2. Location map of the Upper Middle Patuxent, Middle Middle Patuxent, and Lower Middle Patuxent subwatersheds

2 METHODS

Stream monitoring conducted throughout the watershed includes measuring instream water quality, sampling and assessing the biological community (benthic macroinvertebrates), visually assessing the instream and riparian physical habitat, and performing cross sectional analysis, and measuring substrate particle size. During 2014, 10 sites were selected for sampling in each of the 3 PSU's – Upper Middle Patuxent, Middle Middle Patuxent, and Lower Middle Patuxent. The assessment methods followed the current MBSS protocols (DNR 2014) and the SOPs described in the county's QAPP (Howard County 2001). All biological data were collected between April 9, 2014 and May 12, 2014, slightly past the the spring index period as required by MBSS sampling protocols. The delay was due to problems encountered during the landowner permission process. The location of each site was identified using a global positioning system (GPS) unit that is accurate to within 2 meters. All data were entered into a customized geodatabase created by Versar for Howard County's countywide biological monitoring program. Photographs were taken to document conditions at the time of data collection.

2.1 SELECTION OF SAMPLING SITES

A total of 150 sampling sites were selected at random per round of sampling for Rounds 1 and 2 to provide robust assessments of stream condition for the county and its 15 watersheds (or PSUs). Rounds 1 and 2 provide two unbiased assessments of stream condition with the ability to compare changes in the area-wide mean condition between rounds. Round 3 will provide a third unbiased assessment of stream condition while improving the ability to detect change over time (i.e., trends) by incorporating fixed sites (i.e., repeated sampling of sites selected at random for Rounds 1 and 2). New randomly selected sites also will be sampled during Round 3. This "partial replacement" design meets the objective of improved trend detection, while continually improving the accuracy of the status assessment.

To allow for paired site comparisons, 30 sites from Round 1 and 30 sites from Round 2 will be randomly selected for repeat sampling in Round 3. The remaining 90 sites in Round 3 will be new, randomly selected sites. This is consistent with the recommendation of standard statistical texts (e.g., Cochran 1977) to fix between 25% and 50% of the sites. More specifically, 2 sites in each Round 3 watershed will be randomly chosen from the 10 Round 1 sites, and 2 sites will be randomly chosen from the 10 Round 2 sites; the remaining 6 sites in each watershed will be new, randomly selected sites.

The randomly selected sites are distributed in proportion to the length of stream in each stream order within each watershed to ensure adequate coverage of stream sizes. To select primary and alternate sampling sites, stream lengths were summed by stream order within each subwatershed. The length of stream by stream order and its percentage of the total length within the subwatershed determined the number of sites selected on that order stream.

A random number generator was used to select sampling reaches for 2014. Both primary and alternate sites were selected in case the primary site was ephemeral (dry), inaccessible, or unsafe to sample. Site codes contain the PSU code and initials of the watershed (08MP), stream

order (1), a two-digit sequential number (01), either an "R" or an "F" indicating that the site is a randomly selected site or a fixed "revisit" site, the year sampled (2014), and a letter used in the field to differentiate sampling sites (A).

One duplicate site will be monitored in each PSU for a total of 3 duplicate sites per year (15 QC duplicate sites over the course of Round 3). Only the biological assessment will be conducted at the duplicate sites. These sites were selected using aerial photography and then verified in the field. Duplicate sites (including alternates) will be immediately upstream of a sampling site, will have similar habitat characteristics, and will not be affected by road crossings or confluences.

2.2 LAND USE ANALYSIS

The acreage and percentage of various land use categories were calculated for the drainage area to each site using county GIS data. Drainage areas to each sampling site were first delineated using 2-foot contours. Land use was derived from Maryland Department of Planning (MDP) 2010 land use for Howard County. Since the Patuxent River is a large watershed draining several counties, additional GIS data from Carroll, Frederick, and Montgomery counties also were used to delineate drainage areas and calculate land use percentages. Impervious values were derived using Howard County's 2004 planimetric layers, including roads, buildings, parking lots, driveways and sidewalks.

A table with the percentage of land use, including impervious surface, in each subwatershed is included in Appendix A.

2.3 WATER QUALITY SAMPLING

To supplement the macroinvertebrate sampling and physical habitat assessment, water quality is measured in the field at all monitoring stations. All parameters are measured *in situ* with a YSI® multi-probe data storage device. A calibration log is kept to ensure that the equipment is working properly during field visits. Field-tested parameters include:

- pH (standard pH units)
- Temperature (degrees Celsius, °C)
- Dissolved oxygen (milligrams per liter, mg/L)
- Conductivity (microSiemans per centimeter, µS/cm)
- Turbidity (NTU)

The Maryland Department of the Environment (MDE) has established acceptable standards for several water quality parameters for each designated Stream Use Classification. These standards are listed in the *Code of Maryland Regulations (COMAR) 26.08.02.03-03 - Water Quality* (MDE, 1994). The Upper Middle Patuxent, Middle Middle Patuxent, and Lower Middle Patuxent drainage areas are in *COMAR* Sub-Basin 02-13-11: Patuxent River Area. All three drainage areas

are classified as IV-P: Recreational Trout Waters and Public Water Supply. The acceptable standards for Use IV-P are listed in Table 2-1 Data collected at each station are compared with these standards in the site summaries in Section 3.0.

Table 2-1. Water quality sampling and COMAR standards, use IV-P

Parameter	Units	Acceptable COMAR Standard
pH	standard pH units	6.5 to 8.5
Temperature	degrees Celsius, °C	maximum of 75 °F (23.9 °C) or ambient temperature of the surface water, whichever is greater
Dissolved Oxygen (DO)	milligrams per liter, mg/L	may not be less than 5 mg/L at any time
Conductivity	microSiemans per centimeter, μS/cm	no COMAR standard set
Turbidity	Nephelometer Turbidity Units, NTU	maximum of 150 NTUs and maximum monthly average of 50 NTUs

2.4 BIOLOGICAL SAMPLING

Biological monitoring was conducted throughout the Upper Middle Patuxent, Middle Middle Patuxent, and Lower Middle Patuxent subwatersheds following methods detailed in the county's QAPP (Howard County 2001). Biological assessment methods within Howard County are designed to be consistent and comparable with the methods used by Maryland DNR in its MBSS. The county adopted the MBSS methodology to be consistent with statewide monitoring programs and programs adopted by other Maryland counties. The methods were developed locally and are calibrated to Maryland's physiographic regions and stream types. To maintain comparability with prior years of sampling, physical habitat condition was assessed using the EPA's Rapid Bioassessment Protocol (RBP; Barbour et al. 1999) habitat assessment for high-gradient streams. The MBSS habitat parameters required to calculate the MBSS Physical Habitat Index (PHI) were also collected (Paul et al. 2002). Many of the MBSS habitat parameters included in the PHI are usually sampled during the summer index period. For example, percent shading is often misrepresented during the spring index period when leaves typically have not yet opened. Therefore, the PHI score should be used with that particular caveat. Figure 2-1 shows the locations of the bioassessment sites on the Howard County stream layer.

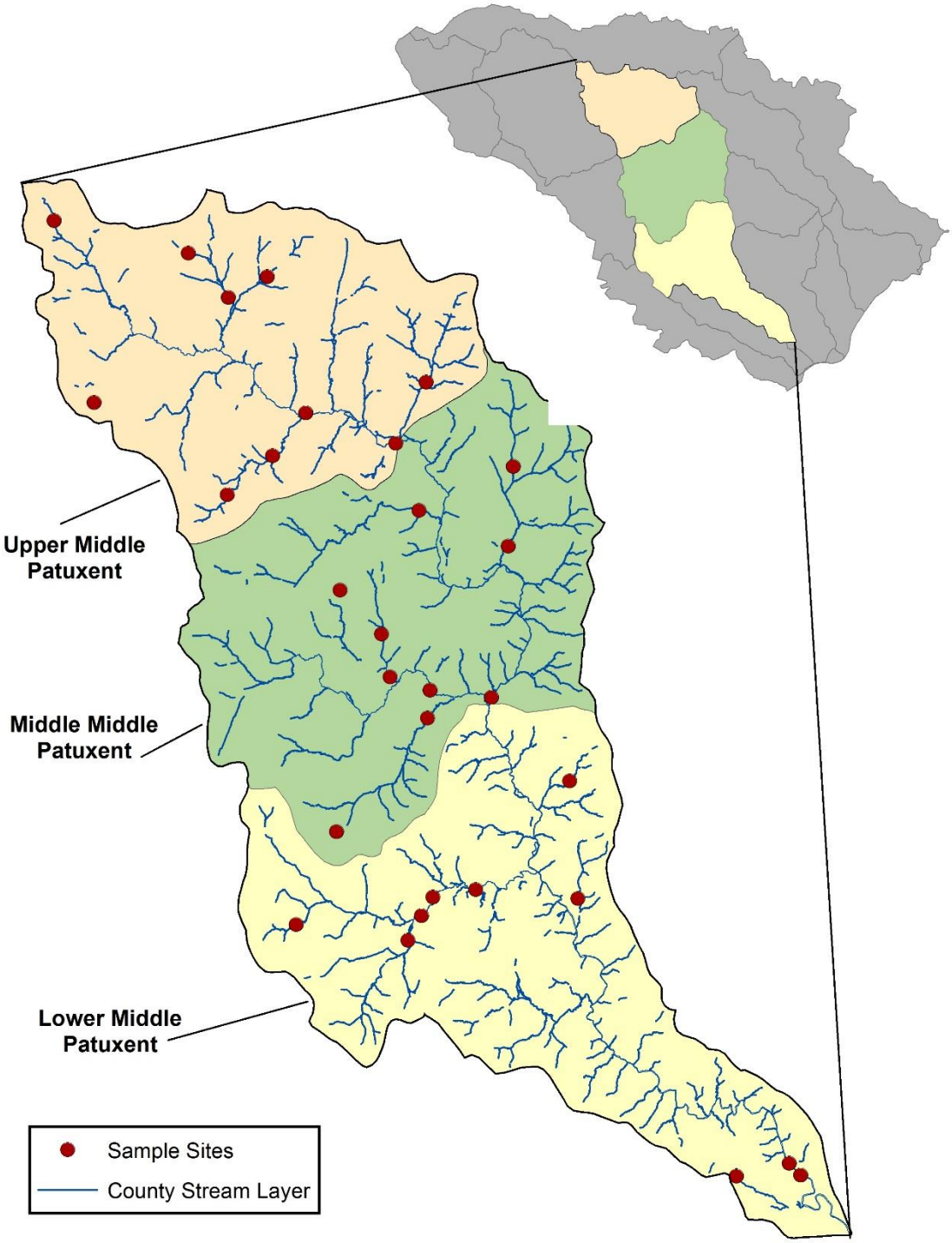

Figure 2-1. Upper Middle Patuxent, Middle Middle Patuxent, and Lower Middle Patuxent bio-assessment sampling locations

2.4.1 Benthic Macroinvertebrate Sampling

Benthic macroinvertebrate collection followed the QAPP, which closely mirrors MBSS procedures (DNR 2010). Benthic macroinvertebrate sampling is conducted during the spring index period (March 1 to April 30) along a 75-meter reach. Systematic field collections of the benthic macroinvertebrate community provide a measure of the biological health of the stream. The multi-habitat, D-frame net approach was used to sample a range of the most productive habitat types within the reach. In this sampling approach, 20 square feet distributed among the best available habitats within the stream system are sampled and combined into one composite sample. Sampled habitats include riffles, rootwads, rootmats and woody debris, leaf packs, submerged aquatic vegetation, and undercut banks.

2.4.2 Sample Processing and Laboratory Identification

Benthic macroinvertebrate samples are processed and subsampled according to methods described in the MBSS Laboratory Methods for Benthic Macroinvertebrate Processing and Taxonomy (Boward and Friedman 2000). Subsampling is conducted to standardize the sample size and reduce variation caused by samples of different size. In this method, the sample is spread evenly across a gridded tray and a randomly selected grid is picked clean (sorted) of organisms. Grids are selected and sorted until a count of 120 is reached. The last grid selected is sorted entirely even if the count of 120 is reached (i.e., if 2 grids contain only 110 organisms an additional grid is selected and sorted completely). The 120 target allows for proper identification of specimens that are missing parts or are early instars that cannot be identified easily.

Organisms were identified by Versar's benthic taxonomist, who is certified by the Society for Freshwater Science (formerly North American Benthological Society) for all macroinvertebrate identifications for East Coast specimens. Most organisms are identified to the genus level, including Chironomidae and Oligochaeta when possible. Individuals of early instars or those that may be damaged were identified to the lowest possible level with certainty. Most taxa are identified using a stereoscope, but permanent slide mounts were used to identify Chironomidae and Oligochaeta to genus level. Results were recorded on a bench sheet and entered into an Access database for analysis.

2.4.3 Biological Data Analysis

Data were analyzed using methods developed by MBSS as outlined in the *New Biological Indicators to Better Assess the Condition of Maryland Streams* (Southerland et al. 2005). The Benthic Index of Biotic Integrity (BIBI) approach involves statistical analysis using metrics that have a predictable response to water quality and habitat impairment. The metrics selected fall into five major groups, including taxa richness, taxa composition, tolerance to perturbation, trophic (feeding) classification, and habit.

Raw values for each metric are given a score of 1, 3, or 5 based on ranges of values developed for each metric. The results are combined into a scaled BIBI score ranging from 1.0 to

5.0, and a corresponding narrative rating is applied. Three sets of metric calculations have been developed for Maryland streams based on broad physiographic regions. These include the Coastal Plain, Eastern Piedmont, and Combined Highlands ecoregions. The Upper Middle Patuxent, Middle Middle Patuxent, and Lower Middle Patuxent subwatersheds are all located in the Eastern Piedmont region; therefore, that formulation of the IBI was used in this report.

DNR updated the benthic metrics, scoring criteria, and individual species tolerance in 2005. The data collected during Round 1 sampling of the Upper Middle Patuxent, Middle Middle Patuxent, and Lower Middle Patuxent subwatersheds were originally analyzed using the old metrics (Stribling et al. 1998); consequently, those results are not directly comparable to the current sampling data. All data from the 2002 sampling were recalculated using the updated metrics to allow for direct comparison with the Round 2 and Round 3 data. For this report, any mention of 2002 BIBI scores refer to these recalculated values.

The following metrics and BIBI scoring were used for data analysis:

Eastern Piedmont BIBI Metrics:

- *Number of Ephemeroptera Taxa* – Equals the total number Ephemeroptera Taxa in the sample. Ephemeroptera (mayflies) are generally considered pollution sensitive, thus communities dominated by Ephemeroptera usually indicate better water quality.
- *Total Number of Taxa* – Equals the richness of the community in terms of the total number of taxa at the genus level or higher. A large variety of genera typically indicate better overall water quality, habitat diversity and/or suitability, and community health.
- *Number of EPT Taxa* – Equals the richness of genera within the Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). EPT taxa are generally considered pollution sensitive, thus higher numbers of EPT taxa would be indicative of better water quality.
- *Percent Intolerant Urban* – Equals the percentage of individuals in the sample that are considered intolerant to urbanization (tolerance values [TV] = 0 – 3). The percent of intolerant urban is expected to decrease with decreasing water quality.
- *Percent Chironomidae* – Equals the percentage of individuals in the sample that are in the Chironomidae (nonbiting midge) family. An increase in the percentage of Chironomidae is generally an indicator of decreasing water quality.
- *Percent Clingers* – Equals the percentage of the total number of individuals who are adapted to attaching to surfaces in stream riffles. Higher percentages of clingers are representative of a decrease in stressors and better water quality.

Information on trophic or functional feeding group and habit were based heavily on information compiled by DNR and from Merritt and Cummins (1996). Scoring criteria for the Piedmont BIBI are shown in Table 2-2. The raw metric value ranges are given with the corresponding scores of 1, 3, or 5. Table 2-3 provides the BIBI scoring ranges and corresponding biological condition ratings.

Table 2-2. Biological index scoring for Piedmont benthic macroinvertebrates			
Metric	**Score**		
	1	**3**	**5**
Total Number of Taxa	< 15	15 – 24	≥ 25
Number of EPT Taxa	< 5	5 – 10	≥ 11
Number of Ephemeroptera Taxa	< 2	2 – 3	≥ 4
Percent Intolerant Urban	< 12	12 – 50	≥ 51
Percent Chironomidae	> 63	24 – 63	≤ 24
Percent Clingers	< 31	31 – 73	≥ 74

Table 2-3. BIBI scoring and rating	
BIBI Score	**Narrative Rating**
4.0 – 5.0	Good
3.0 – 3.9	Fair
2.0 – 2.9	Poor
1.0 – 1.9	Very Poor

2.5 PHYSICAL HABITAT ASSESSMENT

Each biological monitoring site is characterized based on physical characteristics and various habitat parameters following the Environmental Protection Agency's Rapid Bioassessment Protocol (RBP) habitat assessment for high gradient streams (Barbour et. al, 1999). The RBP habitat assessment consists of visually assessing 10 biologically significant habitat parameters that evaluate a stream's ability to support an acceptable level of biological condition. Each parameter is given a numerical score from 0 to 20 and a categorical rating of optimal, suboptimal, marginal or poor. Overall habitat quality typically increases as the total score for each site increases. The parameters assessed for high gradient streams are listed in Table 2-4.

Table 2-4. RBP habitat parameters for high gradient streams	
Parameters Assessed	
Epifaunal substrate/available cover	Channel alteration
Embeddedness	Frequency of riffles/bends
Velocity/depth regime	Bank stability
Sediment deposition	Vegetative protection
Channel flow status	Riparian vegetative zone width

The above parameters for each site were summed to obtain a total habitat score. Since local reference conditions were not available for comparison, the percent comparability was calculated

based on the highest attainable score (200). The percent comparability score is then used to place each site into corresponding narrative rating categories as shown in Table 2-5.

Table 2-5. RBP habitat score and ratings

Percent of Reference	Narrative Rating
> 90.0	Comparable to Reference
75.1 – 89.9	Supporting
60.1 – 75.0	Partially Supporting
< 60.0	Non-supporting

MBSS stream habitat assessment methods (Paul et al. 2002) were used to assess the physical habitat at each site using the Piedmont Physical Habitat Index (PHI). In developing the PHI, MBSS identified eight parameters that have the most discriminatory power for Piedmont streams. These parameters were evaluated on a 0 to 20 scale at each sampling site and used to calculate the PHI (Table 2-6).

Table 2-6. Parameters assessed in MBSS's habitat assessment procedure (Physical Habitat Index or PHI) for Piedmont streams

Parameter	Rating Scale
Remoteness	0 to 20
Shading	0 to 20
Epibenthic Substrate	0 to 20
Instream Habitat	0 to 20
Woody Debris and Rootwads	0 to 20
Bank Stability	0 to 20
Riffle Quality	0 to 20
Embeddedness	0 to 20

PHI is scored based on Table 2-7.

Table 2-7. MBSS Physical Habitat Index (PHI) score and rankings

> 81	Minimally Degraded
66-81	Partially Degraded
51-65	Degraded
< 51	Severely Degraded

2.6 GEOMORPHIC ANALYSIS

A stream geomorphic assessment was conducted to foster a better understanding of the physical processes and features shaping the storm channels in these subwatersheds and to support strategic decisions on how to best protect, manage, and restore watershed resources. Assessment techniques include the cross sectional survey, substrate particle size analysis, and measurement of channel slope.

2.6.1 Cross Section Analysis

Cross sections at each monitoring station were surveyed according to Howard County's SOP to characterize the channel and measure cross sectional area and discharge. Each cross section was located on a representative riffle whenever possible and was surveyed with a laser level and stadia rod.

The cross sections include survey of the floodplain and all pertinent channel features including:

- Top of bank
- Bankfull elevation
- Edge of water
- Limits of point and instream depositional features
- Thalweg
- Floodprone elevation

Sinuosity was calculated using GIS based on the stream length between the upstream and downstream ends of the reach and the straight-line distance between these points. The floodprone width was estimated at an elevation two times the bankfull depth.

Additional survey points were taken near the upstream and downstream ends of the sampling reach to estimate the slope through the reach in order to estimate discharge. Survey points for slope calculations typically were taken at the top of like features (e.g., top of riffle to top of riffle), although this was not always possible.

2.6.2 Particle Size Analysis

The channel bed and bank materials were characterized at each cross section using pebble count analysis. One modified Wolman pebble count (Wolman 1954) was conducted in each reach to determine the composition of channel materials and the median particle size for each site. The pebble count procedure was adapted from *Stream Channel Reference Sites: An Illustrated Guide to Field Technique* (Harrelson et. al. 1994). Pebble counts were conducted at 10 transects across the entire assessment reach. Transects were positioned based on the proportion of riffles, pools, runs, and glides in the assessment reach as estimated by visual inspection. The count was

conducted within the entire bankfull channel. The pebble counts provide roughness values necessary for calculations of velocity and discharge.

2.6.3 Rosgen Classification

The stream cross section, bed and bank material data, and slope were analyzed using the Ohio Department of Natural Resources Reference Reach Spreadsheet Version 4.3L (ODNR 2012). The following values and ratios were calculated:

Sinuosity	Entrenchment ratio	Bankfull cross section area
Slope	Bankfull height	Velocity
Floodprone width	Bankfull width	Discharge
Width / depth ratio	Mean depth	

A Rosgen Level II characterization (Rosgen 1996) was assigned to each stream reach based on field-collected data. Table 2-8 includes general descriptions for each channel type classification based on the Rosgen classification system for natural rivers (Rosgen 1996). The types are determined by a combination of factors including entrenchment, width-to-depth ratio, planform, and slope. Soil types, basin relief, and valley morphology also contribute to the channel type.

Table 2-8. Rosgen Level II channel type description

Channel Type	General Description (from Rosgen 1996)
Aa+	Very steep, deeply entrenched, debris transport, torrent streams.
A	Steep, entrenched, confined, cascading, step/pool streams. High energy/ debris transport associated with depositional soils. Very stable if bedrock or boulder dominated channel.
B	Moderately entrenched, moderate gradient, riffle dominated channel with infrequently spaced pools. Moderate width/depth ratio. Narrow, gently sloping valleys. Very stable plan and profile. Stable banks.
C	Low gradient, meandering, slightly entrenched, point-bar, riffle/pool, alluvial channels with broad, well-defined floodplains.
D	Braided channel with longitudinal and transverse bars. Very wide channel with eroding banks. Active lateral adjustment, high bedload and bank erosion.
DA	Anastomosing (multiple channels) narrow and deep with extensive, well-vegetated floodplains and associated wetlands. Very gentle relief with highly variable sinuosities and width/depth ratios. Very stable streambanks.
E	Low gradient, Highly sinuous, riffle/pool stream with low width/depth ratio and little deposition. Very efficient and stable. High meander/width ratio.
F	Entrenched, meandering riffle/pool channel on low gradients with high width/depth ratio and high bank erosion rates.
G	Entrenched “gully” step/pool and low width/depth ratio on moderate gradients. Narrow valleys. Unstable, with grade control problems and high bank erosion rates.

3 RESULTS

A total of 30 sites were sampled in the Upper Middle Patuxent, Middle Middle Patuxent, and Lower Middle Patuxent subwatersheds, 10 in each subwatershed. Site coordinates are provided in Appendix A. One biological QA/QC sample was collected in each subwatershed at stations where upstream habitat was considered to be similar. The summary results of the habitat assessment, biological assessment, land use, and Rosgen characterization (Rosgen 1996) are divided among the three subwatersheds and presented in detail in this section. A map of each subwatershed displaying the results of the RBP habitat assessment and BIBI is also presented. Full data results are displayed in Appendices A through F.

3.1 UPPER MIDDLE PATUXENT

In 2014, 7 of the 10 sampling sites in the Upper Middle Patuxent subwatershed were on first-order streams, one was on a second-order stream, and two were on third order stream. The field QC sample was collected at site 06MP-322-F-2014H. The subwatershed had an average BIBI score of 3.23 and a "Fair" condition rating; scores ranged from 1.67 to 4.67. The average RBP habitat assessment comparability score was 63.2 or " Partially Supporting," and scores ranged from 34 ("Non-supporting") to 86 ("Supporting"). The average PHI score was 63.0 ("Degraded"). The Upper Middle Patuxent had four stream channels classified as type F, four as C, one as G, and one channel as type E. Channel substrate at seven of the sites was predominantly gravel. Two of the remaining sites had silt/clay substrate and one had a sandy bottom. Table 3-1 summarizes the results for the Upper Middle Patuxent subwatershed and Figure 3-1 shows the sites with BIBI and RBP comparability scores on a map.

Table 3-1. Upper Little Middle Patuxent Sampling Results

Site ID	Drainage Area (acres)	% Impervious	BIBI Score	BIBI Rating	RBP Score	RBP Rating	PHI Score	PHI Rating
06MP-101-R-2014A	26.65	15.39	4	Good	72	Partially Supporting	75.55	Partially Degraded
06MP-104-R-2014B	694.5	10.23	3.67	Fair	63	Partially Supporting	63.89	Degraded
06MP-109-R-2014C	33.52	6.99	2	Poor	46	Non-supporting	49.47	Severely Degraded
06MP-111-R-2014D	100.46	10.4	1.67	Very Poor	34	Non-supporting	32.07	Severely Degraded
06MP-115-R-2014E	739.99	6.64	2.67	Poor	68	Partially Supporting	79.76	Partially Degraded
06MP-218-R-2014F	991.41	9.34	4.67	Good	78	Supporting	63.35	Degraded
06MP-119-F-2014G	186.04	8.31	2	Poor	52	Non-supporting	74.17	Partially Degraded
06MP-322-F-2014H*	9393.28	7.71	4.67	Good	73	Partially Supporting	67.44	Partially Degraded
06MP-123-F-2014I	302.44	13.26	3.33	Fair	60	Non-supporting	44.88	Severely Degraded
06MP-326-F-2014J	7279.29	7.49	3.67	Fair	86	Supporting	79.65	Partially Degraded
Minimum	26.65	6.64	1.67	Very Poor	34.00	Non-supporting	32.07	Severely Degraded
Maximum	9393.28	15.39	4.67	Good	86.00	Supporting	79.76	Partially Degraded
Mean	1974.76	9.58	3.24	Fair	63.20	Partially Supporting	63.02	Degraded
Standard Deviation	3405.48	2.85	1.10		15.70		16.09	

* QC sampling was conducted at this site

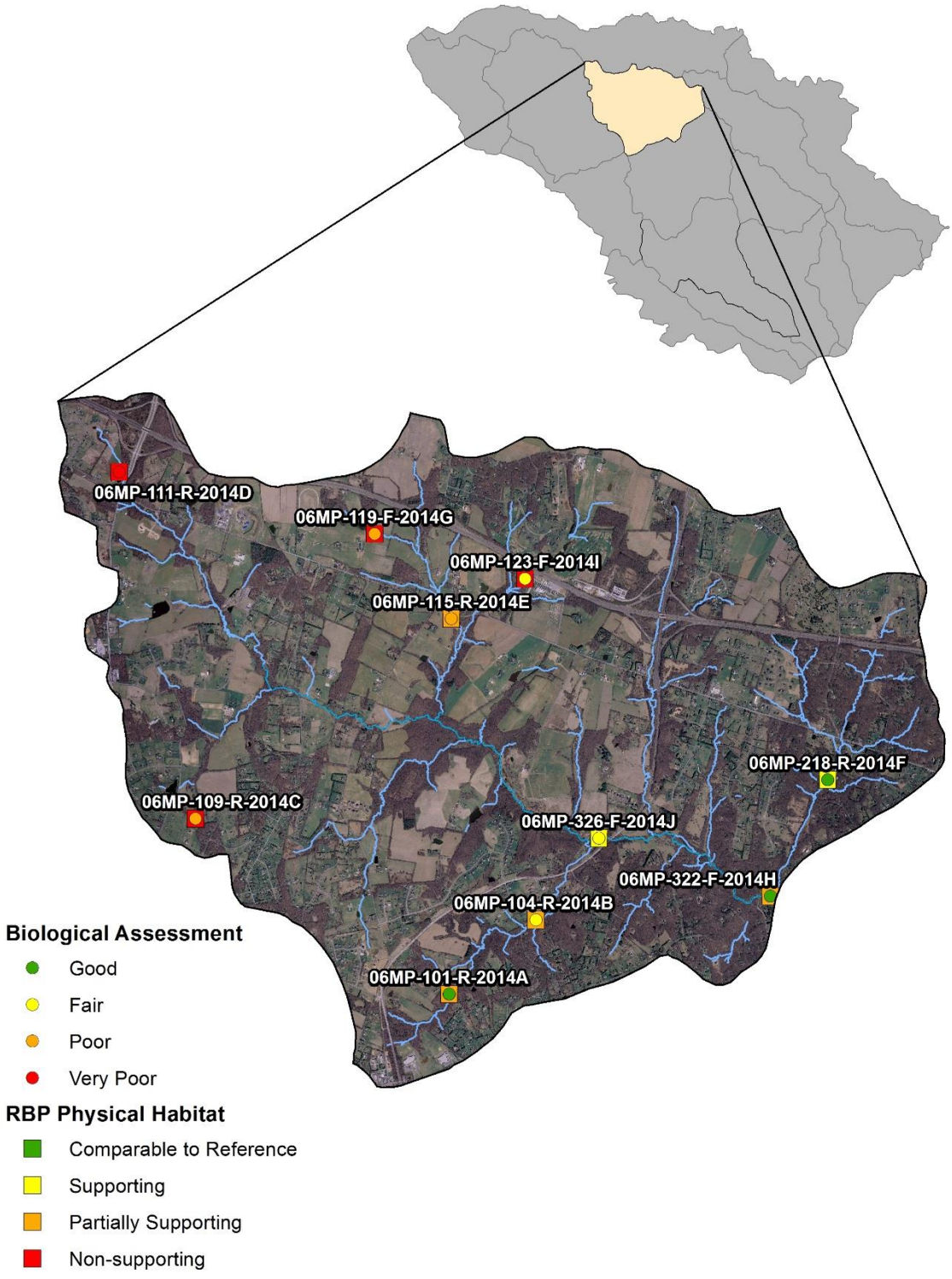

Figure 3-1. Upper Middle Patuxent sampling results

06MP-101-R-2014A – This is a small first-order stream through an open lot in a medium-density urban development. This is an F4 channel dominated by gravel. Within the 263-acre drainage area, the land use is relatively evenly split between low-density residential development (28%), institutional (24%), and forest (20%). The remaining land use is commercial/industrial (7%). Impervious cover accounts for 15% of the drainage area. The RBP habitat assessment resulted in a score of 72 ("Partially Supporting"); the PHI score was 75.6 ("Partially Degraded"). There is moderate evidence of erosion. A total of 30 taxa were present in the benthic macroinvertebrate sample, including 11 Ephemeroptera, Plecoptera, and Tricoptera (EPT) taxa. Forty-seven percent of the individuals in the benthic macroinvertebrate sample were intolerant to urban stressors. The site's overall BIBI score of 4.00 corresponds to a "Good" biological classification. All water quality parameters were within acceptable COMAR standards.

06MP-104-R-2014B – This is a larger first-order stream that flows through a wooded area in a low density housing region. This is a G5 channel dominated by sand. Within the 695-acre drainage area, low-density residential development is the dominant land use (41%), followed by forest (28%), and agriculture (19%). Nine percent of the land use is institutional and three percent of the drainage area is commercial/industrial. Impervious cover accounts for 10% of the drainage area. The RBP habitat assessment resulted in a score of 63 ("Partially Supporting"); the PHI score was 63.9 ("Degraded"). Erosion is extensive and the substrate is deeply embedded. A total of 35 taxa were present in the benthic macroinvertebrate sample, including 11 Ephemeroptera, Plecoptera, and Tricoptera (EPT) taxa. Twenty-one percent of the individuals in the benthic macroinvertebrate sample were intolerant to urban stressors and the site was dominated by Chironomidae midges (52%). The site's overall BIBI score of 3.67 corresponds to a "Fair" biological classification. All water quality parameters were within acceptable COMAR standards.

06MP-109-R-2014C – This is a very small first-order stream that flows through a low-density residential area with large, open lawns. The stream dries up during long periods without rain. This is a C6 channel dominated by silt/clay substrate. Within the 34-acre drainage area, low-density residential development is the dominant land use (70%). The remainder of the land is agricultural. Impervious cover accounts for seven percent of the drainage area. The RBP habitat assessment resulted in a score of 46 ("Non-Supporting"); the PHI score was 49.5 ("Severely Degraded"). Ninety percent of the stream bottom was embedded. There no evidence of erosion, but there is an extensive deer trail crossing through the middle of the stream. A total of 16 taxa were present in the benthic macroinvertebrate sample. There were no Ephemeroptera, Plecoptera, and Tricoptera (EPT) taxa. Only three percent of the individuals in the benthic macroinvertebrate sample were intolerant to urban stressors. The site's overall BIBI score of 2.00 corresponds to a "Poor" biological classification. The pH value of 5.89 was below the acceptable COMAR standard of 6.5, but all other water quality parameters were within acceptable COMAR standards.

06MP-111-R-2014D – This is a small first-order along the edge of a cattle farm. It flows through grassland with no canopy cover. This is a C6 channel dominated by silt/clay substrate. Within the 100-acre drainage area, low-density residential development is the dominant land use (48%), followed by agriculture (29%). Transportation accounts for nine percent of the land use, followed by small amounts of open urban land (7%) and forest (5%). Impervious cover accounts for 10% of the drainage area. The RBP habitat assessment resulted in a score of 34 ("Non-Supporting"); the PHI score was 32.1 ("Severely Degraded"). The stream is choked with grass

and duckweed and has a poorly defined channel structure. Only one percent of the stream was shaded. A total of 14 taxa were present in the benthic macroinvertebrate sample, including only one Ephemeroptera, Plecoptera, and Tricoptera (EPT) taxa. Only eight percent of the individuals in the benthic macroinvertebrate sample were intolerant to urban stressors. The site's overall BIBI score of 1.67 corresponds to a "Very Poor" biological classification. All water quality parameters were within acceptable COMAR standards.

06MP-115-R-2014E – This is a larger first-order stream that is located near low-density housing and agricultural land. This is a C4 channel dominated by gravel. Within the 740-acre drainage area, agriculture is the dominant land use (74%), followed by forest (13%). Ten percent of the land use is low-density residential development and three percent of the drainage area is transportation. Less than one percent of the drainage area is institutional land use. Impervious cover accounts for seven percent of the drainage area. The RBP habitat assessment resulted in a score of 68 ("Partially Supporting"); the PHI score was 79.8 ("Partially Degraded"). A total of 28 taxa were present in the benthic macroinvertebrate sample, including five Ephemeroptera, Plecoptera, and Tricoptera (EPT) taxa. Only five percent of the individuals in the benthic macroinvertebrate sample were intolerant to urban stressors and the sample was dominated by Chironomidae midges (54%). The site's overall BIBI score of 2.67 corresponds to a "Poor" biological classification. All water quality parameters were within acceptable COMAR standards.

06MP-218-R-2014F – This is a second-order site located on a well-forested piece of property in a low-density residential area. This is a F4 channel dominated by gravel. Within the 991-acre drainage area, land use is evenly divided between low-density residential development (41%) and agriculture (40%). Nine percent of the drainage area is open urban land and seven percent is forested. The remaining three percent of the drainage area is either in transportation, institutional land, or bare ground. Impervious cover accounts for nine percent of the drainage area. The RBP habitat assessment resulted in a score of 78 ("Supporting"); the PHI score was 63.4 ("Degraded"). There is minimal evidence of bank erosion. A total of 30 taxa were present in the benthic macroinvertebrate sample, including 13 Ephemeroptera, Plecoptera, and Tricoptera (EPT) taxa. Sixty-nine percent of the individuals in the benthic macroinvertebrate sample were intolerant to urban stressors and only seven percent were Chironomidae midges. The site's overall BIBI score of 4.67 corresponds to a "Good" biological classification. All water quality parameters were within acceptable COMAR standards.

06MP-119-F-2014G – This is a small first-order stream flowing through a horse pasture just south of Route 70. Some parts of the site are highly impacted by unrestricted horse access to the stream. A bridge crossing the stream was constructed at the upper end of the site. This is an E4 channel dominated by gravel. The RBP habitat assessment resulted in a score of 52 ("Non-Supporting"); the PHI score was 74.2 ("Partially Degraded"). Only 5% of the stream was shaded and eighty-five percent of the stream bottom was embedded. A total of 26 taxa were present in the benthic macroinvertebrate sample, including only three Ephemeroptera, Plecoptera, and Tricoptera (EPT) taxa. Only five percent of the individuals in the benthic macroinvertebrate sample were intolerant to urban stressors and the sample was dominated by Chironomidae midges (64%). The site's overall BIBI score of 2.00 corresponds to a "Poor" biological classification. All water quality parameters were within acceptable COMAR standards.

06MP-322-F-2014H – This is a large third-order stream located in low-density residential lots with a C4 channel dominated by gravel. Within the- 9,393 acre drainage area agriculture is the dominant land use (43%), followed by low-density residential development (28%) and forested land (23%). The remaining six percent of the land is either in commercial/industrial, institutional, open urban land, or transportation land uses. Impervious cover accounts for eight percent of the drainage area. The RBP habitat assessment resulted in a score of 73 ("Partially Supporting"); the PHI score was 67.4 ("Partially Degraded"). There is evidence of severe erosion throughout the site. A total of 33 taxa were present in the benthic macroinvertebrate sample, including 14 Ephemeroptera, Plecoptera, and Tricoptera (EPT) taxa. Thirty-six percent of the individuals in the benthic macroinvertebrate sample were intolerant to urban stressors. The site's overall BIBI score of 4.67 corresponds to a "Good" biological classification. All water quality parameters were within acceptable COMAR standards. This site was the Upper Middle Patuxent subwatershed's QC (duplicate) site.

06MP-123-F-2014I – This stream is located on the property of the Howard County Fairgrounds, just south of Route 70. Just upstream of the top of the site, the stream emerges from a culvert under the highway. The channel is very shallow and may have been straightened in the past. This is a F4 channel dominated by gravel. Within the 302-acre drainage area, agriculture is the dominant land use (44%), followed by open urban land (23%). Low-density residential development accounts for 19% of the drainage area and forest for 12%. One percent of the land use is in both institutional and transportation land uses. Impervious cover accounts for 13% of the drainage area. The RBP habitat assessment resulted in a score of 60 ("Non-Supporting"); the PHI score was 44.9 ("Severely Degraded"). The stream was well-shaded (80%). A total of 27 taxa were present in the benthic macroinvertebrate sample, including five Ephemeroptera, Plecoptera, and Tricoptera (EPT) taxa. Only three percent of the individuals in the benthic macroinvertebrate sample were intolerant to urban stressors. The site's overall BIBI score of 3.33 corresponds to a "Fair" biological classification. All water quality parameters were within acceptable COMAR standards.

06MP-326-F-2014J – This is a third-order stream located along the edge of agricultural land near Route 32. This is a F4 channel dominated by gravel. Within the 7,279-acre drainage area, agriculture is the dominant land use (47%), followed by low-density residential development (25%) and forested land (21%). The remaining seven percent of the land is either in commercial/ industrial, institutional, open urban land, or transportation land uses. Impervious cover accounts for seven percent of the drainage area. The RBP habitat assessment resulted in a score of 86 ("Supporting"); the PHI score was 79.7 ("Partially Degraded"). A total of 34 taxa were present in the benthic macroinvertebrate sample, including 13 Ephemeroptera, Plecoptera, and Tricoptera (EPT) taxa. Seventeen percent of the individuals in the benthic macroinvertebrate sample were intolerant to urban stressors. The site's overall BIBI score of 3.67 corresponds to a "Fair" biological classification. All water quality parameters were within acceptable COMAR standards.

3.2 MIDDLE MIDDLE PATUXENT

In 2014, 6 of the 10 sampling sites in the Middle Middle Patuxent were on first-order streams, two were on second and third-order streams, respectively. The field QC sample was

collected at site 07MP-316-R-2014F. The subwatershed had an average BIBI score of 3.77 and a "Fair" condition rating; scores ranged from 2.00 to 5.00. The average RBP habitat assessment comparability score was 67.2 or "Partially Supporting," and scores ranged from 50 ("Non-Supporting") to 76 ("Supporting"). The average PHI score was 66.1 ("Partially Degraded"). Five of the stream channels assessed in the Middle Middle Patuxent were classified as Rosgen type F. Three of the remaining channels were classified as C, one as E, and one as a G stream. Substrates were predominantly gravel at seven of the sites. One site had silt/clay substrate and the remaining two sites had sandy bottoms. Table 3-2 summarizes the results for the Middle Middle Patuxent subwatershed and Figure 3-2 shows the sites with BIBI and RBP comparability scores on a map.

Table 3-2. Middle Middle Patuxent Sampling Results

Site ID	Drainage Area (acres)	% Imper-vious	BIBI Score	BIBI Rating	RBP Score	RBP Rating	PHI Score	PHI Rating
07MP-101-R-2014A	92.92	6.86	2.00	Poor	50.00	Non-supporting	57.52	Degraded
07MP-104-R-2014B	1381.70	9.50	2.67	Poor	74.00	Partially Supporting	66.50	Partially Degraded
07MP-107-R-2014C	436.55	4.55	4.67	Good	73.00	Partially Supporting	79.13	Partially Degraded
07MP-111-R-2014D	1773.86	7.91	4.67	Good	72.00	Partially Supporting	73.45	Partially Degraded
07MP-313-R-2014E	4056.29	7.23	4.00	Good	50.00	Non-Supporting	60.01	Degraded
07MP-316-R-2014F*	17854.81	7.13	3.33	Fair	75.00	Partially Supporting	77.44	Partially Degraded
07MP-119-F-2014G	456.18	8.13	4.00	Good	57.00	Non-Supporting	62.97	Degraded
07MP-221-F-2014H	1041.63	7.11	5.00	Good	76.00	Partially Supporting	52.32	Degraded
07MP-123-F-2014I	30.56	15.32	3.00	Fair	71.00	Partially-Supporting	67.61	Partially Degraded
07MP-225-F-2014J	1651.37	5.07	4.33	Good	74.00	Partially Supporting	63.88	Degraded
Minimum	30.56	4.55	2.00	Poor	50.00	Non-supporting	52.32	Degraded
Maximum	17854.81	15.32	5.00	Good	76.00	Supporting	79.13	Partially Degraded
Mean	2877.59	7.88	3.77	Fair	67.20	Partially Supporting	66.08	Partially Degraded
Standard Deviation	5392.57	2.97	0.98		10.53		8.63	

* QC sampling was conducted at this site

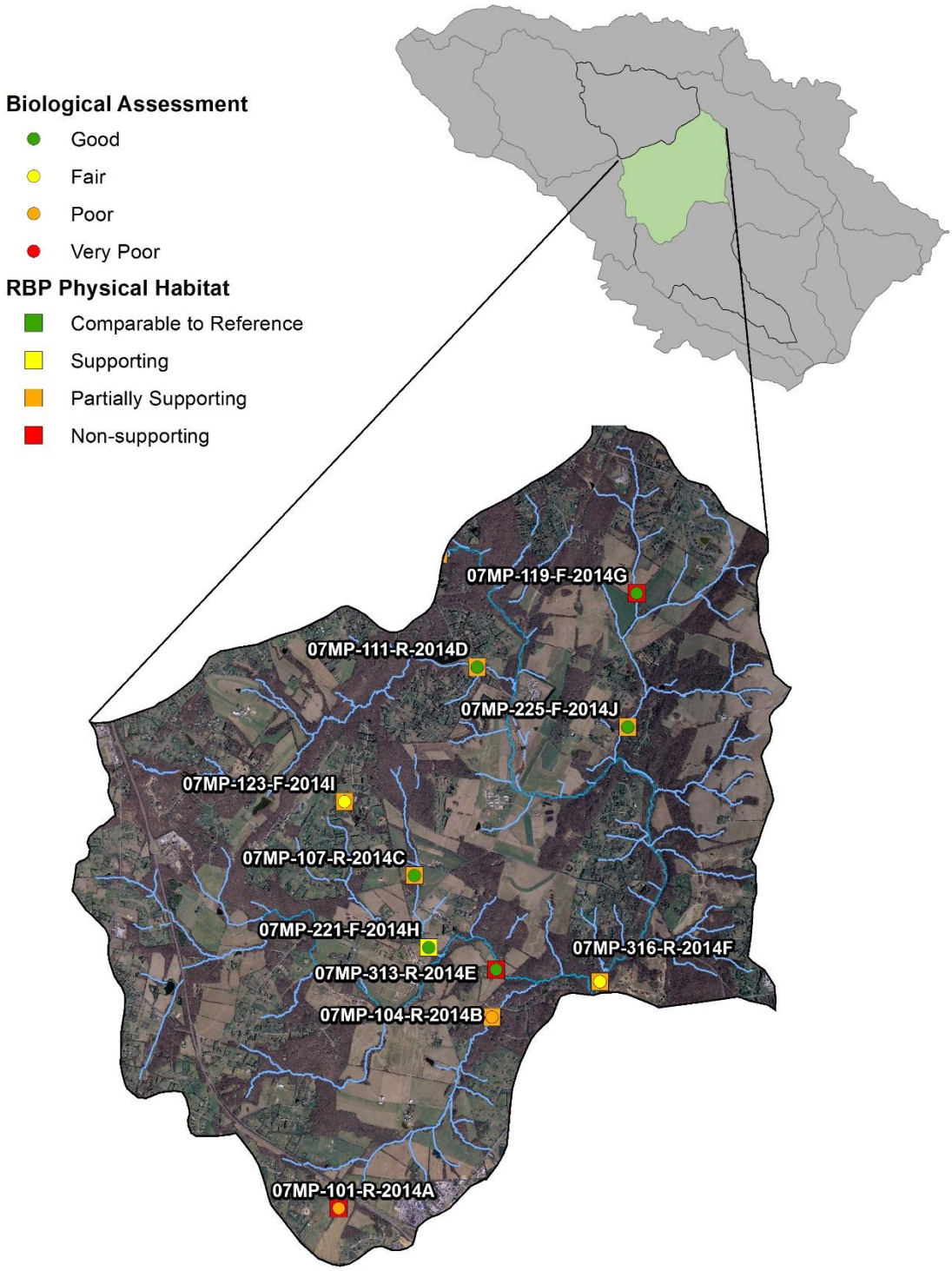

Figure 3-2. Middle Middle Patuxent sampling results

07MP-101-R-2014A – This is a very small first-order stream located in a narrow wooded buffer between two agricultural fields. This is an E6 channel dominated by silt/clay substrate. Within the 93-acre drainage area, agriculture is the dominant land use (65%), followed by low-density residential development (27%). Five percent of the land use is forested and two percent of the drainage area is commercial/industrial land use. Impervious cover accounts for seven percent of the drainage area. The RBP habitat assessment resulted in a score of 50 ("Non-Supporting"); the PHI score was 57.5 ("Degraded"). A total of 21 taxa were present in the benthic macroinvertebrate sample, with no Ephemeroptera, Plecoptera, and Tricoptera (EPT) taxa. Thirteen percent of the individuals in the benthic macroinvertebrate sample were intolerant to urban stressors and the sample was dominated by Chironomidae midges (59%). The site's overall BIBI score of 2.00 corresponds to a "Poor" biological classification. All water quality parameters were within acceptable COMAR standards.

07MP-104-R-2014B – This is a first-order stream in a relatively low-density residential area with large home lots. This is a C5 channel dominated by sand. Within the 1,382 acre drainage area, agriculture is the dominant land use (58%), followed by low-density residential development (24%). Ten percent of the land use is forested and five percent of the drainage area is commercial/industrial. The remaining three percent of the drainage area is medium-density residential development, institutional, or transportation. Impervious cover accounts for 10% of the drainage area. The RBP habitat assessment resulted in a score of 74 ("Partially Supporting"); the PHI score was 66.5 ("Partially Degraded"). A total of 27 taxa were present in the benthic macroinvertebrate sample, including nine Ephemeroptera, Plecoptera, and Tricoptera (EPT) taxa. Only nine percent of the individuals in the benthic macroinvertebrate sample were intolerant to urban stressors and the sample was dominated by Chironomidae midges (66%). The site's overall BIBI score of 2.67 corresponds to a "Poor" biological classification. All water quality parameters were within acceptable COMAR standards.

07MP-107-R-2014C – This first-order stream is located in the woods flowing along the edge of a crop field. This is a C5 channel dominated by gravel. Within the 437-acre drainage area, the land use is relatively evenly split between agriculture (46%) and forest (33%). Low-density residential development accounts for 15% of the drainage area and six percent of the land use is institutional. Impervious cover accounts for five percent of the drainage area. The RBP habitat assessment resulted in a score of 73 ("Partially Supporting"); the PHI score was 79.1 ("Partially Degraded"). A total of 28 taxa were present in the benthic macroinvertebrate sample, including 11 Ephemeroptera, Plecoptera, and Tricoptera (EPT) taxa. The benthic macroinvertebrate sample was dominated by individuals intolerant to urban stressors (57%). The site's overall BIBI score of 4.67 corresponds to a "Good" biological classification. All water quality parameters were within acceptable COMAR standards.

07MP-111-R-2014D – This is a first-order stream in a low-density residential area near Carroll Mill Road. This is a G4 channel dominated by gravel. Within the 1,774-acre drainage area, low-density residential development is the dominant land use (46%), followed by forest (28%) and agriculture (24%). The remaining two percent of the land is either commercial/industrial or open water. Impervious cover accounts for eight percent of the drainage area. The

RBP habitat assessment resulted in a score of 72 ("Partially Supporting"); the PHI score was 73.5 ("Partially Degraded"). A total of 30 taxa were present in the benthic macroinvertebrate sample, including 11 Ephemeroptera, Plecoptera, and Tricoptera (EPT) taxa. Thirty percent of the individuals in the benthic macroinvertebrate sample were intolerant to urban stressors. The site's overall BIBI score of 4.67 corresponds to a "Good" biological classification. All water quality parameters were within acceptable COMAR standards.

07MP-313-R-2014E – This is a third-order stream located in open agricultural land. This is a C4 channel dominated by gravel. Within the 4,056-acre drainage area, agriculture is the dominant land use (48%), followed by low-density residential development (27%) and forested land use (22%). The remaining three percent of the land is either commercial/industrial, institutional, or open water. Impervious cover accounts for seven percent of the drainage area. The RBP habitat assessment resulted in a score of 50 ("Non-Supporting"); the PHI score was 60 ("Degraded"). A total of 49 taxa were present in the benthic macroinvertebrate sample, including 15 Ephemeroptera, Plecoptera, and Tricoptera (EPT) taxa. Twenty-eight percent of the individuals in the benthic macroinvertebrate sample were intolerant to urban stressors. The site's overall BIBI score of 4.00 corresponds to a "Good" biological classification. All water quality parameters were within acceptable COMAR standards.

07MP-316-R-2014F – This is a well-forested, third-order stream located in a low- to medium-density residential area. This is a F4 channel dominated by gravel. Within the very large 17,855-acre drainage area, agriculture is the dominant land use (41%), followed by low-density residential development (30%) and forest (25%). The remaining four percent is dispersed among many land use types: bare ground, commercial/industrial, high-density residential development, institutional land, open urban land, open water, and transportation. Impervious cover accounts for seven percent of the drainage area. The RBP habitat assessment resulted in a score of 75 ("Partially Supporting"); the PHI score was 77.4 ("Partially Degraded"). There is evidence of erosion. A total of 29 taxa were present in the benthic macroinvertebrate sample, including 10 Ephemeroptera, Plecoptera, and Tricoptera (EPT) taxa. Twenty-one percent of the individuals in the benthic macroinvertebrate sample were intolerant to urban stressors. The site's overall BIBI score of 3.33 corresponds to a "Fair" biological classification. All water quality parameters were within acceptable COMAR standards. This site was the Middle Middle Patuxent's QC (duplicate) site.

07-MP-119-F-2014G – This is a well-buffered first-order stream located in open agricultural fields. This is a F5 channel dominated by sandy substrate. Within the 456-acre drainage area, low-density residential development and agricultural land uses are evenly distributed (low-density residential development (38%) and agricultural land (37%)). Forested land use accounts for 22% of the drainage area and institutional land use is four percent of the drainage area. Impervious cover accounts for eight percent of the drainage area. The RBP habitat assessment resulted in a score of 57 ("Non-Supporting"); the PHI score was 63 ("Degraded"). There is evidence of severe erosion. A total of 30 taxa were present in the benthic macroinvertebrate sample, including nine Ephemeroptera, Plecoptera, and Tricoptera (EPT) taxa. Forty-seven percent of the individuals in the benthic macroinvertebrate sample were intolerant to

urban stressors. The site's overall BIBI score of 4.00 corresponds to a "Good" biological classification. All water quality parameters were within acceptable COMAR standards.

07MP-221-F-2014H – This is a second order stream located in a low-density agricultural area that was historically farmed. This is an F4 channel dominated by gravel. Within the 1,042-acre drainage area, agriculture is the dominant land use (55%), followed by forested land use (21%) and low-density residential development (18%). Six percent of the land use is institutional. Impervious cover accounts for seven percent of the drainage area. The RBP habitat assessment resulted in a score of 76 ("Partially Supporting"); the PHI score was 52.32 ("Degraded"). Only five percent of the stream was shaded. There is evidence of severe erosion throughout. A total of 36 taxa were present in the benthic macroinvertebrate sample, including 11 Ephemeroptera, Plecoptera, and Tricoptera (EPT) taxa. The benthic macroinvertebrate sample was dominated by individuals intolerant to urban stressors (54%) and only 15% of the sample was Chironomidae midges. The site's overall BIBI score of 5.00 corresponds to a "Good" biological classification. All water quality parameters were within acceptable COMAR standards.

07MP-123-F-2014I – This is a very small first-order stream located in a low-density residential area that was historically farmed. This is a F4 channel dominated by gravel. The 31-acre drainage area is dominated by low-density residential development. Agricultural land use accounts for 28% of the drainage area and 22% is institutional land. Impervious cover accounts for 15% of the drainage area. The RBP habitat assessment resulted in a score of 71 ("Partially Supporting"); the PHI score was 67.6 ("Partially Degraded"). A total of 27 taxa were present in the benthic macroinvertebrate sample, including only four Ephemeroptera, Plecoptera, and Tricoptera (EPT) taxa. Twenty-seven percent of the individuals in the benthic macroinvertebrate sample were intolerant to urban stressors. The site's overall BIBI score of 3.00 corresponds to a "Fair" biological classification. The pH value of 5.74 was below the acceptable COMAR standard of 6.5, but all other water quality parameters were within acceptable COMAR standards.

07MP-225-F-2014J – This is a well-forested second order stream located in in a low-to medium-density residential area. This is a F4 channel dominated by gravel. Within the 1,651-acre drainage area, agriculture is the dominant land use (50%), followed by forested land (27%) and low-density residential development (22%). The remaining one percent of the land is either high-density residential development or institutional land use. Impervious cover accounts for five percent of the drainage area. The RBP habitat assessment resulted in a score of 74 ("Partially Supporting"); the PHI score was 63.88 ("Degraded"). There is some evidence of erosion. A total of 31 taxa were present in the benthic macroinvertebrate sample, including 10 Ephemeroptera, Plecoptera, and Tricoptera (EPT) taxa. The benthic macroinvertebrate sample was dominated by individuals intolerant to urban stressors (65%) and only 15% of the sample was Chironomidae midges. The site's overall BIBI score of 4.33 corresponds to a "Good" biological classification. All water quality parameters were within acceptable COMAR standards.

3.3 LOWER MIDDLE PATUXENT

In 2014, four of the ten sampling sites in the Lower Middle Patuxent subwatershed were on first-order streams, one was on a second-order stream, three were on third-order streams, and two were on fourth order streams. The field QC sample was collected at site 08MP-123-F-2014I. The subwatershed had an average BIBI score of 3.63 and a "Fair" condition rating; scores ranged from 1.67 to 4.67. The average RBP habitat assessment comparability score was 74.6 or "Partially Supporting," and scores ranged from 56 ("Non-Supporting") to 86 ("Supporting"). The average PHI score was 67.6 ("Partially Degraded"). Eight streams were classified as Rosgen type F channels, one was a type G channel and one was a type C channel. Gravel was the dominant channel substrate at eight sites. One site was dominated by silt/clay and one site had a sandy bottom. Table 3-3 summarizes the results for the Lower Middle Patuxent subwatershed and Figure 3-3 shows the sites with BIBI and RBP comparability scores on a map.

Table 3-3. Lower Middle Patuxent Sampling Results

Site ID	Drainage Area (acres)	% Impervious	BIBI Score	BIBI Rating	RBP Score	RBP Rating	PHI Score	PHI Rating
08MP-101-R-2014A	17.76	2.17	1.67	Very Poor	56.00	Non-Supporting	40.50	Severely Degraded
08MP-104-R-2014B	280.28	11.65	4.67	Good	69.00	Partially Supporting	66.34	Partially Degraded
08MP-208-R-2014C	1163.24	8.16	4.67	Good	73.00	Partially Supporting	66.08	Partially Degraded
08MP-311-R-2014D	3338.39	9.43	4.00	Good	80.00	Supporting	75.33	Partially Degraded
08MP-305-R-2014E	3978.06	11.74	3.00	Fair	78.00	Supporting	63.85	Degraded
08MP-416-R-2014F	36346.41	9.81	4.33	Good	71.00	Partially Supporting	70.08	Partially Degraded
08MP-120-F-2014G	326.88	28.35	1.67	Very Poor	69.00	Partially Supporting	75.45	Partially Degraded
08MP-321-F-2014H	3190.56	8.69	4.00	Good	83.00	Supporting	74.22	Partially Degraded
08MP-123-F-2014I*	154.29	29.21	4.00	Good	86.00	Supporting	69.76	Partially Degraded
08MP-425-F-2014J	36418.53	9.81	4.33	Good	81.00	Supporting	74.65	Partially Degraded
Minimum	17.76	2.17	1.67	Very Poor	56.00	Non-supporting	40.50	Severely Degraded
Maximum	36418.53	29.21	4.67	Good	86.00	Supporting	75.45	Partially Degraded
Mean	8521.44	12.90	3.63	Fair	74.60	Partially Supporting	67.63	Partially Degraded
Standard Deviation	14757.05	8.78	1.14		8.86		10.42	

* QC sampling was conducted at this site

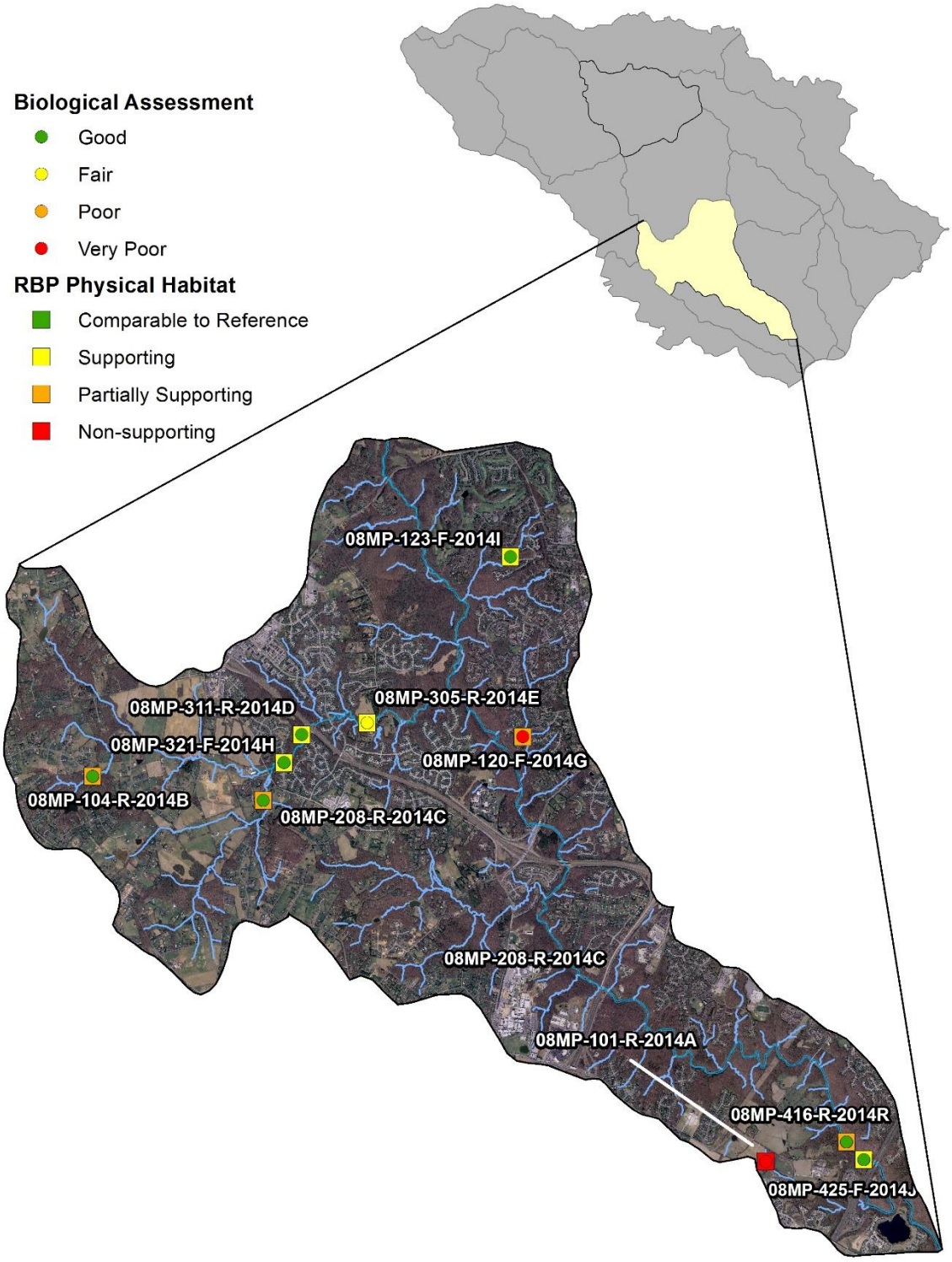

Figure 3-3. Lower Middle Patuxent sampling results

08MP-101-R-2014A – This site is on a very small first-order stream deeply cut into a blown out ravine in a patch of woods alongside a crop field. This is an F6 channel dominated by a silt/clay substrate. The land use in this drainage area is 100% agricultural. Impervious cover accounts for only two percent of the drainage area. The RBP habitat assessment resulted in a score of 56 ("Non-Supporting"); the PHI score was 40.5 ("Severely Degraded"). The substrate at the site is predominately hardened claypan and the water is very shallow. The banks are tall and unstable. A total of 24 taxa were present in the benthic macroinvertebrate sample, including six Ephemeroptera, Plecoptera, and Tricoptera (EPT) taxa. Only twelve percent of the individuals in the benthic macroinvertebrate sample were intolerant to urban stressors and the sample was dominated by Chironomidae midges (67%). The site's overall BIBI score of 1.67 corresponds to a "Very Poor" biological classification. All water quality parameters were within acceptable COMAR standards.

08MP-104-R-2014B – This is a larger first-order stream through a medium- to low-density housing development. This is a G4 channel dominated by gravel. Within the 280-acre drainage area, low-density residential development is the dominant land use (76%), followed by forested land use (18%). Five percent of the land use is agricultural and one percent of the drainage area is open water. Impervious cover accounts for 12% of the drainage area. The RBP habitat assessment resulted in a score of 69 ("Partially Supporting"); the PHI score was 66.3 ("Partially Degraded"). The substrate at the site is cobbled and embeddedness is high. There is evidence of erosion. A total of 34 taxa were present in the benthic macroinvertebrate sample, including 13 Ephemeroptera, Plecoptera, and Tricoptera (EPT) taxa. Thirty-nine percent of the individuals in the benthic macroinvertebrate sample were intolerant to urban stressors. The site's overall BIBI score of 4.67 corresponds to a "Good" biological classification. All water quality parameters were within acceptable COMAR standards.

08MP-208-R-2014C – This is a well-buffered second-order stream located in maintained field/pastureland. This is an F4 channel dominated by gravel. Within the 1,163-acre drainage area, agriculture is the dominant land use (51%), followed by low-density residential development (30%) and forest (16%). The remaining three percent of the land is either in commercial/industrial or institutional land use. Impervious cover accounts for eight percent of the drainage area. The RBP habitat assessment resulted in a score of 73 ("Partially Supporting"); the PHI score was 66.1 ("Partially Degraded"). A total of 42 taxa were present in the benthic macroinvertebrate sample, including 15 Ephemeroptera, Plecoptera, and Tricoptera (EPT) taxa. Thirty-six percent of the individuals in the benthic macroinvertebrate sample were intolerant to urban stressors. The site's overall BIBI score of 4.67 corresponds to a "Good" biological classification. All water quality parameters were within acceptable COMAR standards.

08MP-311-R-2014D – This is a third-order site located just upstream from the bridge where the stream crosses Route 32. This is an F4 channel dominated by gravel. The 3,338-acre drainage area is relatively even divided between agricultural land (41%) and low-density residential development (35%). Seventeen percent of the land use is forested. The remaining six percent of the land is either in commercial/industrial land, institutional, medium-density residential development, or open water. Impervious cover accounts for nine percent of the drainage area. The

RBP habitat assessment resulted in a score of 80 ("Supporting"); the PHI score was 75.3 ("Partially Degraded"). There are signs of erosion on both banks. A total of 34 taxa were present in the benthic macroinvertebrate sample, including 15 Ephemeroptera, Plecoptera, and Tricoptera (EPT) taxa. Sixteen percent of the individuals in the benthic macroinvertebrate sample were intolerant to urban stressors. The site's overall BIBI score of 4.00 corresponds to a "Good" biological classification. All water quality parameters were within acceptable COMAR standards.

08MP-305-R-2014E – This is a broad third-order stream that parallels Trotter Road on the left bank. This is an F4 channel dominated by gravel. The 3,978-acre drainage area has widely dispersed land uses, but mostly consists of agriculture (35%) and low-density residential development (30%). Twenty percent of the land use is forested and ten percent of the drainage area is medium-density residential development. The remaining five percent of the land is either in bare ground, commercial/industrial land, institutional, open water, or transportation. Impervious cover accounts for 12% of the drainage area. The RBP habitat assessment resulted in a score of 78 ("Supporting"); the PHI score was 63.9 ("Partially Degraded"). A total of 33 taxa were present in the benthic macroinvertebrate sample, including 9 Ephemeroptera, Plecoptera, and Tricoptera (EPT) taxa. Fourteen percent of the individuals in the benthic macroinvertebrate sample were intolerant to urban stressors. The site's overall BIBI score of 3.00 corresponds to a "Fair" biological classification. All water quality parameters were within acceptable COMAR standards.

08MP-416-R-2014F – This is a somewhat isolated fourth-order stream with a pipeline easement in the buffer of the right bank. This stream has an F4 channel and a mostly sandy bottom. The large 36,346-acre drainage area has widely dispersed land uses, but consists mostly of agriculture (34%), forest (27%), and low-density residential development (26%). Six percent of the drainage area is medium-density residential development. The remaining seven percent of the drainage area is either bare ground, commercial/industrial land, institutional, high-density residential development, open urban land, open water, or transportation. Impervious cover accounts for 10% of the drainage area. The RBP habitat assessment resulted in a score of 71 ("Partially Supporting"); the PHI score was 70.1 ("Partially Degraded"). There is moderate evidence of erosion. A total of 49 taxa were present in the benthic macroinvertebrate sample, including 23 Ephemeroptera, Plecoptera, and Tricoptera (EPT) taxa. Fifty percent of the individuals in the benthic macroinvertebrate sample were intolerant to urban stressors. The site's overall BIBI score of 4.33 corresponds to a "Good" biological classification. All water quality parameters were within acceptable COMAR standards.

08MP-120-F-2014G – This is a first order stream that flows through a high-density residential area. While the banks of the streams are generally well-buffered, a paved walking path runs parallel to the left bank for approximately 10 meters and a small playground area is located on the right bank. This is an F4 channel dominated by gravel. The land use in the 327-acre drainage area is fairly evenly divided between medium-density residential land use (44%) and high-density residential land use (42%). Eleven percent of the land use is forested and the remaining three percent of the land is either low-density residential development or institutional land. Impervious cover accounts for 28% of the drainage area. The RBP habitat assessment

resulted in a score of 69 ("Partially Supporting"); the PHI score was 75.5 ("Partially Degraded"). There is moderate evidence of erosion. A total of 18 taxa were present in the benthic macroinvertebrate sample, including only 4 Ephemeroptera, Plecoptera, and Tricoptera (EPT) taxa. Only two percent of the individuals in the benthic macroinvertebrate sample were intolerant to urban stressors and the sample was dominated by Chironomidae midges (74%). The site's overall BIBI score of 1.67 corresponds to a "Very Poor" biological classification. All water quality parameters were within acceptable COMAR standards.

08MP-321-F-2014H – This is a third-order stream located in a high-density residential area. This is an F4 channel dominated by gravel. The 3,191-acre drainage area is relatively even divided between agricultural land (43%) and low-density residential development (37%). Eighteen percent of the land use is forested. The remaining three percent of the land is either in commercial/industrial land, institutional, medium-density residential development, or open water. Impervious cover accounts for nine percent of the drainage area. The RBP habitat assessment resulted in a score of 83 ("Supporting"); the PHI score was 74.2 ("Partially Degraded"). A total of 32 taxa were present in the benthic macroinvertebrate sample, including 11 Ephemeroptera, Plecoptera, and Tricoptera (EPT) taxa. Fourteen percent of the individuals in the benthic macroinvertebrate sample were intolerant to urban stressors. The site's overall BIBI score of 4.00 corresponds to a "Good" biological classification. All water quality parameters were within acceptable COMAR standards.

08MP-123-F-2014I – This is a small first-order stream through a high-density housing area, but is well-buffered by forested areas. This is an F4 channel dominated by gravel. The 154-acre drainage area has widely dispersed land uses, but is dominated by high-density residential development (40%). Seventeen percent of the drainage area is open urban land, thirteen percent is forested, twelve percent is medium-density residential development, and eleven percent is commercial/industrial land. The remaining seven percent of the drainage area is either agricultural, bare ground, institutional, or low-density residential development. Impervious cover accounts for 29% of the drainage area. The RBP habitat assessment resulted in a score of 86 ("Supporting"); the PHI score was 69.8 ("Partially Degraded"). There is moderate evidence of erosion. A total of 47 taxa were present in the benthic macroinvertebrate sample, including 16 Ephemeroptera, Plecoptera, and Tricoptera (EPT) taxa. Twenty-two percent of the individuals in the benthic macroinvertebrate sample were intolerant to urban stressors. The site's overall BIBI score of 4.00 corresponds to a "Good" biological classification. All water quality parameters were within acceptable COMAR standards.

08MP-425-F-2014J – This is a well-buffered, fourth-order stream on the Patuxent main-stem just north of the Interstate 95 crossing. This is a C4 channel dominated by gravel. The large 36,419-acre drainage area has widely dispersed land uses, but consists mainly of agriculture (34%), forest (27%), and low-density residential development (26%). Six percent of the drainage area is medium-density residential development. The remaining seven percent of the drainage area is either bare ground, commercial/industrial land, institutional, high-density residential development, open urban land, open water, or transportation. Impervious cover accounts for 10% of the drainage area. The RBP habitat assessment resulted in a score of 81 ("Supporting"); the PHI score was 74.7

("Partially Degraded"). A total of 49 taxa were present in the benthic macroinvertebrate sample, including 13 Ephemeroptera, Plecoptera, and Tricoptera (EPT) taxa. Twenty-seven percent of the individuals in the benthic macroinvertebrate sample were intolerant to urban stressors. The site's overall BIBI score of 4.33 corresponds to a "Good" biological classification. All water quality parameters were within acceptable COMAR standards.

4 DISCUSSION AND COMPARISON

4.1 DISCUSSION OF 2014 ASSESSMENT RESULTS

Bioassessment – Biological results for 2014 in the Upper Middle Patuxent, Middle Middle Patuxent, and Lower Middle Patuxent subwatersheds indicate that conditions in the streams range from very poor to good. Sixteen of the sites sampled received overall BIBI ratings of "Good". Six sites received ratings of "Fair" and five sites received ratings of "Poor." Only three sites, one in the Upper Middle Patuxent subwatershed and two in the Lower Middle Patuxent subwatershed, received a rating of "Very Poor". Duplicate benthic samples were taken at three sites, one within each subwatershed. Comparisons between the original sample and the duplicate were analyzed (see Appendix F for detailed analyses including performance standards).

Physical Habitat – RBP habitat assessment results indicate average subwatershed physical habitat conditions that are "Partially Supporting" in all three subwatersheds. None of the sites sampled in any of the three subwatersheds were "Comparable to Reference" (as defined as > 90% of the maximum score). Eight sites were "Supporting", five of which were in the Lower Middle Patuxent subwatershed. Fourteen sites were "Partially Supporting" and eight were "Non-Supporting."

The PHI results indicate average subwatershed physical habitat conditions that are "Degraded" in the Upper Middle Patuxent subwatershed and "Partially Degraded" in the Middle Middle Patuxent and Lower Middle Patuxent subwatersheds. No sites were "Minimally Degraded." Eighteen sites were "Partially Degraded", eight sites were "Degraded", and four were "Severely Degraded" (3 in the Upper Middle Patuxent and one in the Lower Middle Patuxent).

Appendix D contains details concerning the physical habitat analyses.

Water Quality – One site in the Upper Middle Patuxent and one site in the Middle Middle Patuxent subwatershed were below the minimum COMAR pH standard of 6.5. All other sites sampled showed water quality values (i.e., temperature, dissolved oxygen, pH, conductivity, and turbidity) well within accepted COMAR ranges. A site-by-site breakdown of field-measured water quality parameters is included in Appendix B.

Geomorphology – The geomorphic assessment indicates a variable system. Some of the channels sampled throughout the subwatersheds were classified as stable type C and E channels; however, two-thirds of the channels were classified as unstable, incised F and G channels. Gravel is the dominant substrate type in almost all of the sampled reaches; however, sand- and silt/clay-dominant streams also were present.

Imperviousness – The average percentage of impervious area in the upstream catchments in the Upper Middle Patuxent subwatershed is 10%. Eight percent of the land in the upstream catchments in the Middle Middle Patuxent and 13% of the land in the Lower Middle Patuxent

subwatershed is impervious surface. Imperviousness in the areas draining to each sampling site ranges from 2% to 29% (see Appendix A for impervious values). The benthic community in a freshwater stream can be adversely affected by impervious cover and associated runoff at values below 10% (CWP 2003). A statistical correlation between imperviousness and the BIBI was identified and is discussed in the following section.

Regression Relationships – Regression analysis is a statistical technique for estimating the relationships among variables. It helps one to understand how the typical value of the one variable changes when another variable is varied. It allows a user to use measured data to predict future results. The result of a regression analysis is an R-squared value that ranges from 0 to 1.0. A higher number is indicative of a stronger relationship between the variables.

Land use, habitat, and water chemistry parameters were regressed against the benthic macroinvertebrate IBI scores for each site in order to examine the relationship of those parameters to the biological health of the stream. For the purposes of this analysis and because they were all significantly correlated with each other, percentage impervious was used as a proxy for all of the other land use types.

The relationship of BIBI scores to impervious surface in the catchments upstream of the sample site was not significant (Figure 4-1; R2= 0.01, p = 0.53), primarily due to the relatively small range of impervious values in catchments sampled in 2014. Generally, as impervious surface increased, the BIBI scores decreased. Although not significant, these results are consistent with the notion that overall biological condition is likely being affected by the amount of development (i.e., imperviousness) in the watershed.

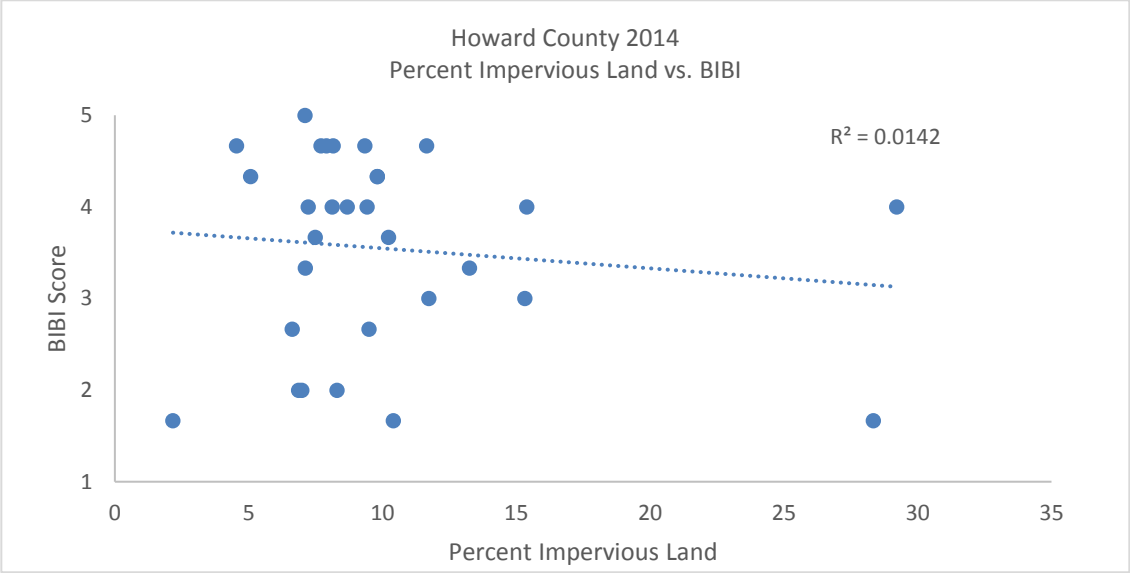

Figure 4-1. Regression relationships between the Benthic Index of Biotic Integrity (BIBI) and impervious surface in upstream catchments during 2014 Howard County Biological Monitoring

There are significant positive relationships between the BIBI and both the RBP habitat assessment score and the PHI score (R2= 0.36, $p < 0.001$, R2 = 0.34, $p < 0.001$, respectively). As the habitat scores increase, so does the BIBI (see Figure 4-2). This suggests that physical habitat conditions directly affect the biological condition of a stream.

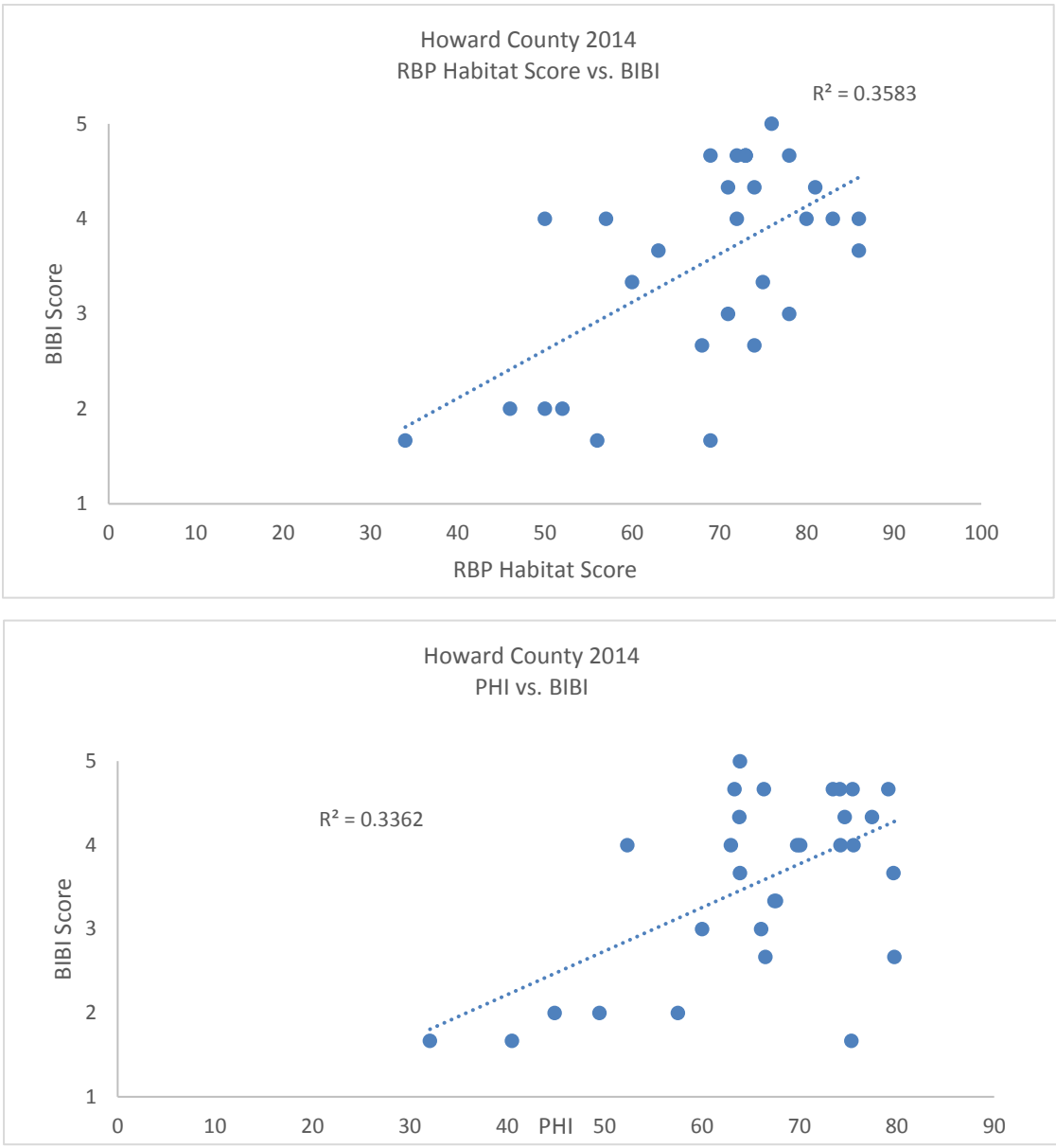

Figure 4-2. Regression relationships between the Benthic Index of Biotic Integrity (BIBI) and both RBP Habitat Assessment Score and Physical Habitat Indicator (PHI) for sites sampled in the 2014 Howard County Biological Monitoring.

Water quality parameters (temperature, dissolved oxygen, pH, conductivity, and turbidity) were also regressed against the BIBI score. None of the results showed significant relationships, although a general trend showed that as dissolved oxygen increased and conductivity decreased, the BIBI scores improved.

4.2 COMPARISON OF 2002, 2007, AND 2014 BIOASSESSMENT DATA

BIBI – Table 4-1 summarizes the 2002, 2007, and 2014 biological index data, and Figure 4-3 is a box plot comparing BIBI scores for each subwatershed (current BIBI calculations were used for all rounds).

In the Upper Middle Patuxent and Middle Middle Patuxent subwatersheds, the assessments in all three Rounds indicated that the subwatersheds were in "Fair" biological condition overall, according to the updated BIBI scores The ANOVA test for differences amongst the years showed that the biological condition in all three Rounds were not significantly different from each other in either subwatershed.

In the Lower Middle Patuxent subwatershed, the Round 1 and Round 3 biological condition were "Fair" overall, but condition decreased slightly in Round 2 to "Poor". Although in different narrative categories, the ANOVA test show that the biological condition was not significantly different in Round 2 than in Rounds 1 and 3.

RBP Physical Habitat Assessment – Table 4-3 summarizes the 2002, 2007, and 2014 RBP comparability scores, and Figure 4-4 is a box plot illustrating RBP comparability scores. In all subwatersheds, Round 1 results showed the physical habitat was "Non-Supporting", while results for Rounds 2 and 3 show RBP results of "Partially Supporting." In all three subwatersheds, the ANOVA test showed that Round 1 habitat results were significantly lower than results in Rounds 2 or 3 ($p < 0.001$ in all three cases).

Table 4-1. Comparison of 2002, 2007, and 2014 BIBI data								
Sampling Year		**Number of Sites Sampled**	**Min BIBI Score**	**Max BIBI Score**	**Median BIBI Score**	**Mean BIBI Score**	**Narrative Rating**	**Standard Deviation**
2002	Lower Middle Patuxent	10	1.33	4	3.33	3.27	Fair	0.78
	Middle Middle Patuxent	10	2.67	4.67	3.67	3.67	Fair	0.52
	Upper Middle Patuxent	8	2	4.67	3.5	3.25	Fair	0.86
2007	Lower Middle Patuxent	10	1	4	3.17	2.67	Poor	1.18
	Middle Middle Patuxent	10	2.33	4.33	3.83	3.57	Fair	0.7
	Upper Middle Patuxent	10	2.33	4	3.17	3.27	Fair	0.56
2014	Lower Middle Patuxent	10	1.67	4.67	4	3.63	Fair	1.14
	Middle Middle Patuxent	10	2	5	4	3.77	Fair	0.98
	Upper Middle Patuxent	10	1.67	4.67	3.5	3.23	Fair	1.1

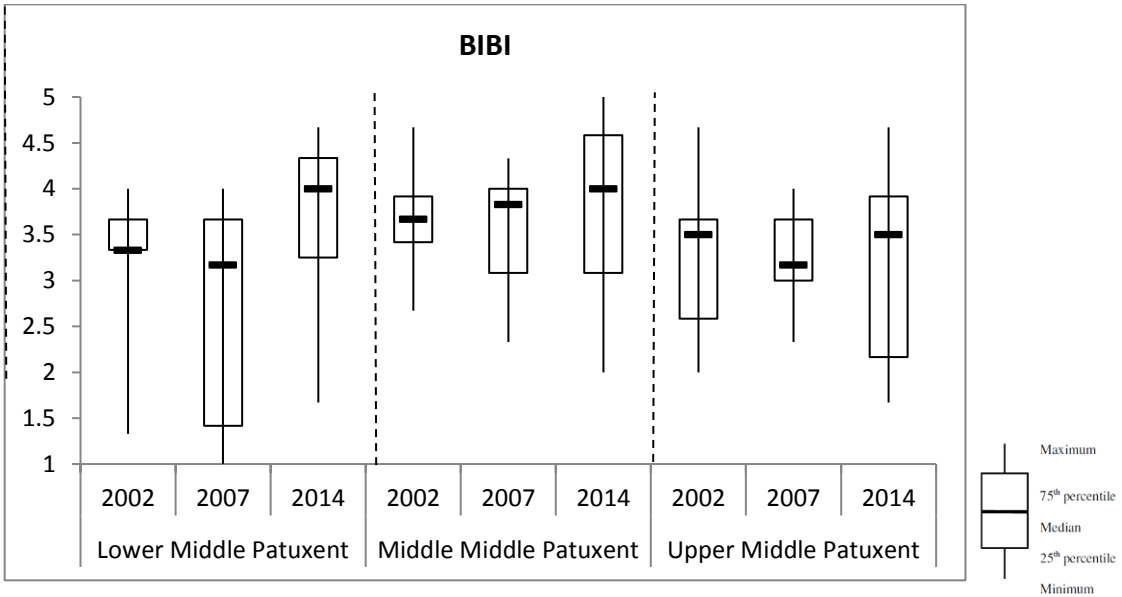

Figure 4-3. Comparison of 2002, 2007, and 2014 BIBI scores

Table 4-2. Comparison of 2002, 2007, and 2014 RBP assessment data								
Sampling Year		**Number of Sites Sampled**	**Min** RBP **Score**	**Max RBP Score**	**Median RBP Score**	**Mean RBP Score**	**Narrative Rating**	**Standard Deviation**
2002	Lower Middle Patuxent	10	44	70	59	58.7	Non-Supporting	7.69
	Middle Middle Patuxent	10	41	62	54.5	52.7	Non-Supporting	6.58
	Upper Middle Patuxent	10	36	67	54	50.9	Non-Supporting	11.73
2007	Lower Middle Patuxent	10	60	76	69	69.5	Partially Supporting	4.95
	Middle Middle Patuxent	10	49	79	68	66.8	Partially Supporting	10.21
	Upper Middle Patuxent	10	56	80	73	68.7	Partially Supporting	9.58
2014	Lower Middle Patuxent	10	56	86	75.5	74.6	Partially Supporting	8.86
	Middle Middle Patuxent	10	50	76	72.5	67.2	Partially Supporting	10.52
	Upper Middle Patuxent	10	34	86	65.5	63.2	Partially Supporting	15.7

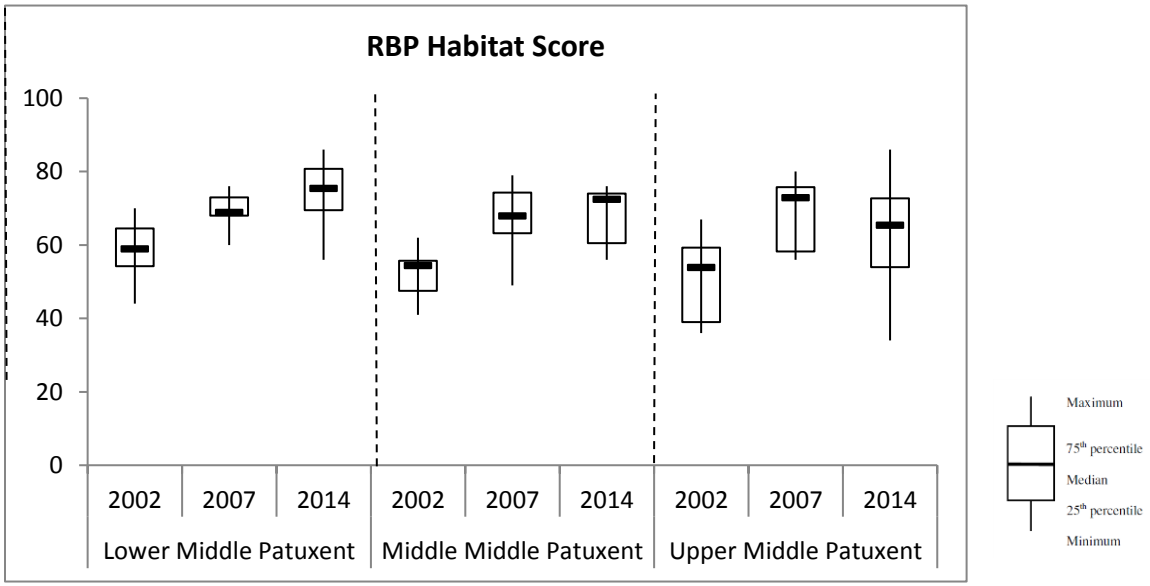

Figure 4-4. Comparison of 2002, 2007, and 2014 RBP assessment scores

5 CONCLUSIONS AND RECOMMENDATIONS

This report is the third of five annual reports that describe Round 3 (2012-2016) of the Howard County Biological Monitoring and Assessment Program. More definitive Round 3 conclusions and comparisons with Rounds 1 and 2 will be provided at the completion of Round 3. These preliminary conclusions and recommendations provide context for interpreting results and identifying possible future revisions.

5.1 WATERSHED CONDITIONS

Additional Water Quality Sampling - Habitat conditions and BIBI scores are not always strongly correlated with each other, indicating that stressors other than habitat are affecting stream conditions. This can be an indication of degraded water quality conditions. Although most of the water quality parameters measured were within the acceptable COMAR standards, additional sampling, especially on those streams rated as "Poor" or "Very Poor" for biological condition, may identify other chemical stressors that are affecting the biota. Supplementary sampling could include **additional parameters** such as nutrients and metals, which may be of concern. It is also likely that high levels of these chemical stressors may only occur in the first flush of stormwater runoff. Because biological monitoring is usually conducted under baseflow conditions, concomitant chemical sampling may fail to identify the effects of pollutants associated with stormwater runoff, specifically in more urban portions of the watershed. **Wet weather monitoring** in these watersheds can be conducted to determine the presence of additional water quality stressors in stormwater runoff. The cost of wet weather monitoring is prohibitive for an extensive bioassessment, but wet weather monitoring could be incorporated into the design as representative downstream sampling in each subwatershed.

Expanded Physical Habitat Assessment - 2012 (beginning of Round 3) was the first year the bioassessment collected the metrics for the MBSS Physical Habitat Index (PHI) and calculated the PHI for comparison with the RBP scores collected in Round 3 and previous rounds. The PHI showed a strong significant relationship to the RBP physical habitat assessment ($R^2 = 0.62$ with a p-value of < 0.001), indicating that the PHI score did not improve the overall assessment of the subwatersheds or individual sites significantly. However, certain metrics that contribute to the overall PHI score did prove useful in site assessments (especially "shading" and "embeddedness"). In addition, collection of the PHI information allows full integration with the MBSS regional assessments. We recommend that the PHI collection be retained through Round 3 and reevaluated prior to Round 4.

Additional MBSS Parameters - Howard County adopted the Maryland DNR's MBSS methods in 2001. The MBSS program continues to evolve and refine its sampling design, field procedures, and data analysis protocols; the most recent field sampling protocols were updated in 2010 (MDNR 2010). Although the benthic macroinvertebrate collection methods implemented herein were not changed during that update, additional surveys were added to the MBSS data collection efforts (i.e., stream salamander sampling in the summer and a seasonal pool search in the spring) that may be of interest to the county. Round 4 of the MBSS includes collecting simple

geomorphic parameters. We recommend that Howard County consider adding these additional salamander, seasonal pool, and geomorphic parameters, in addition to updating methods as needed to stay current with the latest MBSS sampling protocols. Certification by the MBSS is now being provided for both field and laboratory protocols and should be required for conducting this bioassessment. For the 2014 sampling conducted for this project, Versar's fieldcrew leader, benthic sample processor/subsampler, and benthic taxonomist have all received MBSS certification for their respective tasks.

5.2 WATERSHED STUDIES

The Howard County Biological Monitoring and Assessment Program provides valuable information that supports countywide management of aquatic resources. For example, it serves as the most accurate indicator of watershed condition and supports assignment of preservation and restoration priorities. It is a spatial intensification of the statewide MBSS that leverages the regionwide condition assessment and stressor identification tools employed by both Maryland DNR and MDE. In addition, bioassessment results are an essential part of watershed assessments and restoration plans to support the Howard County MS4 permit and Watershed Implementation Plan (WIP) of the Chesapeake Bay TMDL.

Recently, Howard County completed a Phase I Countywide Implementation Strategy (CIS) that identifies restoration projects and programs to meet MS4 permit requirements for treatment of impervious surfaces and reductions in loads of nutrients, sediments, and other pollutants to local waters and the Chesapeake Bay. Phase II will involve preparation of watershed studies with recommendations for site-specific restoration. The results of the biological and physical monitoring in the Upper Little Patuxent, Middle Little Patuxent, and Lower Little Patuxent subwatersheds (and other subwatersheds sampled in Round 3) will help target areas with the greatest restoration potential.

The CIS also includes a proposed monitoring strategy to demonstrate compliance with the MS4 permit and Bay WIP. Both intensive local monitoring and extensive watershed-scale monitoring will be needed to monitor progress in a cost-effective manner. We recommend that the Howard County Biological Monitoring and Assessment Program serve as the framework for assembling this integrated MS4 permit and WIP monitoring strategy.

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