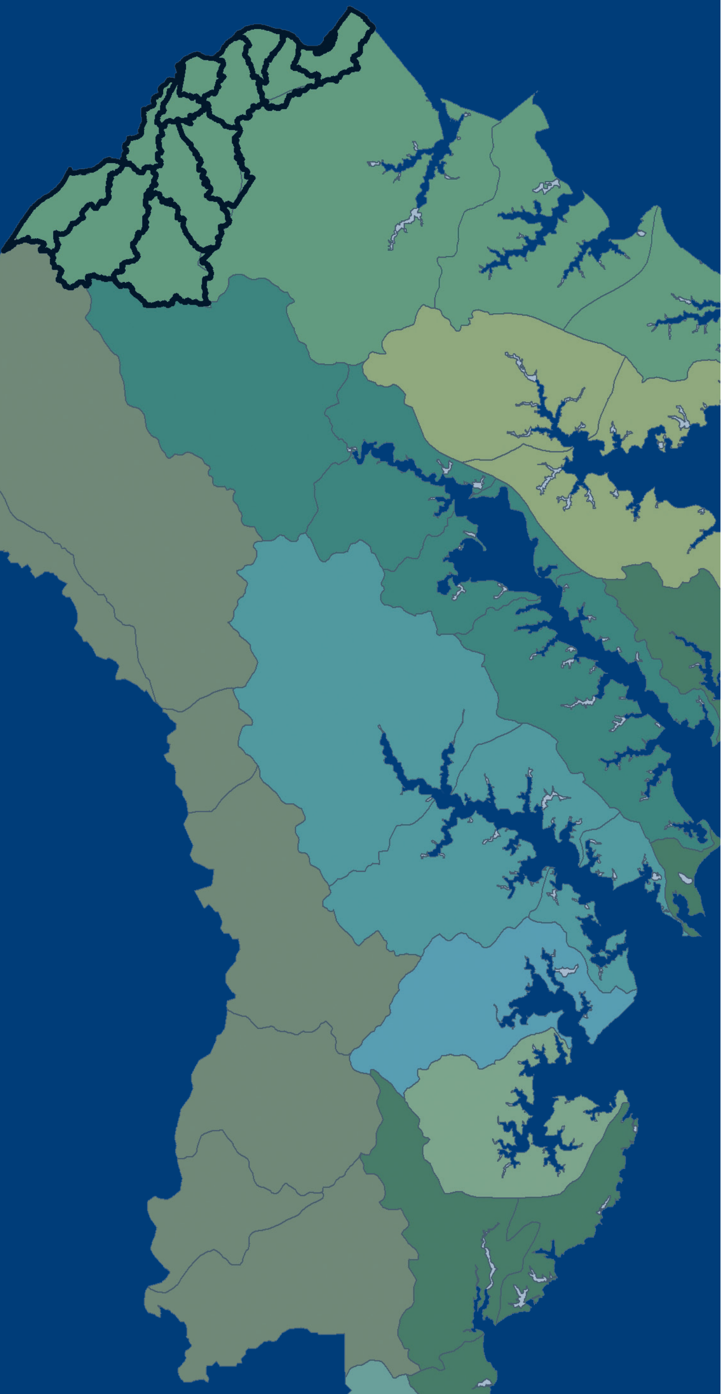


Patapsco Non-Tidal Watershed Assessment

Comprehensive Summary Report

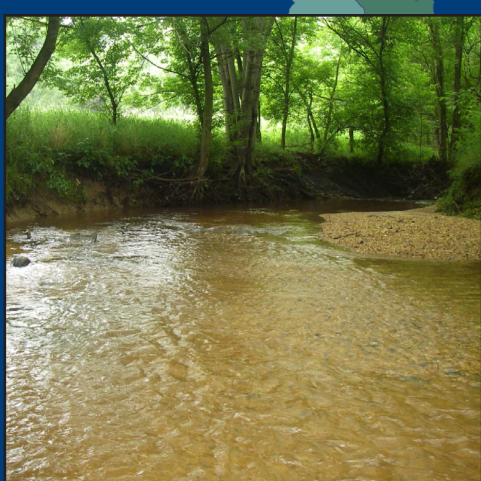
Prepared by:

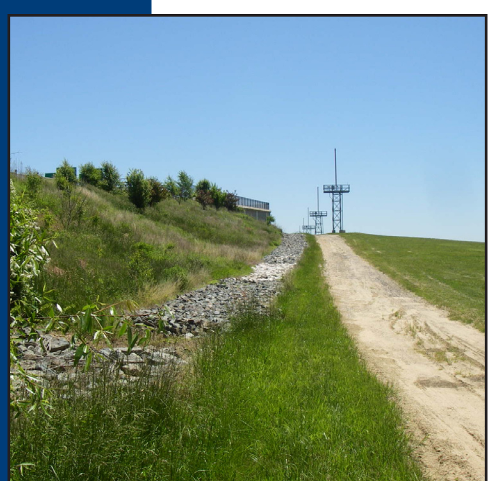
Anne Arundel County
Watershed Assessment & Planning Program

KCI Technologies, Inc.

CH2M HILL

August 2011 FINAL





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PATAPSCO NON-TIDAL WATERSHED ASSESSMENT

COMPREHENSIVE SUMMARY REPORT

AUGUST 2011 | FINAL REPORT

PREPARED BY

ANNE ARUNDEL COUNTY DEPARTMENT OF PUBLIC WORKS

BUREAU OF ENGINEERING

WATERSHED ECOSYSTEM AND RESTORATION SERVICES

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NPDES Section II.F Watershed Assessment and Planning

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The following individuals were instrumental in providing field assessment, modeling, mapping, data analysis, quality control, and reporting. The contributions of each were vital to the successful completion of the project and have furthered the protection and restoration of natural resources in Anne Arundel County.

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1 INTRODUCTION

1.1 PURPOSE AND SCOPE

The Anne Arundel County Watershed Assessment and Planning Program initiated the assessment of the Patapsco Non-Tidal Watershed in 2009. The Patapsco Non-Tidal is the fifth of the County's twelve major watersheds to undergo a comprehensive assessment and development of a management plan. Anne Arundel County began its current and systematic assessment of the County's watersheds in 2002 with the completion of the Severn River Watershed Management Master Plan. The assessment includes characterization of the stream and watershed conditions through analysis of the biological community, water quality investigation, visual assessment of stream resources, and the subsequent modeling and analysis. The data are used to prioritize the watershed's streams and subwatersheds for restoration, and preservation measures, to develop project specific conceptual restoration design, and to ultimately improve the conditions of the watershed. The study partially fulfills the watershed assessment and restoration requirements of the County's National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer (MS4) permit.

This full-scale assessment was designed to catalog infrastructure, assess stream habitat, inventory biological assemblages, characterize channel geomorphology, and assess chemical water quality conditions of watershed streams. The assessment of the physical, biological, and chemical condition of the watershed took place over approximately 96 miles of perennial, intermittent, and ephemeral streams. The collected data will allow County planners to understand the current environmental conditions of the Patapsco Non-Tidal watershed and waterways.

In addition to the stream assessments, indicators of watershed condition related to land use, stormwater best management practices (BMPs), and pollutant loading models were compiled in a prioritization model that ranks and prioritizes the watershed at the stream reach, catchment, and parcel scales. The prioritization model was developed by the Watershed Assessment and Planning group in previous County watershed planning efforts and was refined for the Patapsco Non-Tidal. The results allow for targeted protection of high quality environmental features and restoration of areas with significant degradation.

The County convened a working group, the Professional Management Team (PMT), to provide input and review for most phases of the assessment and planning process including the stream and watershed assessments, water quality modeling procedures and results, the prioritization model and ultimately the recommendation of future studies and an implementation framework. This collaborative team was made up of technical experts from KCI Technologies and CH2M HILL as well as County staff from several departments. This report serves to summarize the procedures and results to date of the Patapsco Non-Tidal Watershed Assessment.

1.2 REGULATORY AND PLANNING CONTEXT

There are many local, state, and federal regulatory requirements impacting the management of natural and water resources in Anne Arundel County, and in the Patapsco Non-Tidal watershed. The current status of several of the main regulatory programs are described below.

1.2.1 NPDES

Section 402(p) of the Clean Water Act required the EPA to add Municipal Separate Storm Sewer System (MS4) discharges to the NPDES permit program. Anne Arundel County holds a Phase I – Large Jurisdiction (greater than 250,000 population) MS4 permit (99-DP-3316, MD0068306) issued by the Maryland Department of the Environment. The County's first generation permit was issued in 1993. The current third generation permit was issued in 2004. The five year permit is currently in the renewal phase and is in draft form for the fourth generation permit.

The Patapsco Non-Tidal Watershed Assessment project satisfies, in part, several sections of the MS4 permit

- Section III.C.2 – Stormwater management facility data including locations and delineated drainage areas
- Section III.E.3 – Illicit Discharge Detection and Elimination (field crews report illicit flows to the County during the Physical Habitat Condition Assessment)
- Section III.F – Watershed Assessment and Planning – to develop watershed management plans for all watersheds in Anne Arundel County. The plans should address the following
    - Determine current water quality conditions;
    - Identify and rank water quality problems;
    - Identify all structural and non-structural water quality improvement opportunities;
    - Include the results of a visual watershed inspection;
    - Specify how the restoration efforts will be monitored; and
    - Provide an estimated cost and a detailed implementation schedule for those improvement opportunities identified above
- Section III.G – Watershed Restoration - the County, is required to restore ten percent of the County's impervious area in the permit term.
- Section III.J – Total Maximum Daily Loads

Changes to the County's NPDES permit are anticipated in the fourth generation permit. The current permit requires the County to retrofit stormwater treatment for 10% of the County's untreated impervious area during every 5-year permit cycle. Future permits will likely increase this percentage to 20% of the County's impervious area that is not already restored to the maximum extent practical. From an implementation standpoint, this will bring a higher priority to projects and programs that deal with older developed areas with little to no stormwater management such as those in Patapsco Non-Tidal watershed, particularly in the northern portions.

Items under Section III.F above will likely be retained but with a greater emphasis on tracking progress towards meeting both local and Chesapeake Bay wide TMDL waste load allocations. Specific Watershed Implementation Plans (WIP) will be required to address meeting TMDLs.

1.2.2 TOTAL MAXIMUM DAILY LOAD

Total Maximum Daily Loads of TMDLs are established for waterbodies on Maryland's 303(d) Integrated list of impaired waterbodies to set pollutant limits to achieve attainment of the designated use. For each combination of waterbody and pollutant, the State must estimate the maximum allowable pollutant load, or TMDL, that the waterbody can receive and still meet water quality standards. TMDLs are required by Clean Water Act.

Category 4 of the 303(d) list describes impaired waters with a TMDL or other reduction measure in place. Category 5 lists impaired waters in need of a TMDL. Map 1.3 displays Category 5 waters and approved TMDLs within Anne Arundel County.

The Patapsco River Lower North Branch (LNB) has been listed under Category 5 for toxics, sediment, nutrients, metals, bacteria, and has been listed for biological impairment. The LNB is the focus within the context of the Patapsco Non-Tidal assessment. The LNB currently has draft TMDLs for bacteria (2009) and for sediment (2009). A final TMDL is in place for nutrients. In addition a Water Quality Analysis was completed in 2004 for heavy metals within the LNB. EPA concurrence was received in 2005 determining that a TMDL was not required.

1.2.3 CHESAPEAKE BAY TMDL

On December 3, 2010, the Maryland Department of the Environment submitted its Final Phase I Watershed Implementation Plan to the Unites States Environmental Protection Agency (EPA) for review. On December 29, 2010, the EPA issued its Final Chesapeake Bay TMDL. The TMDL covers total nitrogen, total phosphorus, and total suspended solids, the highest priority pollutants in the degradation and eventual recovery of the Chesapeake Bay. The State must meet the target allocations by 2017 (70% of target) and 2020 (100% of target). Anne Arundel County plays a role in helping the state meet these target allocations by reducing the input of these pollutants from County watersheds to the extent possible. Currently the TMDL is not allocated at the Lower North Branch or Patapsco Non-Tidal watershed level within Anne Arundel County. The recommendations made in this Patapsco Non-Tidal plan are part of an effort to meet the TMDL requirements at the County scale.

Anne Arundel County is currently developing a Phase II Watershed Implementation Plan (WIP) that defines a detailed plan to meet the target allocations. The plan will include load reduction strategies, definition of current capacity, associated costs, and an implementation schedule. The County is working collaboratively with other state, federal and local landowners, and NPDES permit holders, to address the TMDLs in the 10 designated County segmentsheds, see Map 1.4. The Patapsco Non-Tidal watershed is a portion of one of the 10 segmentsheds.

Phase II WIP development and this Patapsco Non-Tidal assessment were conducted concurrently and great effort has been made to ensure that each effort informed the other. However as this Patapsco Non-Tidal assessment comes to completion, the development of the Phase II WIP is on-going and will continue into late 2011. As such, many of the goals, analyses, and recommendations, will be further defined and refined in the final development of the WIP. Conclusions and recommendations made in this report may ultimately be superseded by the final Phase II WIP.

1.2.4 MARYLAND HOUSE BILL 1141

In 2006, the Maryland General Assembly added new requirements for local comprehensive plans to incorporate the effects of proposed land use on streams and wetlands, forest and agricultural conservation lands, water supplies and water quality to avoid negative impacts to our natural resources.

The bill added a water resources planning element to ensure that existing and future development were adequately served in relation to water resources. Therefore, Anne Arundel County's 2009 General Development Plan included Chapter 10 – the Water Resources Plan (WRP). The WRP's primary functions were to ensure:

- the adequacy of the County's water supply to meet current and future needs and;
- the adequacy of the County's wastewater treatment capacity, septic capacity, and stormwater management capacity to meet current and future needs.

The WRP describes the current planning framework to address these items, and summarized the current capacity. The plan takes additional steps to address the impact of nutrient loads in a watershed context, describing the impact based on the current land use plan and with conditions based on a proposed land use plan. The WRP provides a plan to mitigate impacts and is consistent with watershed protection goals.

The WPR reinforces the need to continually develop Watershed Management Plans and conduct the supporting Stream and Subwatershed Assessments and Rankings.

The WRP addresses nonpoint source loads and the assimilative capacity of the biological community, in this case freshwater benthic macroinvertebrates. In essence the analysis describes how much additional growth can be assimilated before the aquatic biota is impacted. The WRP was developed in the absence of a State assigned assimilative capacity and is a Benthic Index of Biotic Integrity (BIBI)-based capacity developed from a limited statistical correlation with available County biological monitoring data. Impact is defined as a reduction from a 'Fair' biological condition, or a score of 3 using the Maryland Biological Stream Survey's (MBSS) Benthic Index of Biotic Integrity. Analysis of pollutant loading was conducted for four suggested scenarios: 2004 land use, and ultimate build out conditions based on the 2004 GDP, the 2008 GDP, and the 2008 GDP will full implementation of load reduction techniques – specifically On-Site Sewage Disposal Systems (OSDS) for septic source treatment of nitrogen and Environmental Site Design (ESD) for stormwater controls of nitrogen and phosphorus. An implementation plan was not developed as part of the WRP.

1.2.5 MARYLAND STORMWATER REGULATIONS

Maryland's 2007 Stormwater Management Act went into effect in October of 2007. As a result, changes to COMAR and the 2000 Maryland Stormwater Design Manual, Volumes I and II went into effect in May of 2009. The most significant changes relative to watershed planning are in regard to implementation of ESD. The 2007 Act defines ESD as "using small-scale stormwater management practices, nonstructural techniques, and better site planning to mimic natural hydrologic runoff characteristics and minimize the impact of land development on water resources." As such Anne Arundel County has updated Articles 16 and 17 of the County Code to incorporate the requirements for ESD. Anne Arundel County finalized the *Anne Arundel County Stormwater Management Practices and Procedures Manual* (current edition revised

November 2010) to incorporate criteria specific to Anne Arundel County that are not addressed within the Maryland Design Manual.

1.3 PHYSICAL SETTING

The Patapsco Non-Tidal Watershed is one of twelve major watersheds in Anne Arundel County, Maryland, and it is situated in the northwestern portion of the County (see Map 1.1 for orientation of the watershed within the County). The watershed shares political boundaries with Howard County along Deep Run and Baltimore County along the mainstem of the Patapsco River. The most downstream extent of the watershed bounds Baltimore City in the most northern extent of the County.

The Patapsco Non-Tidal watershed is approximately 15,270 acres in area. The watershed includes several named streams including Stoney Run, Piney Run, Deep Run, Holly Creek, and the mainstem of the Patapsco River. These named streams are distributed among 12 subwatersheds, as shown below in Table 1-1 and on Map 1.2. In project planning stages, attempts are made to delineate subwatersheds to a uniform average size; however natural drainage patterns often result in a wider variety of subwatershed areas across the study area. Although the average subwatershed size is 1272 acres, the subwatersheds range in size from 431 in PN6 to 2646 in PNB. By corollary the channel length in each subwatershed also varies. These variations have been considered in the analysis and whenever possible results have been reported in a normalized fashion either by area or stream length. Care should be taken in drawing comparisons between subwatersheds using measures of area, length, or *number of* resources, impacts, BMPs etc.

Although the study is termed the Patapsco Non-Tidal, according to National Wetlands Inventory mapping, the tidal influence extends into the study area to the I-695 Baltimore beltway crossing, near the boundary between subwatersheds PN3 and PN4. The Patapsco River mainstem empties to the open water portions of the Patapsco River in Baltimore City before entering the Chesapeake Bay.

TABLE 1-1: PATAPSCO NON-TIDAL SUBWATERSHEDS

Subwatershed Code	Subwatershed Name	Area (acres)
PN1	Patapsco Mainstem	1030
PN2	Holly Creek	856
PN3	Patapsco Mainstem	526
PN4	Unnamed Tributary	1175
PN5	Patapsco Mainstem	574
PN6	Stoney Run 1	431
PN7	Stoney Run 2	1908
PN8	Stoney Run 3	1440
PN9	Stoney Run 4	2401
PNA	Deep Run	710
PNB	Piney Run	2646
PNC	Deep Run	1571

1.3.1 Physiography

The Patapsco Non-Tidal Watershed is situated in the Glen Burnie Rolling Upland District. This district covers the entire watershed and is an undulating upland with slopes typically less than 8 degrees. It is a transitional area between the Waldorf Upland Plain and the Prince Frederick Knobby Upland (Maryland Geological Survey, 2008).

The entirety of the watershed is located within Maryland's Coastal Plain Physiographic Province in the Western Shore Uplands Region (Maryland Geological Survey, 2008). The majority of the slopes within the watershed are less than 14%. The southwestern part of the Patapsco Non-Tidal has the highest elevation. The northern tip of the watershed is an area of low elevation. Maps 1.5 and 1.6 depict the steep slopes and topography found in the Patapsco Non-Tidal Watershed.

1.3.2 Soils and Geology

Geology of the watershed is dominated by the Potomac Group of the Cretaceous Period which is characterized by interbedded quartoze gravels, argillaceous sands, and white, dark grey and multicolored silts and clays at a thickness of 800 feet. The Potomac Group in this area, particularly in the northern portion of the watershed is interspersed with Upland Deposits of gravel and sand (Maryland Geological Survey, 1968).

Soils within the Patapsco Non-Tidal Watershed are varied in their hydrologic properties and expected erodibility. As shown in Table 1-2, the majority of soils (50.9%) are classified as hydrologic soil group B. These soils have moderately low runoff potential when thoroughly wet and water transmission through the soil is unimpeded. Hydrologic soil group A accounts for 17.5% of the soils in the watershed. These soils have low runoff potential when thoroughly wet and water is transmitted freely through the soil. Soil group C accounts for 16.6% while soil group D is less prominent. Types C and D soils have the highest runoff potential. The hydrologic soil group is especially important when deciding on placement of BMPs, especially infiltration type BMPs which should be limited to soil types A and B as they are not effective in soil types C and D. For the dual soils groups, A/D and B/D in the table below, the first letter represents the drained area and the second letter represents the undrained area. Both of these dual groups are less prominent in the watershed.

TABLE 1-2: HYDROLOGIC SOIL GROUPS PER SUBWATERSHED

Subwatershed	A	A/D	B	B/D	C	D	Urban land	Water
PN1	0.0%	2.0%	22.5%	1.0%	22.5%	4.9%	5.9%	41.2%
PN2	0.0%	1.4%	62.5%	0.0%	27.8%	4.2%	0.0%	4.2%
PN3	0.0%	0.0%	47.8%	0.0%	21.7%	8.7%	2.2%	19.6%
PN4	1.5%	0.0%	73.1%	0.0%	14.6%	1.5%	1.5%	7.7%
PN5	2.8%	0.0%	59.2%	0.0%	23.9%	1.4%	4.2%	8.5%
PN6	6.8%	0.0%	52.5%	0.0%	30.5%	3.4%	3.4%	3.4%
PN7	24.1%	0.0%	52.7%	3.6%	11.6%	0.9%	3.6%	3.6%
PN8	14.5%	0.0%	46.8%	2.4%	19.4%	1.6%	12.9%	2.4%
PN9	43.9%	0.0%	30.2%	3.7%	13.2%	1.1%	0.0%	7.9%
PNA	11.6%	0.0%	52.2%	0.0%	26.1%	4.3%	0.0%	5.8%
PNB	26.5%	1.2%	53.3%	4.2%	11.9%	0.6%	0.0%	2.4%
PNC	15.4%	0.0%	61.1%	4.3%	11.7%	3.7%	0.0%	3.7%
Total	**17.5%**	**0.5%**	**50.9%**	**2.5%**	**16.6%**	**2.3%**	**2.3%**	**7.5%**

Soil erodibility varies across the Patapsco Non-Tidal Watershed. As shown in Table 1-3, 44.5% of the soils in the watershed are classified as potentially highly erodible land and another 39.7% are classified as highly erodible land. Soils classified as not highly erodible are found primarily along the stream systems in zones wetland and floodplain zones. These soils make up 15.8% of the watershed area. Stream systems with high connectivity to floodplains and stream valleys provide storage for transported sediments, however these alluvial sediments can be susceptible to erosion, particularly with changes in hydrologic regime and increased channel planform migration. A map of hydrologic soil groups and soil erodibility factors is presented as Map 1.7.

TABLE 1-3: SOIL ERODIBILITY PER SUBWATERSHED

Subwatershed	Highly erodible land	Not highly erodible land	Potentially highly erodible land
PN1	12.7%	54.9%	32.4%
PN2	40.3%	11.1%	48.6%
PN3	17.4%	37.0%	45.7%
PN4	45.4%	12.3%	42.3%
PN5	45.1%	15.5%	39.4%
PN6	39.0%	11.9%	49.2%
PN7	31.3%	8.9%	59.8%
PN8	40.3%	20.2%	39.5%
PN9	28.6%	15.3%	56.1%
PNA	50.7%	14.5%	34.8%
PNB	48.5%	7.7%	43.8%
PNC	49.5%	11.7%	38.8%
Total	**39.7%**	**15.8%**	**44.5%**

1.3.3 SURFACE WATER

The Patapsco Non-Tidal Watershed contains approximately 96 total miles of reaches, these reaches include:

- perennial reaches, which are permanent channels that generally flow throughout a normal rainfall year, some perennial channels may go dry in times of drought,
- intermittent and ephemeral reaches, in which water is present only during wetter portions of the year such as spring time (intermittent) or during and immediately following rainfall events (ephemeral),
- mainstem, is defined in this study as the non-tidal portion of the mainstem of the Patapsco River,
- tidal portions of a stream, which for this study include both the tidal portions of the Patapsco Mainstem and downstream tidally influenced freshwater streams,
- wetlands and floodways, which may not always have a single defined channel, and
- manmade channels, which include drainage conveyances and stormwater management facilities.

The reaches drain 12 non-tidal subwatersheds ranging in size from 431 to 2646 acres. A map of the subwatersheds, including the subwatershed three-digit code and name, is presented as Map 1.2. Table 1-4 below presents the miles of the major channel classification present in each subwatershed and in the total of the watershed and Map 2.1 presents the stream classification graphically.

TABLE 1-4: MILES OF SURFACE WATER CATEGORIES PER SUBWATERSHED

Subwatershed	Area (Acres)	Perennial	Intermittent & Ephemeral	Mainstem	Tidal	Wetland & Floodway	Manmade[1]
PN1	1,030.5	0.0	2.2	0.0	2.9	0.0	1.4
PN2	855.8	0.6	1.5	0.0	0.6	0.0	1.8
PN3	526.3	0.0	1.3	0.0	2.3	0.0	0.7
PN4	1,175.3	1.0	3.7	0.7	0.0	0.6	0.3
PN5	574.5	1.4	1.5	1.2	0.0	1.1	0.2
PN6	430.7	1.4	1.4	0.1	0.0	0.0	1.1
PN7	1,907.7	2.4	3.4	0.0	0.0	3.7	1.1
PN8	1,440.3	3.2	0.4	0.0	0.0	0.1	2.3
PN9	2,401.2	3.7	2.0	0.0	0.0	4.1	2.4
PNA	709.6	4.2	2.5	0.0	0.0	0.4	0.3
PNB	2,646.1	6.4	8.7	0.0	0.0	0.1	2.3
PNC	1,570.7	8.7	2.6	0.0	0.0	0.1	0.0
Total	**15,268.6**	**33.1**	**31.1**	**2.0**	**5.9**	**10.2**	**13.8**

[1] Manmade includes Concrete, Culvert, Ditch, Pond/Lake, Storm Drain, and SWM categories.

1.3.4 Environmental Features

Many environmental features including wetlands, floodplains, Greenways, and Critical Areas are present within the Patapsco Non-Tidal Watershed, as summarized on Table 1-5. These high quality habitats are sensitive to anthropogenic stress and are identified as priorities for protection. Wetlands are found in the northern portion of the watershed along the floodplain of the Patapsco River mainstem. They are also located also in relative high density in the central portions of the watershed in subwatersheds PN7 and PN9 (along the mainstem of Stoney Run) west of Thurgood Marshall BWI airport. Greenways have been identified for preservation as they provide wildlife movement corridors when complete and contiguous. Critical Areas (CA) are present along the mainstem of the Patapsco River and are important because they provide a buffer to reduce pollution, provide shoreline habitat. The CA program is vital to protecting shoreline and near-shoreline areas from development. The CA in the Patapsco Non-Tidal includes three categories: Intense Development Area (IDA) at 227 acres makes up which makes up 23.5 percent of the CA; Limited Development Area (LDA) at 105 acres makes up 10.8 percent of the CA; and Resource Conservation Area (RCA) which at 632 acres makes up 65.6 percent of the CA. Mapping of these high quality environmental features is presented in as Map 1.8.

TABLE 1-5: ACRES OF RESOURCES PER SUBWATERSHED

Subwatershed	Buffer Management Area[1] (ac)	Greenways[2] (ac)	Wetlands (ac)	100-year FEMA Floodplains (ac)	Treeline[3] (ac)	Critical Area[4]
PN1	68	73	65	157	175	301
PN2	73	103	87	144	166	141
PN3	40	149	98	143	154	204
PN4	116	284	71	131	344	98
PN5	106	177	63	146	362	191
PN6	79	209	12	61	246	25
PN7	201	361	192	234	897	0
PN8	160	7	50	93	239	0
PN9	220	259	131	290	610	0
PNA	118	518	66	115	513	5
PNB	333	913	23	84	1155	0
PNC	202	271	37	72	773	0
Total	**1717**	**3324**	**895**	**1671**	**5634**	**964**

[1] 100-ft stream buffer

[2] As adopted in the County's Master Plan

[3] Derived from the 2007 County landcover dataset 'woods' classification

[4] Includes LDA, IDA and RCA

1.3.5 LAND COVER AND LAND OWNERSHIP

Table 1-6 summarizes land cover in the Patapsco Non-Tidal Watershed based on data from the GIS shapefile titled '2007LandCover'. This shapefile was developed in 2007 based on 6 inch resolution orthophotography incorporating buffering. The classifications were chosen because they were associated with studied Event Mean Concentration (EMC) values. As shown, woods occupy a majority of the watershed, representing approximately 37% of the total area. Collectively, residential land cover categories constitute almost 25% of the watershed. Open space represents the next largest portion of the watershed and occupies over 11% of the total area. Industrial, transportation, commercial, and airport land covers all individually occupy 4% - 10% while water, open and forested wetlands, utilities, row crops, residential woods, pastures/hay, and undesignated covers are all individually less than 0.5%. A map showing the land cover makeup in the watershed is presented as Map 1.9. Data for each subwatershed is located in Appendix B.

TABLE 1-6: LAND USE AND LAND COVER

Land Cover	Land Cover Code	Acres	Percent of Watershed
Airport	AIR	626.5	4.1%
Commercial	COM	965.2	6.3%
Forested Wetland	FRW	34.8	0.2%
Industrial	IND	1,283.3	8.4%
Open Space	OPS	1,699.6	11.1%
Open Wetland	OPW	50.4	0.3%

Land Cover	Land Cover Code	Acres	Percent of Watershed
Pasture/Hay	PAS	1.7	0.0%
Residential 1/2-acre	R12	313.9	2.1%
Residential 1/4-acre	R14	1,167.6	7.6%
Residential 1/8-acre	R18	1,167.9	7.6%
Residential 1-acre	R11	510.6	3.3%
Residential 2-acre	R21	623.9	4.1%
Residential Woods	RWD	13.2	0.1%
Row Crops	SRC	33.7	0.2%
Transportation	TRN	1,032.8	6.8%
Utility	UTL	44.6	0.3%
Water	WAT	81.4	0.5%
Woods	WDS	5,617.5	36.8%
Total		**15,268.6**	

Within the Patapsco Non-Tidal watershed approximately 60% of the total watershed is privately owned and 28% is owned by the State. The County Government and Federal Government own the remaining 9% and 3% of land, respectively. Land Use and Ownership information was developed in order to comply with the Watershed Implementation Plan (WIP) Sectors identified through the Maryland Department of the Environment sponsored WIP pilot initiative.

Impervious surfaces include roads, buildings footprints, parking lots, sidewalks, swimming pools, and other surfaces that prevent natural infiltration. Approximately 28.5% of the Patapsco Non-Tidal Watershed is considered impervious. Approximately 40% (1,726.2 of the 4,352.2 acres) of the total impervious area is being treated by a BMP accounted for in this report (see Section 2.2.2 for more information on BMPs). Within individual subwatersheds imperviousness varies between 6% and 50%. The percentage impervious cover by land use and ownership is presented in Table 1-7 and a map of impervious cover in the watershed is presented as Map 1.10. A full summary of impervious cover by subwatershed can be found in Appendix C.

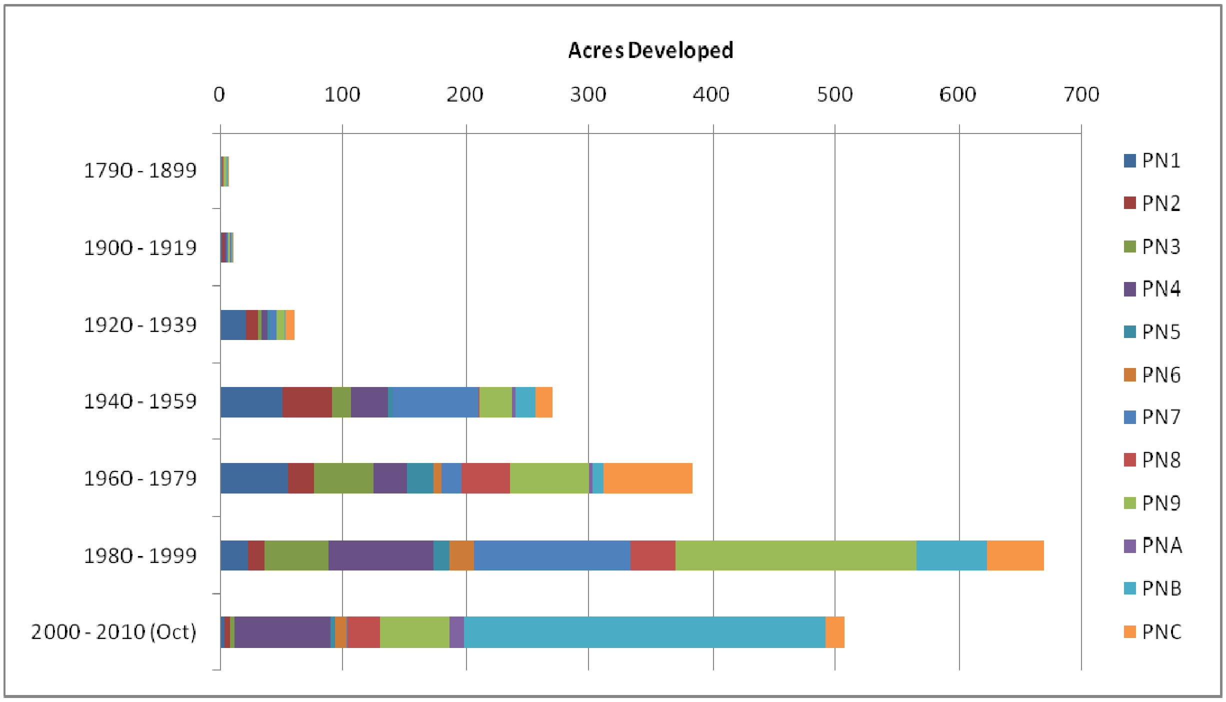
TABLE 1-7: WIP SECTOR IMPERVIOUS LAND USE AND OWNERSHIP

Land Use and Ownership (WIP Sector)	Area (acres)	Impervious Cover (acres)	Impervious % of Land Cover	% of Total Impervious Cover
County - Private Agriculture Lands	34.9	0.5	1%	< 0.1%
County - Private Commercial	854.5	664.4	78%	15%
County - Private High Density Residential	918.6	328.8	36%	8%
County - Private Industrial	1,042.0	793.9	76%	18%
County - Private Low Density Residential	1,009.6	158.3	16%	4%
County - Private Medium Density	1,460.3	432.4	30%	10%

Land Use and Ownership (WIP Sector)	Area (acres)	Impervious Cover (acres)	Impervious % of Land Cover	% of Total Impervious Cover
Residential				
County - Private Natural Resource Lands	3,039.8	39.0	1%	1%
County - Private Open Space	689.3	44.7	6%	1%
County Board of Education	98.2	29.6	30%	1%
County Roads and Facilities	1,262.9	593.7	47%	14%
Maryland Aviation Administration	2,175.5	662.4	30%	15%
Maryland Department of Transportation	157.0	16.7	11%	0%
Maryland DNR Lands	893.3	5.4	1%	0%
Maryland State Highway Administration	1,078.9	402.8	37%	9%
Maryland State Institutional Lands	41.9	6.9	16%	0%
Other DOD Facilities	29.6	23.4	79%	1%
US Park Service	462.0	135.8	29%	3%
US Postal Service	20.4	13.5	66%	0%
Total	**15,268.6**	**4,352.2**	**29%**	-

The Patapsco Non-Tidal watershed has been developed over the course of several centuries. Data from the County on development age was provided for impervious surfaces, excluding most roads (owned by SHA) and BWI Airport. Therefore, development age data presented in this section is largely reflective of development that has occurred on property that is under the jurisdiction of the County. The earliest documented development occurred in the late 1700's and has continued to increase, exponentially so, through the present. Figure 1-1 demonstrates the total number of impervious acres developed in each subwatershed between 1790 and October 2010. The chart shows that development peaked between 1980 and 1999 before stormwater management regulations for water quality were put in place in 1999. However, a significant amount of development has continued to occur throughout the last decade after water quality regulations were developed. The majority of the development in the last decade has occurred in Piney Run (PNB), an area along the Baltimore-Washington Parkway. A map of development age is shown as Map 1.11.

FIGURE 1-1: ACRES DEVELOPED THROUGH TIME BY SUBWATERSHED



Development is expected to continue to occur in the Patapsco-Non Tidal watershed. The County's official zoning map, shown as Map 1.12, was examined to determine where development may occur and was assumed to reflect build out conditions. This zoning information was last updated on February 14, 2011. Overall, the watershed is most likely to experience industrial, residential, and commercial growth through build out conditions. Land previously classified as woods, open space, or residential along the East side of the Baltimore Washington Parkway between MD 100 and I-195 is zoned as 'W1 –Industrial Park' for future development. Comparison of the zoning data to the 2007LandCover data indicates that this area has the greatest potential for development in the future due to the number of undeveloped or residential parcels. Additional industrial development may occur in other areas of the watershed currently classified as woods, open space, or residential, particularly near major intersections such as the BW Parkway and MD 100 or the BW Parkway and I-695.

Residential development will continue to occur in established neighborhoods on empty lots classified as woods or open space. The majority of this residential growth potential is in the southern most portion of the watershed in Deep Run (PNC), Piney Run (PNB), and a small amount in Stoney Run 4 (PN9). Additional residential growth potential (individual parcels) exists in the northern portion of the watershed in PN1, PN2, and PN4.

The potential for commercial development is less prevalent than industrial or residential development. Commercial development is most likely to occur along major roads on land classified as woods or residential in the 2007LandCover dataset.

2 DATA COLLECTION AND COMPILATION

The following subsections present and summarize the collected and compiled data within the Patapsco Non-Tidal tributary streams and the adjacent riparian areas. Stream classifications and verification, physical habitat condition assessment, inventory of infrastructure and environmental features, habitat scores, channel geomorphology, road crossing flood potential, bioassessments, and aquatic resource indicators are all reported in detail. This information is crucial for determining the conditions within the tributary streams and for subsequently identifying and formulating restoration activities and land management decisions to improve stream conditions.

2.1 STREAM DATA COLLECTION AND COMPILATION

2.1.1 STREAM CLASSIFICATION AND VERIFICATION

Approximately 96 miles of streams were verified and characterized. Of these, perennial streams were the most commonly encountered followed by intermittent streams, ephemeral streams, and wetlands. Perennial streams were commonly found in the southern portion of the watershed.

During the field verification efforts, streams were segmented into individual stream reaches to facilitate subsequent assessment and analysis efforts. Stream reaches were segmented in the field as distinct habitat or geomorphic conditions were encountered. A total of 615 individual reaches were identified within the Patapsco Non-Tidal Watershed. The average length was approximately 825 feet.

A summary of stream miles and number of reaches by type is presented in Table 2-1. Stream classifications encountered throughout the watershed are depicted in Map 2.1.

TABLE 2-1: STREAM TYPE RESULTS

Type	Number of Reaches	Stream Miles	Percent of Total Stream Miles
Concrete	6	0.8	0.9%
Culvert	61	4.4	4.5%
Ditch	56	4.6	4.8%
Ephemeral	78	10.8	11.2%
Floodway	12	0.7	0.7%
Intermittent	137	20.3	21.2%
Mainstem	3	2.0	2.1%
Perennial	146	33.1	34.4%
Pond/Lake	2	0.1	0.1%
Storm Drain	10	2.3	2.4%
SWM	29	1.5	1.6%
Tidal	16	5.9	6.2%
Wetland	59	9.6	10.0%
Total	**615**	**96.0**	**--**

Strahler stream ordering was also completed for the final stream reach layer. The results of the ordering are included in Table 2-2. A majority of streams (58 percent) were 1st and 2nd order channels. The largest 5th and 6th order channels made up 11 percent of the total mileage.

TABLE 2-2: STRAHLER STREAM ORDER PER SUBWATERSHED

Subwatershed	1st	2nd	3rd	4th	5th	6th	Total
PN1	1.51	2.09	1.26	0.00	0.00	1.73	6.60
PN2	1.73	0.51	0.72	1.57	0.00	0.04	4.57
PN3	0.03	1.23	1.19	0.00	0.00	1.82	4.27
PN4	0.87	2.17	1.01	1.50	0.00	0.66	6.21
PN5	1.11	1.88	1.25	0.00	0.00	1.20	5.44
PN6	1.21	0.71	0.54	0.00	1.53	0.00	3.99
PN7	3.90	2.13	2.20	2.34	0.00	0.00	10.57
PN8	1.60	0.95	1.44	1.97	0.00	0.00	5.95
PN9	2.88	4.96	2.30	2.16	0.00	0.00	12.30
PNA	2.69	1.06	0.00	0.00	3.63	0.00	7.38
PNB	6.64	5.75	1.80	3.22	0.00	0.00	17.41
PNC	4.78	2.91	1.75	1.91	0.00	0.00	11.35
Total	28.96	26.35	15.44	14.68	5.16	5.45	96.04

2.1.2 Physical Habitat Condition Assessment

Physical habitat condition is a good measure of the overall health of a stream and its ability to support aquatic life. Healthy physical habitat for aquatic organisms is typically comprised of stable channels and substrates, diverse flow characteristics, and abundant cover and food sources. Natural streams are typically in a state of dynamic equilibrium. However, this equilibrium can be disrupted and habitat parameters common in healthy streams begin to deteriorate when increased urban and agricultural stressors are introduced. Examples of stream reaches in the Patapsco Non-tidal Watershed are shown in Figure 2-1.

FIGURE 2-1: EXAMPLES OF ASSESSED STREAM REACHES

Stream Reach in the Stoney Run 1 Subwatershed (PN6) with Minimally Degraded Habitat Condition

Stream Reach in the Deep Run 1 Subwatershed (PNC) with Severely Degraded Habitat Condition

A field assessment of in-stream physical habitat conditions was performed for perennial streams by observing and measuring various physical attributes. This work was completed in accordance with the 2003 *Physical Habitat Index for Freshwater Wadeable Streams in Maryland* report developed by Maryland Department of Natural Resources (MDNR) (Paul et al, 2003). Collected habitat assessment parameters included qualitative observations of in-stream and riparian conditions (*i.e*., fish presence, bacteria or algae presence, aquatic vegetation presence, water clarity and odor, and riparian vegetation character) as well as quantified assessment parameters used to calculate a Maryland Physical Habitat Index (MPHI) score. Data used to support the calculation of the scaled MPHI score for each perennial stream reach included individual scores for remoteness, shading, epifaunal substrate, in-stream habitat, woody debris and rootwads, and bank stability.

Standard MPHI category breakpoints used by MDNR are as follows: 0-50.9 Severely Degraded, 51.0-65.9 Degraded, 66.0-80.9 Partially Degraded, 81.0-100.0 Minimally Degraded. For this study the breakpoint between the Degraded and Severely Degraded category was 59.9 and 60.0. The result is a more conservative approach and identifies additional reaches for restoration. This modified scoring is carried through in the calculation of MPHI scores per watershed and the calculation of Final Habitat Scores (FHS) for reaches and subwatersheds described in section 2.1.4.

Physical habitat condition assessment reaches were created based on observed changes in habitat conditions along a stream. For the Patapsco Non-Tidal Watershed, approximately 32.6 miles of the 33.1 miles of perennial streams were assessed and scored. Approximately half a mile of perennial stream reaches were not assessed due to access issues or due to individual reach lengths being less than the minimum assessment size requirement (75 meters). The aggregate assessed perennial stream length is comprised of 146 individual reaches with an average assessed stream reach length of approximately 0.15 miles (or 812 feet).

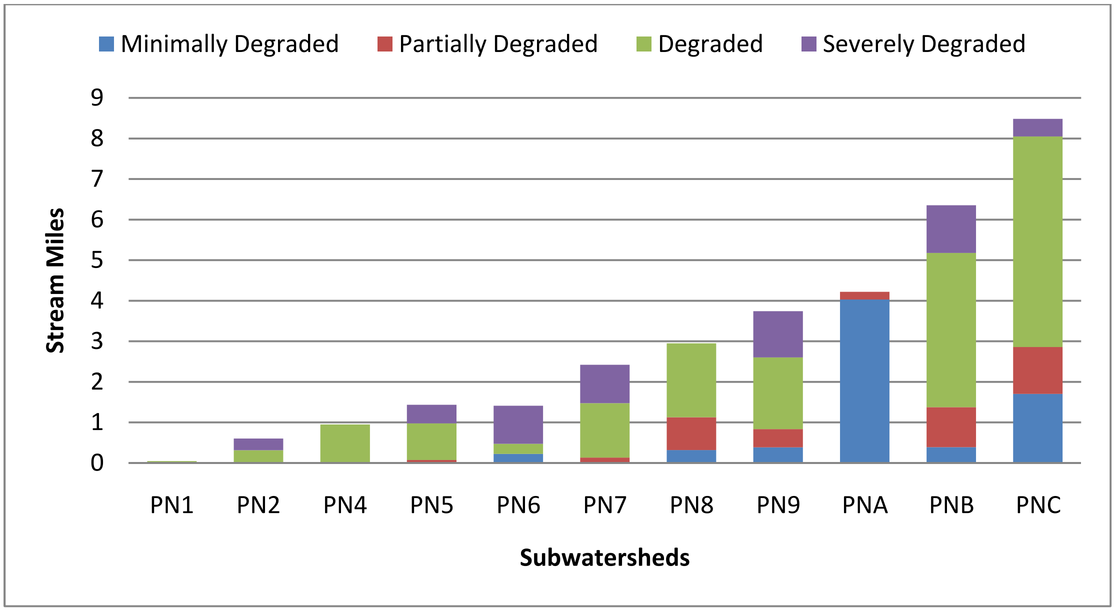
Based on the calculated MPHI score, each stream reach is assigned a condition category of “Minimally Degraded,” “Partially Degraded,” “Degraded,” or Severely Degraded.” The average stream weighted MPHI score for the Patapsco Non-Tidal Watershed is 70.15 which correspond to a “Partially Degraded” condition. Approximately 50.2% of perennial stream miles in the Patapsco Non-Tidal Watershed were rated as “Partially Degraded.” “Severely Degraded” streams comprised roughly of 21.6% of the perennial streams, followed by “Degraded” and “Minimally Degraded” streams at 11.6% and 16.5%, respectively. Deep Run had the highest number of “Severely Degraded” and “Degraded” reaches. Stoney Run 3 subwatershed had the highest percentage of perennial stream miles that were considered “Minimally Degraded” with 40%. A summary of MPHI condition categories by stream mile and number of reaches is provided in Table 2-3. A map of the MPHI conditions throughout the watershed is presented as Map 2.2. Examples of assessed stream reaches are depicted in Figure 2-2.

TABLE 2-3: PHYSICAL HABITAT CONDITION RESULTS, MPHI

MPHI Category[1]	Number of Reaches	Percent of Reaches	Stream Miles	Percent of Stream Miles
Minimally Degraded	19	13.4%	5.4	16.5%
Partially Degraded	73	51.4%	16.4	50.2%
Degraded	25	17.6%	3.8	11.6%
Severely Degraded	25	17.6%	7.1	21.6%
Total	142	--	32.6	--

[1] Using modified MPHI categories as described above in section 2.1.2.

FIGURE 2-2: MPHI RESULTS PER SUBWATERSHED



2.1.3 INVENTORY OF INFRASTRUCTURE AND ENVIRONMENTAL FEATURES

Being aware of and knowledgeable about infrastructure and other environmental features observed along streams is very important for assessment of current conditions. For this reason, fieldwork included an inventory of infrastructure and significant environmental features that compiled within each perennial reach and associated riparian area. These include obstructions to stream flow and organism passage, utilities, channel erosion, dumpsites, head cuts, and outfall pipes and drainage ditches. Depending on the inventory feature type, the associated impact was scored in the field as “Minor,” “Moderate,” “Severe,” or “Extreme” based on its potential impact on the integrity or health of the stream reach. These impacts were translated to a 0-10 point scale depending on the feature type according to the County’s protocol. In addition to the impact scores, other quantitative and qualitative data, such as dimension, relative location, composition, and restoration potential, were collected for each feature. Examples of three types of impacts are shown in Figure 2-3.

FIGURE 2-3: EXAMPLES OF ENVIRONMENTAL AND INFRASTRUCTURE FEATURES

Deficient buffer impacts (residential lawn encroachment), Moderate Impact in the Stoney Run 4 subwatershed (PN9)

Dumpsite impacts in the Patapsco mainstem (PN5) subwatershed with a Moderate Impact

Pipe and ditch impacts contributing to erosion. Moderate Impact in the Stoney Run 1 Subwatershed (PN6)

These infrastructure and environmental features can be critical to the health of the Patapsco Non-Tidal watershed for different reason discussed below. Scores range from 0 to 10, increasing with the level of impact. In general 0, 1, or 2 represent a Minor impact; 5 is Moderate; and 10 represents a Severe impact for each impact type except for Buffer, Erosion and Crossing for which a 7 is Severe and a 10 indicates an Extreme condition. Full description of the scores and ratings are found in *Field Data Collection Guide for Watershed Studies, Anne Arundel County Department of Public Works* (AA DPW, 2010).

- Intact natural vegetated **stream buffers** provide important terrestrial habitat and shading and also serve to dampen runoff velocities and filter runoff pollutants before they enter a stream. These functions are lost or significantly diminished when stream buffers are removed or compromised by land management decisions.

- Stream **crossings** can vary from a foot bridge with only minor impact on channel stability to a large road crossing that forces a stream into a culvert. Culverted stream crossings tend to be the most problematic, because they can become blocked or clogged by accumulated debris and can also act to accelerate stream flow. Stream crossing impacts can include flooding, local bed and bank erosion upstream and downstream of the culvert, and fish passage impediments.

- **Dumpsites** are typically comprised of trash or debris dumped in the stream channel or in the riparian area. Toxic pollutants from dumpsites can impact water quality and bulk trash and debris can alter stream hydrodynamics.

- Although channel bed and bank **erosion** occurs naturally as streams work to maintain a state of dynamic equilibrium, excessive erosion can occur due to increased stream velocities associated with development activities that increase imperviousness within the watershed. Channel erosion can deliver excessive pollutants, such as sediment and phosphorus, downstream, where water quality can be impacted and important habitat for fish spawning and benthic invertebrates can be smothered. Excessive erosion can also threaten the stability of other nearby built infrastructure.

- A **head cut** is an abrupt change or drop in stream channel elevation. Head cuts are often indicators of active channel incision or downcutting. The movement of upstream bed material fills in the low points associated with the head cut, and as a result the head cut migrates upstream until a new grade is established for the entire channel.

- Channel **obstructions** can include natural features like fallen trees as well as man-made features like concrete dams or riprap. These obstructions can partially or completely obscure water flow, which can cause flooding and localized erosion and can impede the passage of fish.

- **Pipes and drainage ditches** are typically associated with stormwater conveyance. Depending on their placement and flow characteristics, pipes and drainage ditches can contribute to water quality impairments and erosion in the receiving streams.

- **Utilities** can include sanitary sewers, storm sewers, water lines, gas lines, and electrical transmission lines (buried or overhead). Impacts from utilities are the most severe when they intersect the stream channel, where they can alter stream hydraulics and cause localized erosion.

A summary of the impacts for each infrastructure feature is presented in Table 2-4. Figure 2-4 and Figure 2-5 show the severity and type of inventory points per subwatershed. The distribution of these features throughout the watershed is presented in Map 2.3.

Erosion impacts accounted for the highest cumulative impact score (1330), followed very closely by buffer impacts (1328). Riparian buffer impacts were most often associated with encroachment from residential lawns. Pipes and drainage ditches were the most common with a total of 623 impact locations. A large percentage (97 percent) of pipe and ditch impacts were considered minor, thus the relatively lower cumulative score of 115; however they do have the potential to contribute high flow and erosive forces to the stream system and the accumulation of many minor impacts can be significant. Pipes and ditches were most often associated with stormwater outfalls. Crossings were the second most common impact, with a total of 23 moderate impacts in the PNA, PNB and PNC subwatersheds. The relative abundance of these infrastructure feature types is consistent with a more urbanized watershed like the Patapsco Non-Tidal Watershed. The remaining features (*i.e.*, dumpsites, obstructions, and utilities) were encountered less frequently, but certainly contributed locally to areas of stream degradation throughout the watershed.

TABLE 2-4: INVENTORY POINT TYPE AND SEVERITY PER SUBWATERSHED

Subwatershed and stream miles		Buffer Impacts			Crossing Impacts			Ditch/Pipe Impacts			Dumpsite Impacts			Erosion Impacts			Obstruction Impacts			Utility Impacts			Total
		5	7	10	2	5	7	0	5	10	1	5	10	5	7	10	2	5	10	0	2	5	
PN1	6.60	5	1		7	1		26	1		1			3	2						1		48
PN2	4.57	6	6	1	19	3		59	2	1					5		1	1		1	3	3	111
PN3	4.27	2	3		3		2	37			1				2			1		1	7		59
PN4	6.21	8	4		8	2		46			1			2	6		1	2		5	7		92
PN5	5.44	4	1		5	2		9	1	1	7	7	3	18	17	2	4	1					82
PN6	3.99	10			17	1		39			3			6	7					7	3		93
PN7	10.57	10	4		36			45			3	1		10			5	2		18	1		135
PN8	5.95	15	3		18	2	2	58	3			1		17	4		4		1	4	5	2	139
PN9	12.30	41	3		39	1		99	3	1	8	1		21	6		4	1		45	5	1	279
PNA	7.38	12	5	1	14	6		12			2	2		6	4			1		1			66
PNB	17.41	21	10	1	51	7	1	129	2					18	27	1	1	2		12			283
PNC	11.35	32	24	2	43	10		46	1	2	11			26	15		10	2		13	3	1	241
Total number per rating		166	64	5	260	35	5	605	13	5	37	12	3	127	95	3	30	13	1	107	35	7	
Total number per type		235			300			623			52			225			44			149			
Score per type[1]		1328			730			115			127			1330			135			105			

Gray =<5 sites Green = 5-10 sites Yellow = 11-20 sites Orange = 21-50 sites Red = 51-100 sites Purple =>100 sites

Scores range from 0 to 10, increasing with the level of impact. In general 0, 1, or 2 represent a Minor impact; 5 is Moderate; 10 represents a Severe impact for each impact type except for Buffer, Erosion and Crossing for which 7 is Severe and 10 indicates Extreme. Full description of the scores and ratings are found in *Field Data Collection Guide for Watershed Studies, Anne Arundel County Department of Public Works* (AA DPW, 2010).

[1] Score is the sum product of the number of points and the related impact scoring summarized per inventory point type. This score is **not** the Total Impact Score (TIS) calculated per reach for development of the Final Habitat Score (section 2.1.4)

PNB is the largest subwatershed in terms of watershed area and stream length; therefore it is not surprising that it was found to have the most inventory points (283), although most are in the minor impact category. PN9 and PNC, also large subwatersheds, follow with 279 and 241 respectively. Table 2-5 below presents the number of inventory points per stream mile for each subwatershed, which represents the density of inventory points. PN2, PN8 and PN6 have the highest densities. The ‘score’ as developed in Table 2-5 is the sum product of the number of inventory points and the impact score received by those points summarized by subwatershed. The score normalized by stream length indicates that PNC and PN5 have the greatest level of impact followed by PN8 and PN2.

TABLE 2-5: INVENTORY POINTS PER STREAM MILE

Subwatershed	Stream Length (miles)	Number of Inventory Points	Number of Inventory Points per Stream Mile	Total Impact Score[1]	Score[1] per Stream Mile
PN1	6.60	48	7.3	88	13
PN2	4.57	111	24.3	218	48
PN3	4.27	59	13.8	85	20
PN4	6.21	92	14.8	173	28
PN5	5.44	82	15.1	376	69
PN6	3.99	93	23.3	177	44
PN7	10.57	135	12.8	230	22
PN8	5.95	139	23.4	327	55
PN9	12.30	279	22.7	522	42
PNA	7.38	66	8.94	238	32
PNB	17.41	283	16.3	640	37
PNC	11.35	241	21.2	796	70

[1] Total Impact Score (TIS) is the sum product of the number of points and impact scoring. This score is equivalent to the TIS calculated per reach for development of the Final Habitat Score (section 2.1.4) but is presented here per subwatershed.

FIGURE 2-4: SEVERITY OF INVENTORY POINTS PER SUBWATERSHED

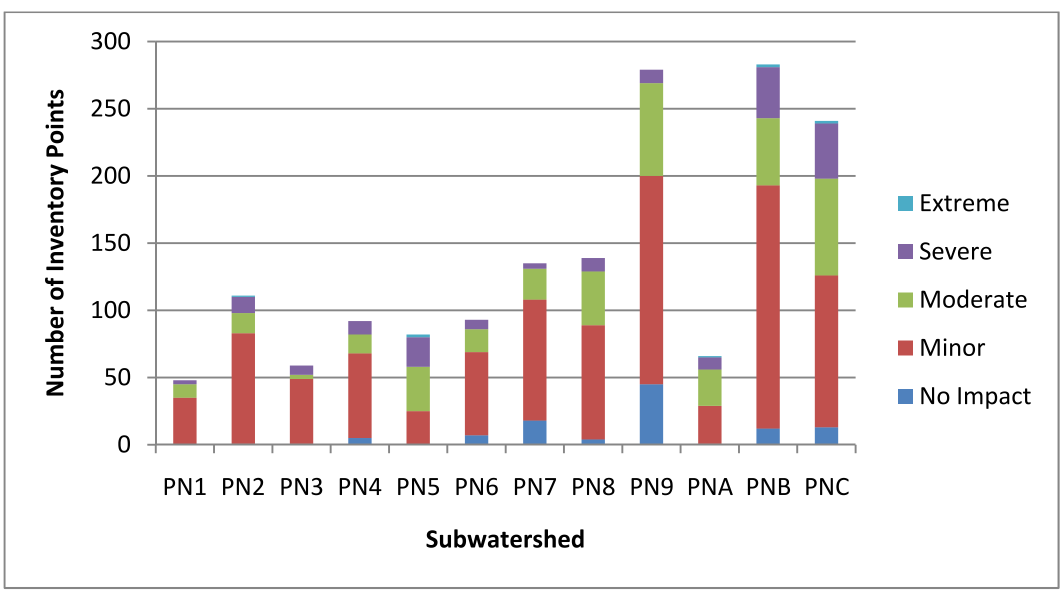
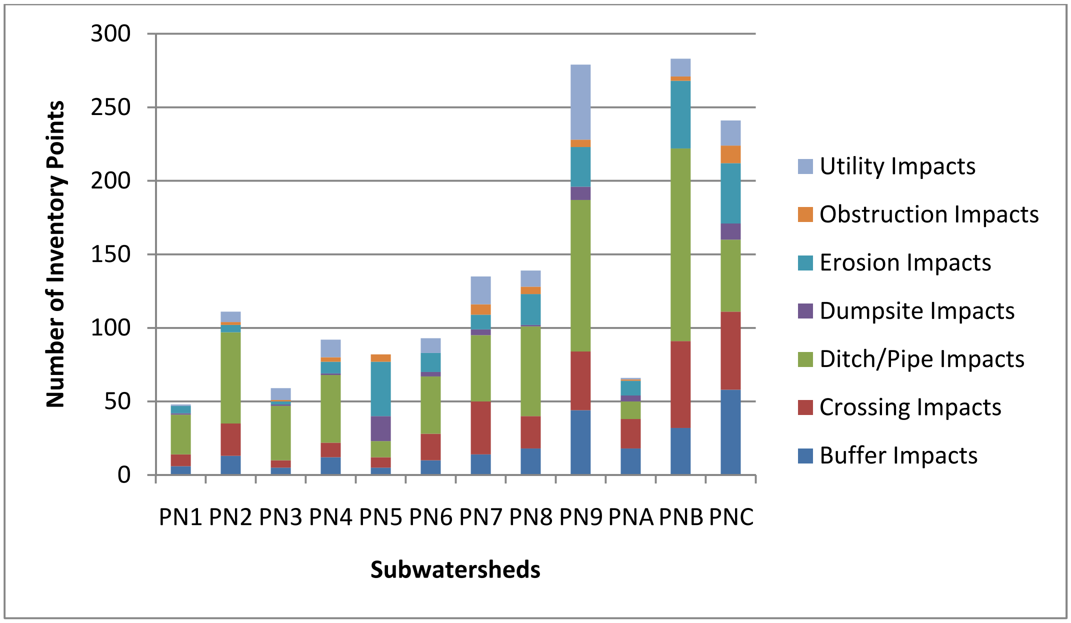


FIGURE 2-5: INVENTORY POINTS PER SUBWATERSHED



2.1.4 Final Habitat Score

Final habitat scores are used as part of the subwatershed prioritization process discussed in more detail in Section 4. Final habitat scores for each perennial stream reach were calculated using the MPHI scores from the physical habitat assessment discussed above combined with the sum of the impact scores from the environmental features and infrastructure inventory according to the following:

$$Final\ Habitat\ Score - 0.5\left(\sum Total\ Impact\ Scores\right)$$

Habitat scores for each perennial reach are combined using a reach length-weighted average, the results of which are shown on Table 2-6. These scores are then extrapolated to the subwatershed level. As with the MPHI, each subwatershed is assigned a category of “Minimally Degraded,” “Partially Degraded,” “Degraded” or “Severely Degraded.” A summary of the final habitat scores for the subwatersheds are shown on Table 2-7 and displayed on Map 2.4.

TABLE 2-6: FINAL HABITAT SCORES BY REACH

Rating[1]	Number of Reaches	Percent of Reaches	Stream Miles	Percent of Stream Miles
Minimally Degraded	10	7.0%	2.8	8.6%
Partially Degraded	45	31.7%	7.7	23.6%
Degraded	30	21.1%	6.1	18.7%
Severely Degraded	57	40.1%	16.0	49.1%
Total	142	--	32.6	--

[1] Using modified MPHI categories as described above in section 2.1.2.

TABLE 2-7: FINAL HABITAT SCORES BY SUBWATERSHED

Rating[1]	Number of Subwatersheds	Percent of Subwatersheds
Minimally Degraded	0	0.0%
Partially Degraded	3	25.0%
Degraded	2	16.7%
Severely Degraded	6	8.3%
Total	12	--

[1] Using modified MPHI categories as described above in section 2.1.2.

No subwatersheds were rated "Minimally Degraded" and only three (25%) are rated as "Partially Degraded." These were Holly Creek PN2, Stoney Run PN7 and Piney Run PNB. Two subwatersheds, PN6 which is the lower portion of Stoney Run and PN1 the most downstream Pataspco Mainstem subwatershed were rated "Degraded." PN3, with no perennial streams identified during the field assessment, was not rated for physical habitat. The remaining six subwatersheds, PN4, PN5, PN8, PN9, PNA, PNC were all rated as "Severely Degraded." It should be noted that the distribution of severely degraded subwatersheds was broad and included Patapsco mainstem, Stoney Run, and Deep Run subwatersheds.

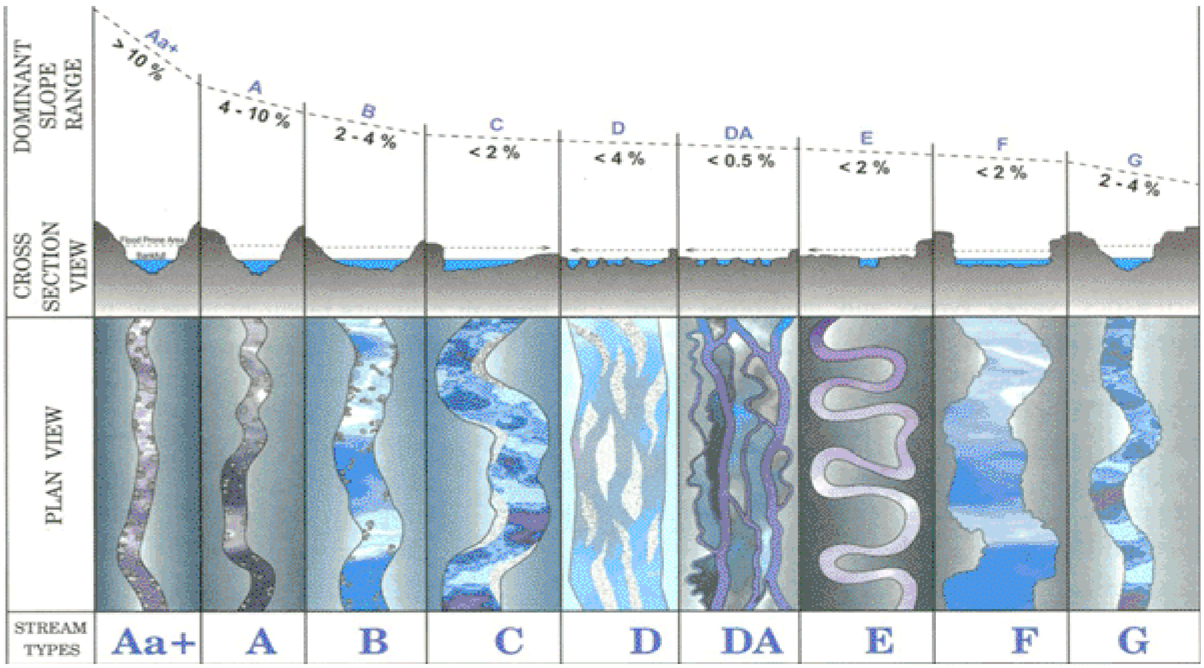
2.1.5 Channel Geomorphology

Over time, a stable natural stream channel will seek and achieve a state of dynamic equilibrium with its contributing watershed. In such a state, the stream will generally maintain its form and function and will undergo lateral adjustments over long periods of time in response to the range of hydrologic conditions to which it is exposed. During periods of normal flow, the stream can safely and efficiently convey the water and sediment that is directed through it. During periods of high flow, the stream can accommodate large volumes of water effectively by allowing it to overtop the stream banks and flow with dissipated energy through the floodplain. Upstream development patterns, however, can alter the volumes and peak flows conveyed through the stream and upset this dynamic equilibrium. This phenomenon causes the stream to actively erode down its channel bed and banks and eventually lose access to its existing floodplain. This can lead to loss of aquatic and terrestrial habitat, decreased water quality, and greater risk of flood-related damage (including loss of property), as the stream seeks out a new state of equilibrium.

An assessment of channel geomorphology is useful to better understand the stability of a stream and its associated behaviors. The Rosgen classification system is one such assessment method. It provides measurable benchmarks for determining stream stability and for comparing the stream with similar streams in an undisturbed state regardless of their locations. The Rosgen classification system has four levels. The Level I classification is a geomorphic characterization that groups stream as Types A through G based on aspects of channel geometry, including water surface slope, entrenchment, width/depth ratio, and sinuosity. A simplification of the longitudinal, cross-sectional, and plan views of the major stream types under the Rosgen Level I classification scheme (Rosgen, 1994) is presented in Figure 2-6.

The County utilized Rosgen Level I geomorphic classifications in its watershed modeling and analysis as indicators of stream stability and channel entrenchment. In the Patapsco Non-Tidal, field data were collected to support the Rosgen Level I geomorphic classification of each single-threaded, perennial reach. These field data were used to support calculation of a Manning's roughness number for each eligible reach using the Cowan method (Cowan, 1956). These calculated Manning's roughness values were used with DEM-derived longitudinal profiles, channel cross-sections, and bankfull discharge calculations to perform the actual Rosgen Level I classification. A County-developed spreadsheet tool was used to facilitate the classifications.

FIGURE 2-6: ROSGEN CLASSIFICATION SCHEMATIC



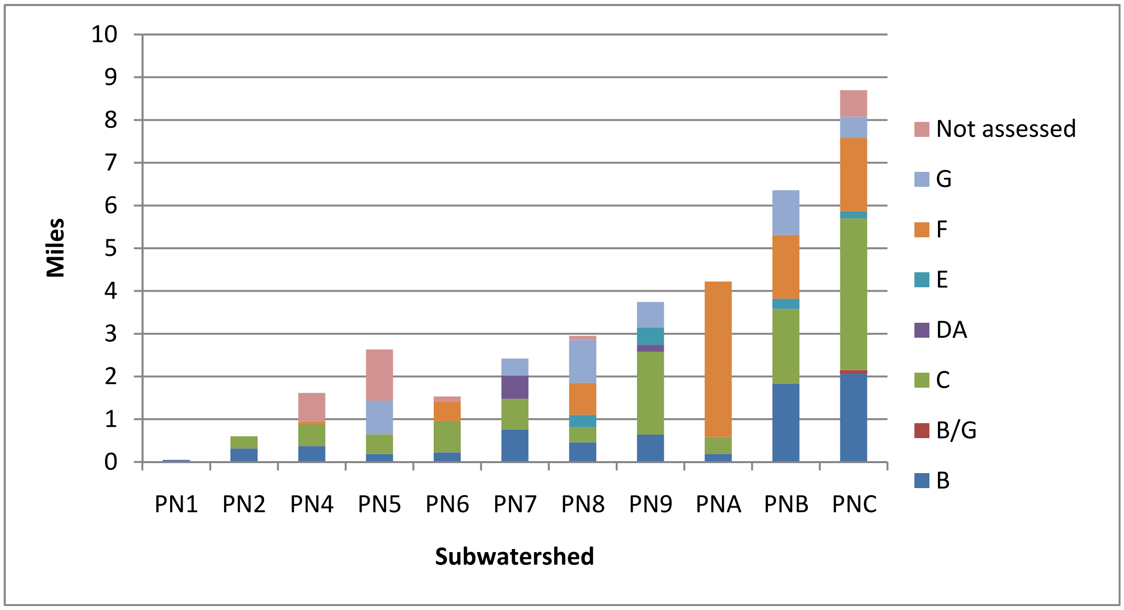
Rosgen, David L. "A classification of natural rivers." Catena 22 (1994): 179. www.wildlandhydrology.com

The distribution of Rosgen Level I classifications across the watershed is depicted in Map 2.5 and summarized in Table 2-8 and Figure 2-7. As shown, approximately 31% of the reaches (11 miles) were classified as Type "C" channels, which are typically characterized as having a well developed floodplain, relatively sinuous with a channel slope of 2% or less.

TABLE 2-8: ROSGEN LEVEL I STREAM TYPE CLASSIFICATION

Classification	Number of Reaches	Stream Miles	Percent of Total Classified Stream Miles
B	38	7.1	20.4%
B/G	1	0.1	0.2%
C	42	10.7	30.7%
DA	3	0.7	2.0%
E	7	1.1	3.2%
F	27	8.1	23.3%
G	20	4.3	12.4%
Not Assessed	9	2.7	7.8%
Total	147	34.8	100.0%

FIGURE 2-7: MILES OF ROSGEN STREAM TYPE CLASSIFICATION PER SUBWATERSHED



2.1.6 Road Crossing Flood Potential

Flooding where streams and roadways cross can be a safety hazard to residents due to high water levels and the potential to isolate properties from emergency vehicle access. Roadway stream crossings throughout the Patapsco Non-Tidal Watershed were analyzed to assess the potential for flooding and the need for replacement or modification. An initial subset of stream crossings with the potential for overtopping was identified during fieldwork activities. Potential sites were then evaluated against the County's established selection criteria which include:

1. County ownership,
2. Road classification as freeway, principal arterial, minor arterial, collector or local,
3. Crossing in flooding condition would cut off an area from emergency services, and
4. Crossing is likely based on the height of road surface relative to the channel.

A total of 19 sites were ultimately selected and surveyed. See Appendix A for the complete description of the selection process. One crossing was surveyed but ultimately eliminated from consideration due to the complex site conditions and the necessity to use a more sophisticated model. The final 18 crossings modeled are shown in Table 2-9.

Of those surveyed and modeled using HY-8 culvert analysis, five were determined to overtop at less than the 2 year storm and two between the 2 and 10 year event. These crossings will be further investigated for remedial actions. See Maps 2.6a and 2.6b for the locations and results.

TABLE 2-9: FLOODING POTENTIAL OF SELECTED ROAD CROSSINGS

Crossing	Drainage Area (sq mi)	1 Year (cfs)	2 Year (cfs)	10 Year (cfs)	100 Year (cfs)	Overtopping Discharge (cfs)	Overtopping Return Period
PN3001.C002	0.1781	110	157	323	518	56	Less than 2 years
PN9001.C002	3.1393	270	451	1168	2129	1835	Between 10 and 100 years
PN9013.C001	3.0437	266	446	1157	2108	508	Between 2 and 10 years
PN9025.C002	1.0048	201	323	778	1365	857	Between 10 and 100 years
PN9046.C001	0.1079	4	10	46	104	211	Over 100 years
PN9060.C001	0.0669	6	12	39	78	66	Between 10 and 100 years
PNB002.C002	4.1161	213	362	968	1800	1576	Between 10 and 100 years
PNB059.C001	0.3488	4	14	75	185	469	Over 100 years
PNB085.C001	0.0604	0	0	6	23	54	Over 100 years
PNB090.C002	0.1337	0	1	18	60	204	Over 100 years
PNC014.C001	0.1211	10	21	70	142	81	Between 10 and 100 years
PNC022.C002	0.0493	65	87	158	240	20	Less than 2 years
PNC024.C004	0.0608	30	46	106	181	115	Between 10 and 100 years
PNC025.C001	2.1315	275	437	1042	1821	134	Less than 2 years
PNC028.C001	0.2023	5	13	58	133	28	Between 2 and 10 years
PNC040.C001	0.1201	8	19	71	149	10	Less than 2 years
PNC063.C001	0.061	15	25	65	118	54	Between 10 and 100 years
PNC064.C001	0.2093	20	36	106	202	27	Less than 2 years

2.1.7 BIOASSESSMENT

The County has conducted both random and targeted sampling of the Patapsco Non-tidal watershed. Random samples were collected in 2004 and 2007 as part of the County's full Countywide bioassessment program. Targeted sampling was also conducted in 2008 and 2009 to supplement the random sampling program. The full 2008 targeted sampling summary report is included as Appendix E.

Benthic macroinvertebrate collection follows the County's Quality Assurance Project Plan (QAPP) which closely mirrors MBSS procedures (MDNR, 2007). The monitoring sites include a 75-meter reach and benthic macroinvertebrate sampling is conducted during the spring season (March 1st to April 30th).

Benthic macroinvertebrate data was 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/or habitat impairment.

Raw values from 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 from 1.0 to 5.0 and a 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, piedmont and combined highlands regions, divided by the Fall Line. The study area is located in the coastal plain region. The metrics and BIBI scoring used for the analysis are listed in Table 2-10, below. Table 2-11 gives the BIBI ranges and ratings, and Map 2.7 provides the site locations and ratings for the random and targeted sampling from 2004 to 2009.

TABLE 2-10: BIOLOGICAL CONDITION SCORING (COASTAL PLAIN)

Metric	Score		
	5	3	1
Total Number of Taxa	≥22	14-21	<14
Number of EPT Taxa	≥5	2-4	<2
Number of Ephemeroptera Taxa	≥2.0	1-1	<1.0
Percent Intolerant Urban Taxa	≥28	10-27	<10.0
Percent Ephemeroptera Taxa	≤11	0.8-10.9	>0.8
Number Scraper Taxa	≥2	1-1	<1.0
Percent Climber Taxa	≥8.0	0.9-7.9	<0.9

TABLE 2-11: 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

The BIBI results from the targeted and random sampling events combined show that 18 of the 80 sampled sites (23%) were rated as "very poor," and an additional 35 (44%) were rated as "poor." Twenty-six of the sites (33%) were rated as "fair" and only one site, a targeted site in Deep Run, was rated as "good." Subwatersheds with targeted sites that received a "very poor" rating include PN1, PN2, PN3 and PN8. Table 2-12 shows the summary of all bioassessment sites in the Patapsco Non-tidal Watershed.

TABLE 2-12: BIOLOGICAL ASSESSMENT SUMMARY

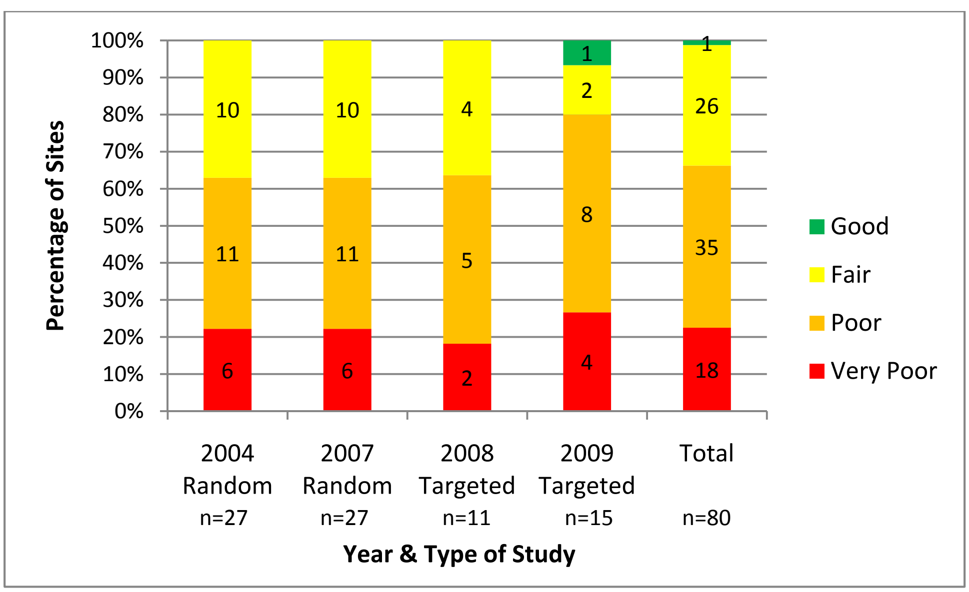
Subwatershed	Sample ID	SAT ID	Study	BIBI Score	Ranking
PN7	PANT-11-2008	PN9001.G001	2008 Targeted	3.0	Fair
PNC	PANT-07-2008	PNC006.G001	2008 Targeted	2.7	Poor
PNB	PANT-08-2008	PNB004.G001	2008 Targeted	2.7	Poor
PNA	PANT-06-2008	PNA014.G001	2008 Targeted	2.4	Poor
PN7	PANT-02-2008	PN7006.G001	2008 Targeted	3.6	Fair
PN8	PANT-01-2008	PN8001.G001	2008 Targeted	3.3	Fair
PN6	PANT-03-2008	PN6003.G001	2008 Targeted	3.9	Fair
PN5	PANT-05-2008	PN5002.G001	2008 Targeted	2.7	Poor
PN2	PANT-10-2008	PN2002.G001	2008 Targeted	1.6	Very Poor
PN4	PANT-04-2008	PN4007.G001	2008 Targeted	2.4	Poor
PN3	PANT-09-2008	PN3003.G001	2008 Targeted	1.6	Very Poor
PN9	02-04		2004 Random	3.0	Fair
PN9	02-03		2004 Random	2.1	Poor
PNB	01-01		2004 Random	1.6	Very Poor
PNB	01-13A		2004 Random	1.3	Very Poor
PN9	02-11A		2004 Random	3.6	Fair

Subwatershed	Sample ID	SAT ID	Study	BIBI Score	Ranking
PN9	02-01		2004 Random	2.1	Poor
PN9	02-05		2004 Random	3.0	Fair
PN9	02-19A		2004 Random	2.1	Poor
PN7	02-06		2004 Random	1.3	Very Poor
PNC	01-05		2004 Random	3.3	Fair
PNC	01-02		2004 Random	3.9	Fair
PNB	01-12A		2004 Random	3.0	Fair
PNB	01-04		2004 Random	3.0	Fair
PNC	01-07		2004 Random	2.7	Poor
PN8	02-07		2004 Random	1.6	Very Poor
PN4	03-02		2004 Random	2.4	Poor
PN4	03-16A		2004 Random	1.6	Very Poor
PN6	02-18A		2004 Random	2.7	Poor
PN6	02-20A		2004 Random	2.1	Poor
PN4	03-04		2004 Random	2.7	Poor
PN5	03-07		2004 Random	2.4	Poor
PN5	03-05		2004 Random	3.6	Fair
PN2	03-12A		2004 Random	3.0	Fair
PN2	03-09		2004 Random	2.7	Poor
PN4	03-13A		2004 Random	3.3	Fair
PN2	03-01		2004 Random	1.9	Very Poor
PN4	03-17A		2004 Random	2.7	Poor
PN9	02-04		2007 Random	3.0	Fair
PN9	02-03		2007 Random	2.1	Poor
PNB	01-01		2007 Random	1.6	Very Poor
PNB	01-13A		2007 Random	1.3	Very Poor
PN9	02-11A		2007 Random	3.6	Fair
PN9	02-01		2007 Random	2.1	Poor
PN9	02-05		2007 Random	3.0	Fair
PN9	02-19A		2007 Random	2.1	Poor
PN7	02-06		2007 Random	1.3	Very Poor
PNC	01-05		2007 Random	3.3	Fair
PNC	01-02		2007 Random	3.9	Fair
PNB	01-12A		2007 Random	3.0	Fair
PNB	01-04		2007 Random	3.0	Fair
PNC	01-07		2007 Random	2.7	Poor
PN8	02-07		2007 Random	1.6	Very Poor
PN4	03-02		2007 Random	2.4	Poor
PN4	03-16A		2007 Random	1.6	Very Poor
PN6	02-18A		2007 Random	2.7	Poor
PN6	02-20A		2007 Random	2.1	Poor
PN4	03-04		2007 Random	2.7	Poor
PN5	03-07		2007 Random	2.4	Poor
PN5	03-05		2007 Random	3.6	Fair
PN2	03-12A		2007 Random	3.0	Fair
PN2	03-09		2007 Random	2.7	Poor

Subwatershed	Sample ID	SAT ID	Study	BIBI Score	Ranking
PN4	03-13A		2007 Random	3.3	Fair
PN2	03-01		2007 Random	1.9	Very Poor
PN4	03-17A		2007 Random	2.7	Poor
PNC	PANT-01-2009	PNC031.G001	2009 Targeted	4.7	Good
PNB	PANT-02-2009	PNB045.G001	2009 Targeted	2.1	Poor
PNB	PANT-03-2009	PNB030.G001	2009 Targeted	2.7	Poor
PN9	PANT-04-2009	PN9025.G001	2009 Targeted	2.7	Poor
PNA	PANT-07-2009	PNA022.G001	2009 Targeted	2.4	Poor
PN1	PANT-14-2009	PN1014.G001	2009 Targeted	1.9	Very Poor
PN1	PANT-15-2009	PN1009.G001	2009 Targeted	2.7	Poor
PN2	PANT-08-2009	PN2011.G001	2009 Targeted	1.3	Very Poor
PN3	PANT-09-2009	PN3001.G001	2009 Targeted	1.9	Very Poor
PN5	PANT-13-2009	PN5010.G001	2009 Targeted	2.1	Poor
PN8	PANT-11-2009	PN8027.G001	2009 Targeted	1.9	Very Poor
PN8	PANT-10-2009	PN8006.G001	2009 Targeted	2.7	Poor
PN6	PANT-12-2009	PN6010.G001	2009 Targeted	3.3	Fair
PN7	PANT-05-2009	PN7053.G001	2009 Targeted	2.7	Poor
PN7	PANT-06-2009	PN7065.G001	2009 Targeted	3.0	Fair

Figure 2-8 provides the percentages of each rating category for each of the sampling years. There is a good deal of consistency over time in the proportion of sites in each of the categories. Additionally, the percentages described above for the entire dataset follow closely the pattern displayed by each year.

FIGURE 2-8: BIOASSESSMENT RATINGS BY YEAR AND STUDY



2.1.8 Aquatic Resource Indicators

Areas that support trout spawning, anadromous fish spawning, and threatened and endangered species are all considered high-quality sensitive habitat that should be preserved. The locations of each of these sensitive habitat types in the Patapsco Non-Tidal Watershed were provided my MDNR and supplemented with additional information from the County. The threatened and endangered species habitat was represented by the Natural Heritage Program's Sensitive Species Project Review Areas (SSPRA). The county overlaid GIS data with locations of these sensitive habitat areas to obtain a single representative GIS layer of all three aquatic resource indicators.

No subwatershed in the Patapsco Non-Tidal Watershed contained areas identified as trout spawning habitat or anadromous fish spawning, while 7 subwatersheds were determined to contain SSPRA habitat. Based on the presence of one or more of these indicators, subwatersheds were prioritized "High," "Medium High," "Medium," or "Low" for preservation. A summary of ratings for Patapsco Non-Tidal subwatersheds is presented in Table 2-13. No subwatersheds rate "High" or "Medium High" for aquatic resources. Approximately 58% of subwatersheds are prioritized "Medium" for this indicator. Subwatershed ratings for aquatic resources are presented in Map 2.8 in which preservation values of "Low" are represented by the yellow coloration, while the "Medium" value is represented by orange.

TABLE 2-13: AQUATIC RESOURCE INDICATOR RATINGS

Subwatershed	Anadromous Fish	SSPRA	Trout	Indicator	Preservation Value
PN1	Absent	Absent	Absent	Absent	Low
PN2	Absent	Absent	Absent	Absent	Low
PN3	Absent	Absent	Absent	Absent	Low
PN4	Absent	Absent	Absent	Absent	Low
PN5	Absent	Absent	Absent	Absent	Low
PN6	Absent	Present	Absent	Present	Medium
PN7	Absent	Present	Absent	Present	Medium
PN8	Absent	Present	Absent	Present	Medium
PN9	Absent	Present	Absent	Present	Medium
PNA	Absent	Present	Absent	Present	Medium
PNB	Absent	Present	Absent	Present	Medium
PNC	Absent	Present	Absent	Present	Medium

2.2 Upland Data Collection and Compilation

2.2.1 Contributory Impervious Cover to Streams

Links have been well established between the level of impervious cover within a drainage area and the overall health of downgradient water bodies. The Center for Watershed Protection (CWP) suggested that streams with greater than 25% tributary impervious cover are typically considered impaired or non-supporting; streams with 10 to 25% impervious cover are typically considered stressed or impacted, and streams with less than 10% imperviousness can support sensitive habitat and are typically relatively unimpaired (Schueler, 1992). The County utilized its impervious cover GIS layer based on 2007 land use data to calculate the impervious percent cover within the drainage area of all assessed perennial reaches. Based on the guidance discussed above from CWP, each perennial reach was assigned a rating of "Sensitive," "Impacted," or "Non-supporting" related to its percent impervious cover. Approximately 48.6% of the stream reaches in the Patapsco Non-Tidal Watershed were rated "Non-Supporting." A summary of impervious cover ratings is provided in Table 2-14. As described earlier, a map depicting impervious cover throughout the watershed is presented in Map 1.10.

Table 2-14: Impervious Cover Ratings, Perennial Reaches per Indicator Value

	Indicator Value				
Subwatershed	**Sensitive 1-10**	**Impacted 10-19**	**Impacted 19-25**	**Non-Supporting 25-100**	**Total Reaches**
PN1	0	0	0	1	1
PN2	0	0	0	2	2
PN3	0	0	0	0	0
PN4	0	0	0	5	5
PN5	1	0	3	2	6
PN6	0	0	0	4	4
PN7	0	1	2	7	10
PN8	0	0	0	15	15
PN9	0	1	6	7	14
PNA	0	2	0	4	6
PNB	2	14	4	10	30
PNC	19	5	13	12	49
Total	22	23	28	69	142

2.2.2 Urban Stormwater Best Management Practices

Best management practices (BMP) are a method by which the adverse impacts of development and redevelopment are controlled. Urban stormwater BMPs are utilized throughout the County to intercept, retain, drain, and/or treat stormwater prior to discharge to receiving waters. The installation of BMPs is required in all new development and in certain individual lot developments. The level of stormwater management required (e.g. recharge volume, water quality volume, channel protection volume, etc.) is dependent on a number of factors including but not limited to development size, proximity to Critical Areas, and downstream conditions. In the case of redevelopment, requirements for stormwater management include reductions in impervious cover or effective impervious cover through the use of BMP implementation, BMP upgrades, or other restoration activities. Additional BMP implementation in the County may include retrofits of publicly owned property as a part of its capital improvement program and its watershed management planning activities.

The first step towards understanding the current stormwater management activities in the Patapsco Non-Tidal watershed was to compile a spatially accurate GIS inventory of all existing public and private BMPs in the watershed. Accurate spatial and descriptive information is essential to identify areas which are under managed and to guide future implementation and retrofit efforts. The final BMP inventory contained accurate and up-to-date BMP location, type, drainage area, and ownership information. The effort to develop the dataset included acquiring preliminary information from County and State sources, eliminating BMPs outside the Patapsco Non-Tidal watershed and confirming or updating the location of those within the watershed, removing duplicate records, and filling in missing information by performing records research.

The preliminary data gathered for this effort included geographic information in ArcGIS format from the County, Maryland State Highway Association (SHA), and Baltimore Washington International Airport (BWI). For the SHA and BWI datasets, the facilities located within the Patapsco Non-Tidal watershed were selected and isolated from their respective databases at large using the ArcGIS 'Select by Location' function and a watershed boundary from the County in ArcGIS format. This methodology for the SHA and BWI datasets assumed the raw data provided by these entities was spatially accurate.

The process of eliminating County BMPs outside of the Patapsco Non-Tidal watershed included several different steps. Data from the County was included spatial information that could be viewed in ArcMap and attribute data including Zip Code and ADC Map code for many BMPs. The first step was to eliminate all BMPs that were both located outside the Patapsco Non-Tidal watershed boundaries and had a Zip Code and ADC Map Code that were outside the watershed boundary. The remaining BMPs were examined to compare the Zip Code and ADC Map code contained in the attribute data of the BMP database to the Zip Code and ADC Map code of the geographic location of the point in the database. BMPs were eliminated from the dataset when all location information indicated they were outside Patapsco Non-Tidal Watershed. If the location could not be determined using these preliminary GIS processing steps, records research was performed in order to determine the BMP's location.

Several different approaches were used to complete records research when location, structure type, or drainage area information were not provided in the original dataset. The following is a description of the data sources and methods utilized to fill in missing information. Records research was only performed on County BMPs.

The first approach to determining BMP location during records research was to search for the address listed in the attribute table using a web based mapping application with satellite imagery (i.e. Google or Bing maps) and compare the location of the BMP as shown in ArcMap to the physical address provided in the attribute table. The comparison was accomplished using reference layers (i.e. streets and parcels) in ArcMap to determine relative locations of landmarks and/or intersections as shown in the web map. The next approach was to search for a historical drawing or document on the County's server using the BMP's grading permit number. If a drawing or document for the BMP was located, the address listed in the attribute table was compared to the address shown on the permit. If no address was given in the attribute table, the address given in the permit was mapped using a web application and compared to the location of the BMP in ArcMap as described above. The final approach was to search for drawings using the County View system by either clicking on the As-Built grid where the BMP is located in the geodatabase or by searching based on a descriptor found in the attributes table (i.e. street name, neighborhood, structure name). If an As-Built for the BMP could be found then it was deemed to be inside the watershed.

Similar methods were used to locate structure type information. The first approach was to search for historical drawings and/or documents on the County's server using the grading permit number of the BMP in question. If historic documents or drawings were available, the structure type was searched for within the documents. Another method was to use orthophotography or web based mapping application to search for the BMP location using the address or nearby intersection. The orthophotography could then be inspected for a BMP. This approach worked well for large, visible structures such as ponds. Lastly, the CountyView system could be utilized to search As-Built plan. If As-Builts were available, structure type was searched for on the plans.

In order to properly account for load reductions associated with each BMP, the County delineated a drainage area for each BMP. The variety of BMP structure type, original data source, and accuracy of the BMP's spatial location required several different delineation methods. To keep track of the method used to delineate each BMP's drainage area a *Comment* field was added to the final dataset and populated with the method used to determine the BMP drainage area. The methods employed to determine drainage area in the Patapsco Non-Tidal watershed include "Snapped", "Buffer", and "Missing Record". The points for BMPs with typically large drainage areas (i.e. wet ponds, dry ponds, infiltration basins, wetlands) and with spatially accurate locations were snapped to the nearest flow accumulation grid cell which captured the approximate design drainage area. In a few instances two non-converging flow paths defined the drainage area of a BMP. These instances required two separate points be snapped to the flow accumulation grid to define the drainage area. After snapping points to the flow accumulation grid the drainage area was delineated using the ArcHydro Batch Watershed Delineation tool. The *Comment* field for these BMPs was populated with "Snapped".

For BMPs where the design drainage area was known, but only a general location of the BMP was known, an artificial circular drainage area polygon was created. This was accomplished by calculating the radius of the circle that has an area equivalent to the known drainage area of the BMP. This radius was then used to draw a buffer around the general location of the BMP. The polygon created by this buffer was used as the BMP drainage area. The *Comment* field for these BMPs was populated with "Buffer". For example, dry wells and infiltration trenches typically have relatively small drainage areas. Snapping the BMP point to the flow accumulation grid is more difficult for these smaller areas because a flow path is not necessarily apparent. Therefore, the drainage area for dry wells and infiltration trenches was often determined by applying a buffer around the BMP point.

A small subset of BMPs with limited attributes and/or questionable spatial locations were categorized as a "Missing Record" in the *Comment* field. These BMPs will be researched further in future work as additional data becomes available.

Drainage area polygons for the BMPs associated with the **Capital Improvement Program Restoration Project Dataset, Maryland SHA BMP Database, and Baltimore Washington International Airport** were developed previously as part of the original dataset development. These drainage area polygons were used as-is with no modifications.

After setting up the drainage area, the County identified overlapping drainage areas. In areas with overlapping drain areas, best professional judgment was used to determine which BMP was predominantly managing a particular intersected drainage area. The drainage area polygon was then assigned to the predominant BMP. This check was performed to ensure that only a single BMP managed a particular area and that the appropriate BMP was receiving the management credit.

Patapsco Non-Tidal BMPs were grouped into seven major categories based on their primary management mechanism. These categories include Dry Detention, Extended Dry Detention, Filtration, Infiltration, Wet Ponds, Wetlands, and Other. A detailed list of the general BMP types that fall into each of these categories can be found in Appendix D. In total, 676 BMPs were determined to be located within the Patapsco Non-Tidal watershed. Drainage areas for each BMP were delineated for All County owned BMPs using several different methodologies including using the County's flow accumulation grid and ArcHydro tools or developing an area buffered around the BMP. Drainage areas were provided by BWI and MSHA for their BMPs. Drainage areas for 117 of the 676 BMPs could not be delineated and therefore the County is not taking credit for any treatment these 117 BMPs may have offered. Therefore there are 559 BMPs providing treatment in the Patapsco Non-Tidal watershed. The total drainage area treated by these 559 BMPs is 4,636 acres. A summary of all Patapsco Non-Tidal BMPs by type is presented in Table 2-15 and a map of all BMPs located in the watershed is presented as Map 2.9.

TABLE 2-15: SUMMARY OF BMPS BY TYPE

BMP Category	Quantity	Percent by Quantity	Drainage Area (acres)	Percent by Drainage Area
Dry Detention	57	8%	416	9%
Extended Detention Dry	116	17%	1,250	27%
Filtration	113	17%	248	5%
Infiltration	274	41%	931	20%
Wet Ponds	77	11%	29	1%
Wetlands	7	1%	1,608	35%
Other	32	5%	154	3%
Total	**676**	**100%**	**4,636**	**100%**

Of the total 15,269 acres in the Patapsco Non-Tidal watershed, approximately 30% of the drainage area is receiving treatment from a BMP. A small number of BMP areas are nested, so a small portion of this area is receiving treatment by a series of BMPs. BMP treatment areas range in size from 0.01 to 500 acres with the average treatment area equal to 8.3 acres and the median equal to 3.3 acres. These statistics indicate that the majority of BMPs treat an area that is small to medium in size. Many BMP drainage areas are quite small with 26% treating less than 1.0 acre and 56% treating less than 4 acres. About 80% of the BMPs treat less than 10 acres and an additional 18%, or 107 BMPs, treat between 10 and 50 acres. Only four BMPs treat over 50 acres. All statistics describing drainage areas are based on the 559 BMPs for which a drainage area could be delineated.

Stormwater BMPs in the Patapsco Non-Tidal watershed are typically owned by private land owners, the County, state agencies such as the Maryland State Highway Administration (SHA), or private entities such as Baltimore Washington International Airport (BWI). Table 2-16 provides a summary of Patapsco Non-Tidal BMPs by owner and type. The majority of Patapsco Non-Tidal BMPs are owned by the county (86% by quantity), and SHA and BWI each own about 7% of the 676 BMPs. The relative ownership is similar when evaluated on an acres treated basis with the county owning 84% and SHA and BWI owning about 5% and 11% respectively.

This watershed plan focuses on the urban BMPs and does not include an analysis of the BMPs that may treat the agricultural lands in Patapsco Non-Tidal watershed. Since agricultural lands make up less than 1% land area of the watershed, it did not seem pertinent to include an Agricultural BMP analysis.

TABLE 2-16: SUMMARY OF BMPS BY OWNER

BMP Category	**Owned by SHA**				**Owned by County**				**Owned by BWI**			
	Quantity	Percent by Quantity	Drainage Area (acres)	Percent by Drainage Area	Quantity	Percent by Quantity	Drainage Area (acres)	Percent by Drainage Area	Quantity	Percent by Quantity	Drainage Area (acres)	Percent by Drainage Area
Dry Detention	5	10%	14	6%	44	8%	320	8%	8	18%	82	16%
Extended Detention Dry	1	2%	4	2%	79	14%	805	21%	36	82%	442	84%
Filtration	0	0%	0	0%	113	19%	248	6%	0	0%	0	0%
Infiltration	34	71%	83	35%	240	41%	848	22%	0	0%	0	0%
Wet Ponds	7	15%	113	48%	70	12%	1495	39%	0	0%	0	0%
Wetlands	1	2%	20	8%	6	1%	134	3%	0	0%	0	0%
Other	0	0%	0	0%	32	5%	29	1%	0	0%	0	0%
Total	**48**	**100%**	**234**	**100%**	**584**	**100%**	**3879**	**100%**	**44**	**100%**	**523**	**100%**

2.2.3 ONSITE SEWAGE DISPOSAL SYSTEMS

OSDSs or septic systems can contribute high levels of nutrients, particularly nitrogen, and bacteria to downstream water bodies via subsurface migration. This is especially true for older or poorly maintained OSDSs. In 2008, the County conducted a study to evaluate service options for properties with OSDSs and to develop a cost-effective approach to reducing pollutant loads from OSDSs (Anne Arundel County, 2008). As part of this study, information was used with data on per capita loading to quantify aggregate pollutant loads from OSDSs across the Patapsco River Non-Tidal Watershed.

The 2008 OSDS study noted that the Patapsco River Watershed has 3,283 OSDSs, which represents approximately 8% of the OSDS County-wide. These systems contribute 74,729 lbs of total nitrogen annually to streams within the watershed. Of this total nitrogen load to the streams, 24,770 lbs is from the non-tidal part of the Patapsco watershed, which comprises of 1,120 OSDSs (2.8% of County-wide OSDSs). However, after 2008, due to changes in the way the County mapped the watershed; a few OSDSs were added to the non-tidal part of the watershed. Currently the Patapsco non-tidal watershed has 1,168 OSDSs which contribute a total nitrogen load of 25,109 lbs.

This study identifies the most cost-effective approaches to reducing nitrogen loads from OSDSs. Treatment alternatives examined included sewer extension to an existing water reclamation facility (WRF) (both in areas of no public service and areas with an existing sewer system), clustering of community sewer service, OSDS upgrades with enhanced nitrogen removal, and no action. In the Patapsco River Watershed, approximately 65% of OSDSs are recommended for connection to a sewer extension, 20% are recommended for cluster treatment, and 10% are recommended for enhanced nitrogen removal upgrades at individual OSDS. The implementation of all treatment options would be expected to reduce total nitrogen from OSDSs by approximately 80% or 142,000 pounds per year. A map of OSDS locations and the areas associated with treatment recommendations is presented in Map 2.10.

Since nitrogen is generally the most mobile of the typical pollutants associated with OSDSs, it is used in the County's prioritization assessments as an indicator of septic system impacts to streams within the watershed. Subwatersheds are prioritized as "Very Poor," "Poor," "Fair," or "Good" based on the natural breaks (a systematic method for classification) in the cumulative annual total nitrogen loading (in pounds) within the subwatershed. A breakdown of ratings for total nitrogen loading from OSDSs for Patapsco River non-tidal subwatersheds is presented in Table 2-17 and in Map 2.11. Approximately 50% of subwatersheds within the Patapsco River Non-Tidal Watershed are rated "Very Poor" or "Poor." Two subwatersheds, Holly Creek (PN2), and Stoney Run 1 (PN6), are rated "Good" for total nitrogen contributions from OSDSs. Collectively, the estimated annual total nitrogen contribution from these two subwatersheds is 328 lbs/yr. This represents approximately 13% of the non-tidal watershed-wide total nitrogen load contribution from OSDSs and 17% of the subwatersheds.

TABLE 2-17: TOTAL ANNUAL NITROGEN LOAD RATING OSDS

Subwatershed	Subwatershed	Number of OSDS	TN loading by subwatershed (lbs/yr)	Rating[1]
PN1	Patapsco Mainstem	22	1,058	Fair
PN3	Patapsco Mainstem	12	711	Fair

Subwatershed	Subwatershed	Number of OSDS	TN loading by subwatershed (lbs/yr)	Rating[1]
PN4	Unnamed Tributary	53	851	Fair
PN8	Stoney Run 3	33	537	Fair
PN2	Holly Creek	7	148	Good
PN6	Stoney Run 1	10	180	Good
PN5	Patapsco Mainstem	57	1,646	Poor
PNA	Deep Run	50	1,265	Poor
PN7	Stoney Run 2	202	4,274	Very Poor
PN9	Stoney Run 4	244	4,153	Very Poor
PNB	Piney Run	186	4,004	Very Poor
PNC	Deep Run	292	6,280	Very Poor
Total		**1,168**	**25,109**	

[1] Ratings are represented on Map 2.11; Very Poor is highest priority for restoration (Red), Poor is the next highest priority (Orange), Fair is a lower priority (Yellow), and Good is the lowest priority (Green)

2.2.4 Soil Indicators

Native soils vary in their susceptibility to erosive forces. Clay soils, for instance, are less susceptible to erosion than are coarse sandy soils. The soil erodibility factor, K, is a measure of the susceptibility of soil to detachment and transport by precipitation and runoff. Soil erodibility factors for Anne Arundel County were obtained from NRCS datasets. The County uses these soil erodibility factors to identify areas susceptible to soil erosion as part of its subwatershed preservation assessment.

Subwatersheds are prioritized “High,” “Medium High,” “Medium,” or “Low” based on natural breaks in soil erodibility factor across subwatersheds. A summary of subwatershed ratings for soil erodibility is presented in Table 2-18 and depicted in Map 2.12. Approximately 8% of subwatersheds are prioritized “High” for susceptibility to soil erosion.

TABLE 2-18: SUBWATERSHED RATINGS FOR SOIL ERODIBILITY

Subwatershed	NRCS Erodibility Factor	Rating	Preservation Value
PN1	0.1	Not Highly erodible land	Low
PN2	0.2	Potentially erodible land	Medium
PN3	0.2	Potentially erodible land	Medium
PN4	0.3	Potentially erodible land	Medium
PN5	0.3	Potentially erodible land	Medium
PN6	0.3	Potentially erodible land	Medium
PN7	0.2	Potentially erodible land	Medium
PN8	0.1	Not highly erodible land	Low
PN9	0.2	Potentially erodible land	Medium
PNA	0.4	Highly erodible land	High
PNB	0.3	Potentially erodible land	Medium
PNC	0.3	Potentially erodible land	Medium

2.2.5 LANDSCAPE INDICATORS

The County employs a variety of landscape-based indicators for restoration and preservation assessments. Percent impervious cover, percent forest within the 100-foot stream buffer, ratio of existing wetlands to potential wetlands, and acres of developable land within the Critical Area are used as indicators of the potential need for restoration activities. Percent forest cover, percent wetland cover, density of headwater streams, percent of land within the Greenway Master Plan, the presence of bog wetlands, acres of Resource Conservation Area (RCA) lands within Critical Area, percent of protected lands, and presence of Wellhead Protection Area are used as indicators of the potential need for preservation. GIS datasets were used by the County to quantify the extent of the landscape indicators within each Patapsco Non-Tidal subwatershed. The GIS analyses related to impervious area, forest cover, bog wetland locations, Critical Areas, protected lands, land associated with the Greenway Master Plan, and density of headwater streams were performed using the County's existing geodatabase of land use and land features. GIS analyses associated with wetland cover were performed using MDNR datasets.

Subwatersheds are prioritized "Low," "Medium," "Medium High," or "High" based on natural breaks in the data. Summaries of these ratings for Patapsco Non-Tidal subwatersheds are presented in Table 2-19 and Table 2-20 and on Maps 2.13, 2.14 and 2.15. The ratio of existing to potential wetlands was the most evenly distributed of the landscape indicator ratings for subwatershed restoration. The percent impervious cover indicator had the most subwatersheds rated "Medium High" or "High." Acres of developable land within the Critical Area were predominantly rated "Low" to "Medium."

TABLE 2-19: LANDSCAPE INDICATOR RATINGS (SUBWATERSHED RESTORATION)

Subwatershed	Percent Impervious Cover	Percent Forest within the 100-foot Stream Buffer	Ratio of Existing to Potential Wetlands	Acres of Developable Critical Area
PN1	High	Low	High	High
PN2	High	Low	High	Medium
PN3	High	Medium	High	Medium High
PN4	High	Medium High	Medium High	Low
PN5	Medium	High	Medium High	Low
PN6	Medium High	High	Medium	Low
PN7	Medium High	High	Medium High	Low
PN8	High	Low	Medium High	Low
PN9	High	Low	Medium	Low
PNA	Low	High	High	Low
PNB	High	Medium High	Low	Low
PNC	Medium	Medium High	Low	Low
Percent of Watershed				
High	58.3%	33.3%	33.3%	8.3%
Medium High	16.7%	25.0%	33.3%	8.3%
Medium	16.7%	8.3%	16.7%	8.3%
Low	8.3%	33.3%	16.7%	75.0%

TABLE 2-20: LANDSCAPE INDICATOR RATINGS (SUBWATERSHED PRESERVATION)

Subwatershed	Percent Forest Cover	Percent Wetland Cover	Density of Headwater Streams	Percent of Land within the Greenway Master Plan
PN1	Low	Medium	Medium High	Medium
PN2	Low	Medium High	Low	Medium
PN3	Medium	High	Low	Medium High
PN4	Medium	Medium High	Low	Medium High
PN5	High	High	High	Medium High
PN6	High	Low	Medium High	High
PN7	Medium High	Medium High	Medium	Medium High
PN8	Low	Low	Low	Low
PN9	Medium	Medium	Medium	Medium
PNA	High	Medium High	High	High
PNB	Medium High	Low	Medium High	High
PNC	Medium High	Low	Medium High	Medium
Percent of Watershed				
High	25.0%	16.7%	16.7%	25.0%
Medium High	25.0%	33.3%	33.3%	33.3%
Medium	25.0%	16.7%	16.7%	33.3%
Low	25.0%	33.3%	33.3%	8.3%

Subwatershed	Presence of Bog Wetlands	Acres of RCA lands with the Critical Area	Percent of Protected Lands	Presence of Wellhead Protection Areas
PN1	Low	Medium	Medium	Low
PN2	Low	Medium	Medium	Low
PN3	Low	Medium High	Medium High	Low
PN4	Low	Medium	Medium	Low
PN5	Low	High	High	Low
PN6	Low	Low	Medium High	Low
PN7	Low	Low	Low	Low
PN8	Low	Low	Low	Low
PN9	Low	Low	Medium High	High
PNA	Low	Low	High	Low
PNB	Low	Low	Low	High
PNC	Low	Low	Low	Low
Percent of Watershed				
High	0.0%	8.3%	16.7%	16.7%
Medium High	0.0%	8.3%	25.0%	0.0%
Medium	0.0%	25.0%	25.0%	0.0%
Low	100%	58.3%	33.3%	33.3%

3 HYDROLOGIC AND POLLUTANT LOAD MODELING

Computer simulation modeling is utilized to predict natural processes and utilizes data collected in the field during the stream walks as an input. This allows for the extrapolation from existing conditions to alternative future conditions (scenarios) that reflect differing assumptions about the course of land development and the implementation of pollutant controls within the watershed.

Land development is typically associated with increased imperviousness and decreased capacity for managing precipitation. As watersheds become more developed, runoff volumes and peak flow rates increase and stream base flows decrease. This often results in destabilized streams, increased pollutant loading, and adverse impacts to physical habitat. Nutrients and suspended solids are two of the leading causes of water quality impairment in sensitive water bodies, including the Chesapeake Bay and its tributaries. Nutrients, such as nitrogen and phosphorus, can cause excessive algae growth and eutrophication. Suspended solids can limit growth of aquatic vegetation and destroy physical habitat.

The County's hydrologic and pollutant load modeling provides quantification of watershed processes and allows for the comparison of different scenarios used to prioritize restoration and mitigation projects. The County performed hydrologic and pollutant load modeling to help assess existing conditions as well as future development and pollutant control scenarios within the watershed. The results were used to understand the extent of potential water quality improvements necessary for satisfying MS4 permit and TMDL requirements.

This section presents and discusses the methods and inputs used in the hydrologic and water quality modeling of current and future build-out conditions (Section 3.1) and the results of that modeling (Section 3.2). Discussions of future scenario modeling to support development of the implementation plan for the watershed are presented in Section 5.

3.1 METHODS

This subsection describes two types of modeling performed in the watershed characterization to help evaluate and prioritize areas and projects for action. Hydrologic modeling, which involves simulation of the runoff and conveyance of rain falling on the watershed, was done to improve understanding of reach and subwatershed sensitivity to erosion and to development. Pollutant load modeling of current conditions, which entails the simulation of the generation, transport, and delivery of solids, nutrients, and pathogens, provides the basis for assessment of current and future condition pollutant loading. Model results enable comparison and prioritization of mitigation strategies and projects as discussed in Section 5. The methods and inputs for each model are discussed below.

3.1.1 HYDROLOGIC MODELING

Hydrologic modeling is used to represent rainfall-induced runoff conditions and the conveyance of streamflow in the watershed. The County applies the NRCS TR-20 for hydrologic modeling. This NRCS model is a single event watershed scale runoff and routing model that was used to evaluate runoff volumes and peak flow for one-year (2.7" rainfall) and two-year (3.3" rainfall) storm events. The one-year and two-year events were selected because bankfull conditions for streamflow, which are generally considered to be the most critical condition for delivery of sediment and associated pollutants, typically occur about once every one to two years in the Chesapeake Bay region.

The TR-20 model results, presented as peak flow rate normalized to area (cfs/acre) and surface runoff yield (inches), are used to evaluate the likely sensitivity of the Patapsco Non-Tidal Watershed areas to gullying and stream erosion. Areas with higher normalized peak flow rates and/or surface runoff yields are more likely to suffer from erosion in-stream or on the land surface, and therefore could be prioritized higher for restoration versus areas with lower normalized peak flow rates or surface runoff yields. Higher rates and yields are often expected in urbanized areas with more extensive impervious surface area.

3.1.2 Water Quality Modeling

Water quality modeling is used to represent the generation of pollutant loads and their potential control by BMPs. The County's water quality model for the Patapsco Non-Tidal Watershed is based on EPA's Simple Method (Schueler, 1987) and PLOAD models (EPA, 2001). The water quality model calculates annual loadings for total nitrogen (TN), total phosphorus (TP), total suspended solids (TSS), and fecal coliforms (FC) under various pristine, current, and ultimate build-out conditions. A summary of the modeled scenarios is presented in Table 3-1.

TABLE 3-1: MODELED WATER QUALITY SCENARIOS

Modeled Scenario	Purpose
A. Pristine Condition no development	Baseline, all-forested condition representing pre-development state
B. Current Condition with fully maintained BMPs	Current land use and existing BMPs fully maintained
C. Future Conditions with fully maintained BMPs and implementation of all future stormwater management regulations (SWM) and sewer master plan	Expected future land use with existing BMPs; development informed by future stormwater regulations and sewer master plan.

Pristine (pre-development) conditions were modeled for contextual purposes only and assumed the watershed was entirely forested prior to development. Existing conditions were based on high resolution 2007 land cover and impervious surface data collected by the county. Eighteen various land cover classifications have been used for current conditions modeling and aggregated based on event mean concentration (EMC) values. These loadings are used in the restoration and preservation prioritization assessment. A summary of the EMC values and landuse type are presented in Table 3-2 below.

TABLE 3-2: WATER QUALITY MODELING EVENT MEAN CONCENTRATIONS

Landuse Type	TN (mg/L)	TP (mg/L)	TSS (mg/L)	Fecal Coliforms (MPN/100ml)
Airport	2.24	0.30	99.0	4500
Commercial	2.24	0.30	77.0	4500
Forested Wetlands	1.15	0.15	0.0	500
Industrial	2.22	0.19	77.0	2614
Open Space	1.15	0.15	43.0	3100
Open Wetlands	1.15	0.15	0.0	500
Pasture and Hay	1.71	1.00	250	500

Landuse Type	TN (mg/L)	TP (mg/L)	TSS (mg/L)	Fecal Coliforms (MPN/100ml)
Residential 2-Acre Lot	2.74	0.32	48.0	7750
Residential 1-Acre Lot	2.74	0.32	48.0	7750
Residential ½-Acre Lot	2.74	0.32	48.0	7750
Residential ¼-Acre Lot	2.74	0.32	48.0	7750
Residential ⅛-Acre Lot	2.74	0.32	48.0	7750
Residential Woods	1.55	0.19	24.0	952.25
Single Row Crops	1.71	1.00	400	500
Transportation	2.59	0.43	99.0	1400
Utility	2.59	0.43	43.0	3100
Water	1.20	0.03	0.0	500
Woods	1.15	0.15	0.0	500

The model's basic elements are polygons determined in GIS by the geometric intersection of land use and hydrologic (subwatershed) boundaries. Table 3-3 lists the spatial layers used by the model for calculation and for definition of development and management scenarios. The polygon information is imported into the County's spreadsheet model for calculation purposes using the EPA Simple Method. In one modification to the Simple Method, the model uses the County's impervious cover delineation to explicitly represent impervious surface runoff instead of the standard impervious rating approach.

Future conditions were based on an analysis of ultimate build-out conditions in the watershed. Each modeled scenario began with the geometric intersection of the GIS layers described in Table 3-3, followed by application of various rules regarding development and redevelopment to constrain future development. For example, future development is assumed infeasible or inappropriate in floodplains, steeply sloped areas, wetlands, certain stream buffers, schools and parks, cemeteries, and utility corridors. Results for the modeled future development conditions are considered very conservative. As a result of the layer intersects, various pieces of a parcel were considered for future development regardless of the likelihood of such development to occur. For example, a portion of wooded space on a residential lot within a subdivision was assumed to be further developed if current zoning enable such development. This resulted in overestimate of pollutant loads. It was decided that it would be better to overestimate future build-out pollutant loads rather than to under estimate.

TABLE 3-3: WATER QUALITY MODELING GIS LAYERS

GIS Layer	Description	Purpose
Land cover	2007 delineation of land cover types (*e.g.*, industrial, commercial)	Helps determine runoff volumes and pollutant loading
Impervious cover	2007 delineation indicates presence or absence of impervious cover	Helps determine runoff volumes and pollutant loading
Hydrologic soil groups	Indicates NRCS soil groups A, B, C, or D	Helps determine recharge potential

GIS Layer	Description	Purpose
Steep slopes	Derived from the digital elevation model (DEM)	Defines areas ineligible for development
Wetlands	Indicates presence or absence of wetlands	Defines areas ineligible for development
FEMA 100 year floodplains	Indicates presence or absence of floodplain	Defines areas ineligible for development
Critical areas	Includes Intense Development Areas, Limited Development Areas, and Resource Conservation Areas	Helps determine appropriate BMP placement
Regulatory stream buffer	Buffer width varies depending on stream class	Defines areas ineligible for development
Redevelopment value and zone	Includes assessed value of land for a particular parcel plus improvements	Identifies new development or redevelopment likelihood
Schools and parks	Indicates presence or absence of schools or parks	Defines areas ineligible for development
Utilities	Indicates presence or absence of utilities (defined by land cover layer)	Defines areas ineligible for development
Cemeteries	Indicates presence or absence of cemeteries	Defines areas ineligible for development
Ownership	Indicates private or public ownership	Guides BMP placement for future development scenarios
Greenways	Includes lands designated as such on the Greenways Master Plan	Defines areas ineligible for development
Expanded buffer	Includes a 300-foot stream buffer in areas with no public sewer service	Defines areas ineligible for development
Zoning codes	Includes County zoning codes (*e.g.*, commercial, low density residential, etc)	Defines areas eligible for specific development types
Sewer timing	Includes estimates for when and where future sewer systems will be installed	Helps determine septic pollutant loading
Septic delivery ratio	Septic pollutant delivery ration obtained from 2008 septic system study	Helps determine septic pollutant loading

The County's spreadsheet model provides flexibility to evaluate non-traditional elements that are not feasible to simulate with PLOAD. Water quality benefits from a variety of these non-traditional elements can be simulated in the County's spreadsheet model, including:

Impacts of new stormwater regulations **-** Maryland's stormwater regulations are expected to improve water quality within the Patapsco Non-Tidal Watershed. As an example, new development and future BMPs will have an infiltration component, and the County has incorporated this into the model by reducing rainfall runoff from new development/redevelopment areas. Additional measures include general BMPs in areas of new development meeting average efficiency requirements and imperviousness reductions in redevelopment areas. Chesapeake Bay regulations govern development in the Critical Areas and are also reflected in the model.

OSDS upgrades - OSDS loads were based on the County's 2008 OSDS study. In the Patapsco Non-Tidal Watershed application of the water quality model, all of the recommended improvements to septic systems are incorporated. These improvements include sewer extension to existing WRFs (in areas of no public service and in areas with an existing sewer system), clustering of community sewer service, and OSDS upgrades with enhanced nitrogen removal.

3.2 Modeling Results

3.2.1 Hydrologic Modeling

The hydrologic model results consisted of four hydrologic indicators for each of the Patapsco Non-Tidal subwatersheds:

- Area-normalized peak flow (cfs/acre) for a 2.7" (one-year storm)
- Area-normalized peak flow (cfs/acre) for a 3.3" (two-year storm)
- Surface runoff yield (inches) for a 2.7" (one-year storm)
- Surface runoff yield (inches) for a 3.3" (two-year storm)

Subwatersheds were prioritized and rated "High," "Medium High," "Medium," or "Low" based on the natural breaks for each of the four hydrologic indicators. A summary of these ratings for Patapsco Non-Tidal subwatersheds is presented in Table 3-4. For all twelve of the Patapsco Non-Tidal subwatersheds, the one-year peak flow scores were identical to the two-year peak flow scores, and the one-year yield scores were identical to the two-year yield scores. As shown in Map 3.1, most of the subwatersheds have low area-normalized event peak flow values that translate into lower priorities. Approximately 25% of subwatersheds within the Patapsco Non-Tidal Watershed are rated "Low" for the two peak flow indicators. Two subwatersheds, Patapsco Mainstem (PN1) and (PN3), were both rated "High" for peak flow associated with both the one-year and two-year storm events. The hydrologic indicator ratings for surface runoff yield were similar to peak flow rating categories. Approximately 25% of the subwatersheds were rated "Low" or "Medium" for the runoff indicator for the one-year storm event. The remaining 75% of the subwatersheds were rated "High" or "Medium High." For the two-year runoff storm event approximately 33 % of the subwatersheds were rated "Low" or "Medium". The remaining 66% of the subwatersheds were rated as either "High" or "Medium High".

3.2.2 Water Quality Modeling

Water quality modeling results are summarized in Table 3-4, which lists the model-predicted annual loadings for the entire Patapsco Non-Tidal Watershed of total phosphorus, total nitrogen, total suspended solids, and fecal coliforms for pristine, current, and future build-out scenarios. Pollutant loading results for existing conditions and future conditions are also depicted in Map 3.2 and Map 3.3, respectively.

TABLE 3-4: HYDROLOGIC INDICATOR RATINGS

Rating	Number of Subwatersheds	Percent of Subwatersheds
Peak Flow (one-year storm)		
High	2	16.7
Medium High	4	33.3
Medium	2	16.7
Low	4	33.3
Peak Flow (two-year storm)		
High	2	16.7
Medium High	4	33.3
Medium	2	16.7
Low	4	33.3
Surface Runoff (one-year storm)		
High	4	33.3
Medium High	5	41.7
Medium	2	16.7
Low	1	8.3
Surface Runoff (two-year storm)		
High	4	33.3
Medium High	4	33.3
Medium	3	25.0
Low	1	8.3

TABLE 3-5: ANNUAL LOADS PER SCENARIO AND POLLUTANT

Scenario	TP (lbs/yr)	TN (lb/yr)	TSS (tons/yr)	Fecal Coliforms (cfu/yr)
A. Pristine	1,007	7,717	0	3.4E+06
B. Current	3,905	60,147	399	5.4E+12
C. Future	4,933	59,466	526	6.8E+12

note: cfu = coliform forming units

Table 3-5 shows the annual loads under each scenario for each pollutant. Additional detail about the sources of pollutant loadings watershed-wide under each scenario is provided in Table 3-6. Review of the results by components provides the following additional insights:

- Urban runoff is the primary loading component for total phosphorus, total suspended solids, and fecal coliforms.
- OSDS loads are the primary loading component for total nitrogen.

- Under the future condition scenario, loads from urban areas generally increase while loads from agricultural and other lands decrease, reflecting assumptions regarding changes in land use with development and shifts in agricultural activities.

TABLE 3-6: ANNUAL LOADS PER SCENARIO PER LOADING SOURCE

Scenario	Total	Loading Source			
		Urban	OSDS	Other	Agricultural
Total Phosphorus (lb/yr)					
A. Pristine	1,007	---	---	1,007	---
B. Current	3,905	3,504	---	390	11
C. Future	4,933	4,756	---	175	2
Total Nitrogen (lb/yr)					
A. Pristine	7,717	---	---	7,717	---
B. Current	60,147	31,845	25,109	3,175	18
C. Future	59,466	40,655	17,434	1,373	4
Total Suspended Solids (tons/yr)					
A. Pristine	0	---	---	0	---
B. Current	399	379	---	18	2
C. Future	526	518	---	7	0
Fecal Coliform (cfu/yr)					
A. Pristine	3.4E+06	---	---	3.4E+06	---
B. Current	5.4E+12	5.1E+12	---	3.5E+11	5.4E+08
C. Future	6.8E+12	6.6E+12	---	1.5E+11	1.2E+08

Pollutant loading was considered in the assessments of both subwatershed restoration and subwatershed preservation that are discussed in more detail in Section 4. For the subwatershed restoration assessment, the County evaluated two water quality indicators based on existing conditions: total nitrogen load from runoff (lbs/acre/yr) and total phosphorus load from runoff (lbs/acre/yr). For the subwatershed preservation assessment, the County evaluated water quality indicators based on the percent future departure of loading conditions for total nitrogen and total phosphorus in terms of pounds per acre per year.

Subwatersheds were prioritized and rated “High,” “Medium High,” “Medium,” or “Low” for each of the water quality indicators related to the subwatershed restoration analysis. A summary of these ratings for Patapsco Non-Tidal subwatersheds is presented in Table 3-7. A visual representation of the existing condition pollutant loads within Patapsco Non-Tidal subwatersheds is depicted in Map 3.4. Ratings were fairly evenly distributed among the rating categories. The majority of subwatersheds were rated either “Medium High” or “Medium” when evaluating total nitrogen or total phosphorus loading. 16.7% of the subwatersheds were rated “High” for the two indicator categories.

TABLE 3-7: WATER QUALITY INDICATOR RATINGS (SUBWATERSHED RESTORATION)

Rating	Number of Subwatersheds	Percent of Subwatersheds
Total Nitrogen Load from Runoff		
High	3	25.0
Medium High	3	25.0
Medium	4	33.3
Low	2	16.7
Total Phosphorus Load from Runoff		
High	2	16.7
Medium High	6	50.0
Medium	3	25.0
Low	1	8.3

For the subwatershed preservation assessment, subwatersheds are rated and prioritized “High,” “Medium High,” “Medium,” or “Low” based on their relative need for preservation. A summary of these ratings for Patapsco Non-Tidal subwatersheds is presented in Table 3-8 and is shown visually on Map 3.4. For the percent future departure of total nitrogen loading, over half (50%) of the subwatersheds were rated as “Low” or Medium” priorities. For the percent future departure of total phosphorus loads, “Low” or Medium” priorities comprise two thirds (66%) of the total.

TABLE 3-8: WATER QUALITY INDICATOR RATINGS (SUBWATERSHED PRESERVATION)

Rating	Number of Subwatersheds	Percent of Subwatersheds
Percent Future Departure of Total Nitrogen Load		
High	2	16.7
Medium High	4	33.3
Medium	4	33.3
Low	2	16.7
Percent Future Departure of Total Phosphorus Load		
High	3	25.0
Medium High	1	8.3
Medium	5	41.7
Low	3	25.0

4 PRIORITIZATION AND RATING

To aid planners and to inform decision making efforts within the County on land use management and restoration/retrofit project selection, four separate prioritization models are completed for each of the County’s major watersheds. The models integrate historical environmental data, current stream assessment monitoring data, drainage area characteristics (GIS data), and watershed modeling results into indicators of watershed condition and need. The indicators are combined into the four models:

- Stream Reach Restoration
- Subwatershed Restoration
- Subwatershed Preservation
- Parcel Preservation

The models are designed to operate at three management scales, first at the individual stream reach scale, and second at the subwatershed scale, and lastly at the parcel scale. Additionally the models differentiate between identification of restoration opportunities for the degraded portions of the watershed (reach and subwatershed scale), and identification of preservation opportunities (subwatershed and parcel scale) for high quality sensitive areas that could be subject to additional stressors in future scenarios.

4.1 STREAM RESTORATION ASSESSMENT AND RATING

The stream restoration prioritization model is guided by the County's need to plan its expenditure of funds related to stream stability and biological health. The model output will direct future stream restoration projects and capital improvement planning and implementation.

4.1.1 METHODS

The stream restoration prioritization uses a suite of indicators that are weighted and then combined into a final relative rating for each perennial reach as identified in the Physical Habitat Condition Assessment. The suite of stream restoration indicators used in the Patapsco Non-Tidal watershed, along with the indicator weight is presented in Table 4-1.

TABLE 4-1: STREAM PRIORITY RATING INDICATORS FOR RESTORATION

Category	Indicator	Weight
Stream Habitat	MPHI score	31.6%
Stream Morphology	Rosgen Level I Classification	5.3%
Land Cover	Percent Imperviousness	5.3%
Infrastructure	Riparian buffer impacts	5.3%
	Channel erosion impacts	10.5%
	Head cut impacts	5.3%
	Dumpsite impacts	5.3%
	Other infrastructure impacts (pipes, ditches, stream crossings, obstructions)	15.8%
Hydrology and Hydraulics	Road Crossing Flooding Potential	15.8%

Although all stream channels (perennial, intermittent, ephemeral etc.) were walked and assessed during the Physical Habitat Condition Assessment, several of the metrics used to calculate the Maryland Physical Habitat Index (MPHI) (Paul et al 2003) are not appropriate for channels other than perennial. Thus the MPHI is completed only for perennial channels. Because stream habitat is critical to overall stream condition, the MPHI rating is an important indicator and is weighted over 30% in the model. The prioritization model then is relegated to only perennial channels.

4.1.2 FINDINGS

A total of 142 reaches were processed in the stream restoration model. Table 4-2 and Map 4.1 summarize the results of the stream restoration model. Nine reaches were categorized as "High" priority, 31 were "Medium High", 48 were "Medium", and 54 were "Low". The Deep Run subwatershed ranked as a very high priority overall, as seven of the nine "High" reaches are located in Deep Run. The Stoney Run subwatersheds had a combined total of 13 reaches rated in the "Medium High" category.

TABLE 4-2: STREAM PRIOTITY RATING FOR RESTORATION

Subwatershed Code	Subwatershed Name	Number of Reaches with Rating				
		Low	Medium	Medium High	High	Total
PN1	Patapsco Mainstem	1	0	0	0	1
PN2	Holly Creek	1	1	0	0	2
PN3	Patapsco Mainstem	0	0	0	0	0
PN4	Unnamed Tributary	0	5	0	0	5
PN5	Patapsco Mainstem	1	4	1	0	6
PN6	Stoney Run 1	2	1	1	0	4
PN7	Stoney Run 2	6	4	0	0	10
PN8	Stoney Run 3	0	6	8	1	15
PN9	Stoney Run 4	5	6	2	1	14
PNA	Deep Run	0	1	4	1	6
PNB	Piney Run	16	8	6	0	30
PNC	Deep Run	22	12	9	6	49
Total		**54**	**48**	**31**	**9**	**142**
Percent of Total		**38%**	**34%**	**22%**	**6%**	

4.2 SUBWATERSHED RESTORATION ASSESSMENT AND RATING

The County uses a subwatershed restoration assessment to identify and rate areas where conditions warrant restoration activities. This section presents the methods and results for the subwatershed restoration assessment.

4.2.1 METHODS

Similar to the stream restoration assessment, the restoration assessment uses a collection of restoration indicators to assign a rating to a subwatershed. The indicators are weighted and combined into a single restoration rating for each subwatershed. Restoration indicators fall into one of six categories: stream ecology, TMDL impairments, OSDSs, BMPs, H&H, Water Quality, and Landscape. Each category contains one to four different indicators. Table 4-3 provides a summary of the categories, indicators, and relative weighting assigned by the County.

TABLE 4-3: SUBWATERSHED PRIORITY RATING INDICATORS FOR RESTORATION

Category	Indicator	Weight
Stream Ecology	Final habitat score	8.1%
	Bioassessment score	8.1%
303(d) List	Number of TMDL impairments	8.1%
OSDSs	Nitrogen Loads from septics (lbs)	2.0%

BMPs	Impervious area treated by BMPs (%)	6.4%
H&H (Land and Soils only)	Peak flow from 1-year storm event (cfs/acre)	4.4%
	Peak flow from 2-year storm event (cfs/acre)	4.4%
	Runoff volume from 1-year storm event (inches/acre)	5.6%
	Runoff volume from 2-year storm event (inches/acre)	5.6%
Water Quality (land only)	Nitrogen load from runoff (lbs/acre/yr)	6.7%
	Phosphorus load from runoff (lbs/acre/yr)	6.7%
	Total Suspended Solids from runoff (Tons/acre/yr)	0.0%
Landscape	Impervious cover (%)	9.3%
	Forest within the 100 ft stream buffer (%)	10.1%
	% of existing wetlands to potential wetlands	9.3%
	Acres of developable critical area	5.2%

Each of the indicators provided in Table 4-3 provide key insight into the need for restoration in a subwatershed. The stream ecology indicators, final habitat score and bioassessment score, provide information on the physical and biological quality of the stream reaches in the subwatershed. OSDS and water quality indicators provide information potential water quality degradation based on the relative magnitude of total nitrogen loading from septics and total nitrogen and total phosphorus loading from runoff. Runoff volumes and peak flows are indicators of hydrologic changes caused by increased development and urbanization. BMP and Landscape indicators, impervious area treated by a BMP, impervious cover, and forested cover influence storm water volumes, peak flows and pollutant loadings. Also in the landscape category, the indicators which relate to wetlands and development of Critical Area provide insight into restoration potential.

4.2.2 Results

The 12 subwatersheds in the Patapsco Non-Tidal watershed were assessed by the County to identify restoration needs. A summary of the ratings results is presented in Table 4-4 and on Map 4.2. The final ratings range from “Lowest Priority for Restoration” to “Highest Priority for Restoration” where “Lowest Priority” indicates that a subwatershed is a low priority for restoration and therefore in good condition whereas “Highest Priority” indicates that a subwatershed should be a priority for restoration. The intermediate values “Yellow” and “Orange” fall in between the lowest and highest priority rankings with “Yellow” being a lower priority for restoration than “Orange”. The Patapsco Mainstem Watershed (PN1) was rated the highest priority for restoration. Four watersheds, PN5, PNA, PN7, and PNC were rated the lowest priorities for restoration.

Table 4-4: Subwatershed Priority Rating for Restoration

Subwatershed Code	Subwatershed Name	Restoration Rating
PN1	Patapsco Mainstem	Highest Priority for Restoration
PN3	Patapsco Mainstem	Orange
PN8	Stoney Run 3	Orange
PN4	Unnamed Tributary	Orange

PN9	Stoney Run 4	Orange
PN2	Holly Creek	Yellow
PNB	Piney Run	Yellow
PN6	Stoney Run 1	Yellow
PN5	Patapsco Mainstem	Yellow
PNA	Deep Run	Lowest Priority for Restoration
PN7	Stoney Run 2	Lowest Priority for Restoration
PNC	Deep Run	Lowest Priority for Restoration

4.3 Subwatershed Preservation Assessment and Rating

The County uses a subwatershed preservation assessment to identify and rate areas where conditions warrant preservation activities. This section presents the methods and results for the subwatershed preservation assessment.

4.3.1 Methods

The subwatershed preservation assessment uses a collection of preservation indicators to assign a rating to a subwatershed. The indicators are weighted and combined into a single preservation rating for each subwatershed. Preservation indicators fall into one of five categories: stream ecology, future departure of water quality conditions, soils, landscape, and aquatic living resources. Each category contains one to eight different indicators. Table 4-5 provides a summary of the categories, indicators, and relative weighting assigned by the County.

TABLE 4-5: SUBWATERSHED PRIORITY RATING INDICATORS FOR PRESERVATION

Category	Indicator	Weight
Stream Ecology	Final Habitat Score	7.4%
	Bioassessment Score	7.4%
Future Departure of Water Quality Conditions	Percent Future Departure of Total Nitrogen	11.1%
	Percent Future Departure of Total Phosphorous	11.1%
Soils	NRCS Erodibility Factor	7.4%
Landscape	Percent Forest Cover	11.1%
	Percent Wetland Cover	11.1%
	Density of Headwater Streams in feet/Acre	7.4%
	Percent of Land within the Greenway Master Plan	3.7%
	Presence of Bog Wetlands	3.7%
	Acres of RCA Lands within the Critical Area	3.7%
	Percent of Protected Lands	3.7%
	Presence of Wellhead Protection Areas	3.7%
Aquatic Living Resources	Presence of Trout Spawning, Anadromous Spawning, and SSPRA	7.4%

4.3.2 RESULTS

The final ratings range from "Lowest Priority for Preservation" to "Highest Priority for Preservation" where "Lowest Priority" indicates that a subwatershed is a low priority for preservation whereas "Highest Priority" indicates that a subwatershed is in good condition and should be a priority for preservation. The intermediate values "Yellow" and "Orange" fall in between the lowest and highest priority rankings with "Yellow" being a lower priority for preservation than "Orange". The Deep Run Watershed (PNA) and Patapsco Mainstem (PN5) were rated the highest priority for preservation. Two watersheds, Stoney Run 3 (PN8) and Patapsco Mainstem (PN1) were rated the lowest priorities for preservation. A summary of the distribution of ratings among the 12 subwatersheds is provided in Table 4-6. Map 4.3 depicts the subwatershed preservation assessment results.

TABLE 4-6: SUBWATERSHED PRIORITY RATING FOR PRESERVATION

Subwatershed Code	Subwatershed Name	Preservation Rating
PNA	Deep Run	Highest Priority for Preservation
PN5	Patapsco Mainstem	Highest Priority for Preservation
PN6	Stoney Run 1	Orange
PN7	Stoney Run 2	Orange
PNC	Deep Run	Orange
PNB	Piney Run	Orange
PN9	Stoney Run 4	Yellow
PN4	Unnamed Tributary	Yellow
PN3	Patapsco Mainstem	Yellow
PN2	Holly Creek	Yellow
PN8	Stoney Run 3	Lowest Priority for Preservation
PN1	Patapsco Mainstem	Lowest Priority for Preservation

Given that land management decisions most often occur on a smaller scale than these results allow for, the County recognized that finer resolution of the preservation assessment results would be required. Therefore, the County completed the same preservation assessment on a parcel level. This analysis allowed for the assignment of preservation ratings to each parcel in the Patapsco Non-Tidal watershed as shown in Map 4.4. A list of the top 100 parcels for preservation is provided in Appendix F.

5 Restoration and Preservation Implementation Plan

Previous sections of this report detail the Patapsco Non-Tidal watershed's water resources and land use characteristics and the extensive field work and water quality/quantity modeling work that was conducted to identify subwatersheds and reaches for restoration and preservation. This section of the report presents the various restoration approaches that are under consideration for the watershed, the subwatersheds and locations where those approaches are proposed, the estimated pollutant reduction, and the associated costs.

The outcome is a plan that addresses stream condition and watershed health to meet the various restoration and management challenges facing the County. The selection of preferred restoration approaches is based on efficient use of County resources using a cost-benefit analysis. The plan includes potential sites identified throughout the watershed in each of the restoration type categories and goes further to include detailed conceptual design plans for a representative sampling of projects.

5.1 Watershed Goals

The goals of the management plan follow from the regulatory and planning context provided in Chapter 1 that set the planning parameters within which the plan was developed. The plan is designed to move the County forward towards fulfilling each of the associated major regulatory requirements; namely the NPDES MS4 fourth generation permit (currently in draft form) and the Chesapeake Bay TMDL. The MS4 permit, by its nature, applies to the non-point source runoff from the County's developed or urban lands. The scope of the Bay TMDL is much wider and includes all source sectors including agricultural land uses.

The focus of this study is on developing solutions and strategies for addressing the non-point source urban, non-agricultural sources. As such, the current pollutant loads, existing treatment, and proposed treatment activities are derived from only those associated with urban development and sources. Urban lands, as defined in this plan, include lands coded as industrial, transportation, commercial, residential (all densities), utility, open space, airport, and residential woods. Lands not included as urban are those coded as pasture/hay, row crops, woods, water, and wetland.

5.1.1 Chesapeake Bay TMDL

Progress towards meeting the Bay TMDL will be based on reduction of total nitrogen (TN), total phosphorus (TP) and total suspended solids (TSS); therefore the priority pollutants addressed by this plan are TN, TP and TSS. The Bay TMDL allocations are currently being developed at the County scale, for each sector – urban, agricultural, concentrated animal feeding operations (CAFO), Septic, Forest, Air, wastewater treatment plants (WWTP) and combined sewer overflows (CSO). This plan addresses the urban portion and makes basic recommendations for the septic sector for system upgrades for those located outside of the sewer service area. A more detailed septic retrofit plan is under development by the Anne Arundel County Bureau of Utilities.

5.1.2 NPDES MS4 Permit

The forthcoming NPDES MS4 permit renewal is anticipated to require the planning and restoration of 20 percent of the County's untreated impervious surface in the next 5-year permit term. The tally of impervious surfaces currently managed by stormwater BMPs is updated with the completion of each watershed study. To date, seven of the County's 12 major watersheds have updated BMP information.

For the remaining five watersheds, the level of treatment is assumed to be 30 percent of the impervious area. Based on the 2010 NPDES Annual Report (Anne Arundel County 2011), the entire County is 17 percent impervious with an estimated impervious treatment level of 39 percent. The Patapsco Non-Tidal represents approximately six percent of the County's total land area, but at 27 percent impervious, contributes a disproportionate amount of impervious area at just over nine percent of the County total.

According to the 2010 NPDES Annual Report, after accounting for treated areas, non-jurisdictional areas, management provided by CIP restoration projects, and rooftop disconnects, there are 101 acres of County uncontrolled impervious in the Patapsco Non-Tidal watershed. The total of the currently untreated County impervious addressed by full implementation of this plan has not been calculated. However a summation of the impervious area in the contributory drainage area to each project identified in this plan yields a total impervious acreage of 7,740. This total represents a gross overestimation of the total level of additional treatment however it does provide some level of assurance that the 101 acre would be satisfied. The total drainage area overestimates due to the following factors; it includes areas already receiving treatment, it includes areas of non-County imperviousness, for several restoration practices such as stream restoration and wet pond retrofits full credit will not likely be given for the entire impervious area in the contributory drainage. The County's NPDES compliance program will continue to track implementation and progress towards meeting the NPDES permit requirements.

5.1.3 Biological Nutrient Target

Additionally the County is deriving a nutrient target goal based on the relationship between instream biological and pollutant loading (Flores, 2011). Following analysis of the County's comprehensive biological monitoring data and the relationship with nutrient loading (TN and TP), the County has proposed to set a stormwater target load at a level that corresponds with a "Fair" biological condition, using the Benthic Index of Biotic Integrity (BIBI). A Total Nitrogen load from stormwater sources ranging from 3 lbs/acre to 3.5 lbs/acre and a Total Phosphorous load ranging from 0.37 lbs/acre to 0.43 lbs/acre may result in achieving "Fair" biological conditions in non-tidal streams. Achieving the "fair" condition will of course be reliant on other confounding stressors such as quality and availability of adequate instream habitat and control of other water quality stressors; however by setting the stormwater target loads below the values correlated with the "Fair" condition, the County can utilize its ongoing comprehensive biological monitoring program to track implementation success.

5.1.4 Scenario Results

Numeric goals have been set by running several management scenario model runs and tabulating the results under certain assumptions. The goals are derived to satisfy the planning estimates prepared for the County's development of the Phase II Watershed Implementation Plan (WIP) for the Bay TMDL. Although the Bay TMDL allocations are not developed at the scale of the Pataspco Non-Tidal, the values have been extracted for the Patapsco Non-Tidal watershed and are presented in Table 5-1. The first scenario (1) presented is the load for each of the three priority pollutants for the entire Patapsco Non-Tidal Watershed under the assumption that no existing stormwater management is in place (i.e. without SWM credit). An extraction of the public and private urban land for which the County is responsible, within the context of the Bay TMDL and Phase II WIP, is provided on line 2 – again without accounting for existing stormwater management.

TABLE 5-1: NPS URBAN RETROFIT SCENARIOS AND GOALS FOR PATAPSCO NON-TIDAL

	Stormwater Pollutant Sector	TN (lbs/year)	TP (lbs/year)	TSS (Tons/year)
1	Watershed Total Load - current condition without existing SWM credit	72,183	7,500	1,107
2	County Urban Lands Load – current condition, public & private without existing SWM credit	52,971	5,234	761
3	Full Plan Implementation Load *Reduction* - current condition county urban lands without existing SWM credits	39,019	7,349	1,169
4	Full Plan Implementation Load – current condition county urban lands without existing SWM credits (line 2 minus line 3)	13,952	-2,115	-408
5	Chesapeake Bay TMDL Load Goal (assumed 36% reduction applied to line 2)	33,901	3350	487
6	Nitrogen Load Equivalent to BIBI = Fair Conditions	20,805	2,566	533
7	County Nutrient Trading Potential (line 4 minus line 5)	-19,950	-5,465	-895

County urban lands can further be broken down by the contribution from public and private lands. Private lands make up 5,965 acres or 86 percent of the total 6,935 urban acres, while public lands account for 14 percent at 970 acres. The contribution of TN, TP and TSS from the private and public land sources is approximately 80 percent and 20 percent respectively, a 4 to 1 ratio. Assuming a full implementation of the plan as drafted (lines 3 and 4 in Table (5-1) indicates a net negative TN, TP and TSS load when compared to the load requirement under the Chesapeake Bay TMDL (which has been assumed at a 36% reduction as a surrogate until final allocations are developed), which could be available to the County for credit trading.

Line 6 represents the biological nutrient target for TN and TP using an annual 3.0 lbs/acre loading rate for TN and a 0.37 lbs/acre loading rate for TP applied to the total 6,935 acres of urban area in the Patapsco Non-Tidal watershed. As with the comparison above to the Bay TMDL full plan implementation would achieve the target biological nutrient target also with a net surplus of reduced pollutant. Surpluses calculated against the biological target are TN=-6,853, TP=-4,681, and TSS=-941.

5.2 Development of Potential Restoration Activities

Strategies included in this plan, and those that will ultimately be selected for implementation, are selected based on their ability to manage and treat stormwater, improve instream and riparian habitat conditions, and restore functionality of the County's natural resources. In addition the restoration activity must be cost effective relative to the area treated, or in this case, the quantity of pollutant removed. In addition to performance, other considerations include maintenance, life expectancy, and public acceptance of the proposed measure.

The County has therefore selected the following activities for inclusion in this plan. These activities have been implemented successfully by the County in other watershed restoration efforts and it is expected that they will translate very well to the conditions encountered in the Patapsco Non-Tidal watershed.

Additionally, the County has selected several 'Core Strategies' that are given high priority in the County's Phase II WIP and are vital components on meeting the goals of the Chesapeake Bay TMDL. The Core Strategies include: Dry and Wet Pond Retrofits, Stream Restoration, and Stormwater Outfall Retrofit. Core and supplemental strategy descriptions are provided here and in graphically on mapping in Appendix I.

- Dry Pond Retrofits – Dry pond retrofits add water quality treatment to ponds that were originally designed for water quantity treatment. Conversion of dry ponds to shallow wetland marsh, regenerative step pool storm conveyance, or constructed wetland systems typically increase permanent pool volumes, extend flow path and detention times and add vegetative nutrient uptake potential. A total of 18 dry pond retrofits including public and private are proposed for extended detention facilities with design plans approved before 2002, a cutoff selected based on the implementation of MDE water quality treatment criteria. All dry ponds approved before 2002 were selected regardless of subwatershed or stream condition, however those factors could be use to prioritize implementation.

- Wet Pond Retrofits – This retrofit activity is proposed for both private and public wet ponds and involves conversion of wet ponds, which although provide better treatment than dry ponds, are suboptimal to shallow marsh, regenerative step pool storm conveyance and constructed wetlands in terms of TN, TP and TSS removal. Some wet facilities could also be candidates for other treatments such as floating wetlands, or wetland seepage systems, however these applications have not been included in the analysis of potential reduction. A total of 27 wet pond retrofits are proposed in the plan, 13 private and 14 public. As with dry ponds, all wet ponds approved before 2002 were selected.

- Stream Restoration – This restoration approach includes a combined total of 9 stream miles deemed 'degraded' and 'severely degraded' based on the physical habitat assessment. With the priority on pollutant removal and halting channel erosion and downcutting, approaches that provide water quality treatment through floodplain connection and extension of residence time will be considered in the appropriate settings. These measures include installation of low head rock weirs for grade control and floodplain connection, sand seepage berms for additional nutrient filtration, wetland creation, oxbow ponds, bio-engineering, and riparian stream plantings. Calculations of treatment have been calculated based on a conversion to a regenerative wetland seepage system.

- Retrofit of Stormwater Outfalls – As of November 2010, there are a total of 5,206 closed-stormdrain outfalls in the County. In the Patapsco Non-Tidal watershed a combined total of 443 outfalls could be further investigated for retrofit potential using step pool storm conveyance (SPSC) treatment. The SPSC is designed to stabilize outfalls and provide water quality treatment through pool, subsurface flow, and vegetative uptake. The retrofits promote infiltration and reduce stormwater velocities. The initial identification of potential outfalls is based on a selection of major outfalls (diameter of 18 inches or larger for commercial and industrial areas and 36 inches for all other areas) within subwatersheds ranking in the 1st and 2nd quartile in the subwatershed restoration prioritization. Additionally outfalls found to be in disrepair during routine dry weather illicit discharge inspections were automatically selected. A total of 72 outfalls have been preliminarily selected. A cross-reference against the conditions observed during the inventory of infrastructure and environmental features would aid in the prioritization of outfalls for consideration and additional field investigation would be necessary to verify site conditions and constraints.

- Street Sweeping – This treatment activity captures roadway pollutants before they fully enter the stormwater system and receiving waters. In recent years the County has swept main thoroughfares, business districts and industrial areas four times per year. Total closed section, or curbed, roadway in the County is approximately 921 miles according to the County DPW's Road Inventory and Road Condition Database. Yearly totals of curb-miles/month swept fluctuated greatly between 2009 and 2010 from 140 curb-miles/month to 64 curb-miles/month (Anne Arundel County, 2011) respectively. A proposed 74 miles per month, or 148 curb-miles on curbed County roads in the Patapsco Non-Tidal watershed alone represents a major increase in the level of treatment.

- Inlet cleaning - is proposed at 1,399 inlets conducted semi-annually. This represents between six and nine percent of the County's overall inlet cleaning program depending on the year of comparison (2009 and 2010 data was readily available from Anne Arundel County, 2011).

- Septic System Upgrades – Subsurface nitrogen loading from septic systems will be treated by proposed septic system upgrades for systems outside of the Sewer Service area to Enhanced Nitrogen Removal Systems (ENR). Excluded from this plan is the septic retrofit plan currently in development by the County's Bureau of Utilities Division. The retrofit plan may include other approaches such as sewer extension/connection and community cluster systems and builds on the findings of the County's Onsite Sewage Disposal System (OSDS) Evaluation Study and Strategic Plan (Anne Arundel County, 2008).

- Environmental Site Design Retrofit – This proposed restoration activity focuses on retrofitting existing County facilities (County Board of Education and Dept. of Recreation and Parks properties) using environmental site design techniques, such as bioretention and permeable pavement. These techniques treat stormwater closer using smaller controls to capture and treat runoff.

These activities are listed also in Table 5-4 with the estimated quantity (stream miles, sites, projects etc.) and the associated drainage area, pollutant reduction and cost.

5.3 COST-BENEFIT ANALYSES OF RESTORATION SCENARIOS

To adequately define the level of County resources necessary to implement the plan, and to prioritize treatment types, cost benefit analyses were developed for the restoration strategies included in the plan. The results highlight the relative effectiveness of each restoration type and allow planners a useful tool in implementing the plan and setting priorities. In addition the results indicate, at a planning level, the total magnitude of resources necessary to meet the goals of the plan.

5.3.1 METHODS

The methods used derive cost for each treatment type are detailed in a March 11, 2011 County technical memorandum that documents the methods and procedures used for estimating the preliminary unit cost of various WIP Phase II urban restoration strategies. The methods are summarized here and in Table 5-2 for brevity. The development of cost is based on a combination of data and varies by restoration type. The goal is to derive an average unit cost that would apply to most implementation situations. Municipalities across the mid-Atlantic region can have varying design and construction standards in terms of the level of detail, the permits and review agencies required, the type of construction materials allowed for, the type of contracting mechanisms in place, and the type of bidding procedures. All of which can affect a project's cost. With these factors in mind, and because Anne Arundel County has implemented all of these types of projects recently, the use of Anne Arundel County specific recent historical information was determined to be the most effective tool to derive costs. Data were compiled for each activity and normalized by units such as acres treated or linear feet, whichever measure was best in determining the scaling factor for the type of project. The resulting average unit cost is them applied to the proposed projects to develop a planning level cost estimate.

It should be noted that activities involving an ongoing program, such as street sweeping and inlet cleaning do include County operations costs; however the costs for the remaining restoration activities represent only the upfront capital expenditure (survey, design, permitting, construction, easements), and generally do not include internal County operations and program/project management costs, and do not include system maintenance or monitoring.

Many ESD retrofits, such as the Brooklyn Park Green Alleyways concept plan, can be incorporated into regular on-going maintenance, upgrade, and replacement schedules to reduce the overall capital expenditure. The unit cost used for this plan (approx $91, 000 per impervious acre treated) assumes that the retrofit is completed outside of any scheduled activity; however an alternative method is to use the marginal cost of the green infrastructure upgrade which in this case would be $43,000 per impervious acre treated. In this manner the ESD retrofits would become a relatively more efficient solution. More data is needed to further inform the true cost of ESD retrofits for future plans.

TABLE 5-2: UNIT COSTS FOR EACH RESTORATION TYPE

Restoration Type	Cost Derivation and Assumptions
	Core Strategies
Dry and Wet Pond Retrofits	\$8,987 per acre treated – Derived from historic County data converting dry ponds to shallow marsh; includes upfront capital expenditure
Stream Restoration	\$8,104 per acre treated – Derived from historic County data; includes upfront capital expenditure
Stormwater Outfall Retrofit	\$16,160 per acre treated – Derived from historic County data; includes upfront capital expenditure
	Supplemental Strategies
Street Sweeping	\$20.42 per mile treated – Derived from historic County data; includes equipment, operations, and maintenance costs
Inlet Cleaning	\$200 per inlet cleaned – Derived from historic County data; includes equipment, operations; cost is expanded to cover 30 years of implementation
Septic System Upgrades	\$13,000 per system upgrade – Derived from historic County data (Anne Arundel County, 2008); includes upfront capital expenditure
ESD Retrofit	\$120,000 per impervious acre treated – Derived from the Brooklyn Park Green Alleyways concept plan utilizing porous pavement, permeable pavers, and bioretention; includes upfront capital expenditures and adds a 30% contingency ; an alternative cost of \$43,000 could also be used based on marginal cost

Removal efficiencies used for the three priority pollutants, TN, TP and TSS are listed in table 5-3 below. The dry and wet pond retrofits include the gain in removal percentage between the current condition, dry and wet ponds, to the optimal restored condition.

TABLE 5-3: REMOVAL EFFICIENCIES

Restoration Type	TN	TP	TSS
Dry Pond Retrofit Restored Condition (SPSC, Shallow Marsh, Constructed Wetland)	40%	60%	85%
(increase from current to restored condition[1])	35%	50%	75%
Wet Pond Retrofit Restored Condition (SPSC, Shallow Marsh, Constructed Wetland)	40%	60%	85%
(increase from current to restored condition[1])	20%	15%	25%
Stream Restoration	40%	60%	60%

Restoration Type	TN	TP	TSS
Stormwater Outfall Retrofit	40%	60%	85%
Street Sweeping	4%	4%	22%
Inlet Cleaning	2%	6%	35%
Septic System Upgrades	50%	0%	0%
ESD Retrofit	50%	70%	90%

[1] These rows represent the difference in removal efficiency between the current condition and the ultimate restored condition.

5.3.2 Results and Discussion

The costs and pollutant removal in lbs/year were tabulated for each treatment type and for the full implementation of the plan. Refer to Table 5-4 for the summarized results. Figure 5-1 demonstrates the total cost per treatment type and the nitrogen reduction rate for each restoration activity.

To characterize and compare the treatment capability based on cost, calculated costs per treatment type are combined with the pollutant reduction benefit to derive cost-benefit value using cost (dollars) per pound of TN removed per year and TP removed per year (Table 5-4). These values are compared to determine the most cost-effective measures. Figure 5-2 provides a graphical representation with the treatment types roughly ordered in terms of increasing cost per lb of TN removed. TN was selected as the measure of comparison as each treatment type has some effectiveness in treating nitrogen, while TP and TSS are not controlled by each type.

The results indicate that for TN, street sweeping and septic system upgrades are potentially the most cost-effective solution at $706 and $891 per pound of TN removed respectively. It should also be noted that street sweeping was by far the most cost effective measure for reducing phosphorus loading at $5,799 per pound and sediment loading as well at approximately $11,000 per ton.

Other highly effective measures include stream restoration, outfall retrofits, and inlet cleaning. The least cost-effective solutions based on this analysis were the ESD retrofits for public facilities at County schools and Recreation and Parks facilities. These results are based on a quite limited dataset and it is recommended that more data points be added to the analysis before a final determination is made of the cost effectiveness of these ESD and LID type solutions.

While useful as a tool for prioritizing and selecting project types, and even individual projects for implementation, the cost-effectiveness of removing these priority pollutants will not be the only criteria for project selection. Factors such as habitat improvement, community/neighborhood improvement and acceptability, infrastructure protection, public safety etc. are all factors in final project selection.

FIGURE 5-1: NITROGEN REDUCTION COSTS PER TREATMENT TYPE

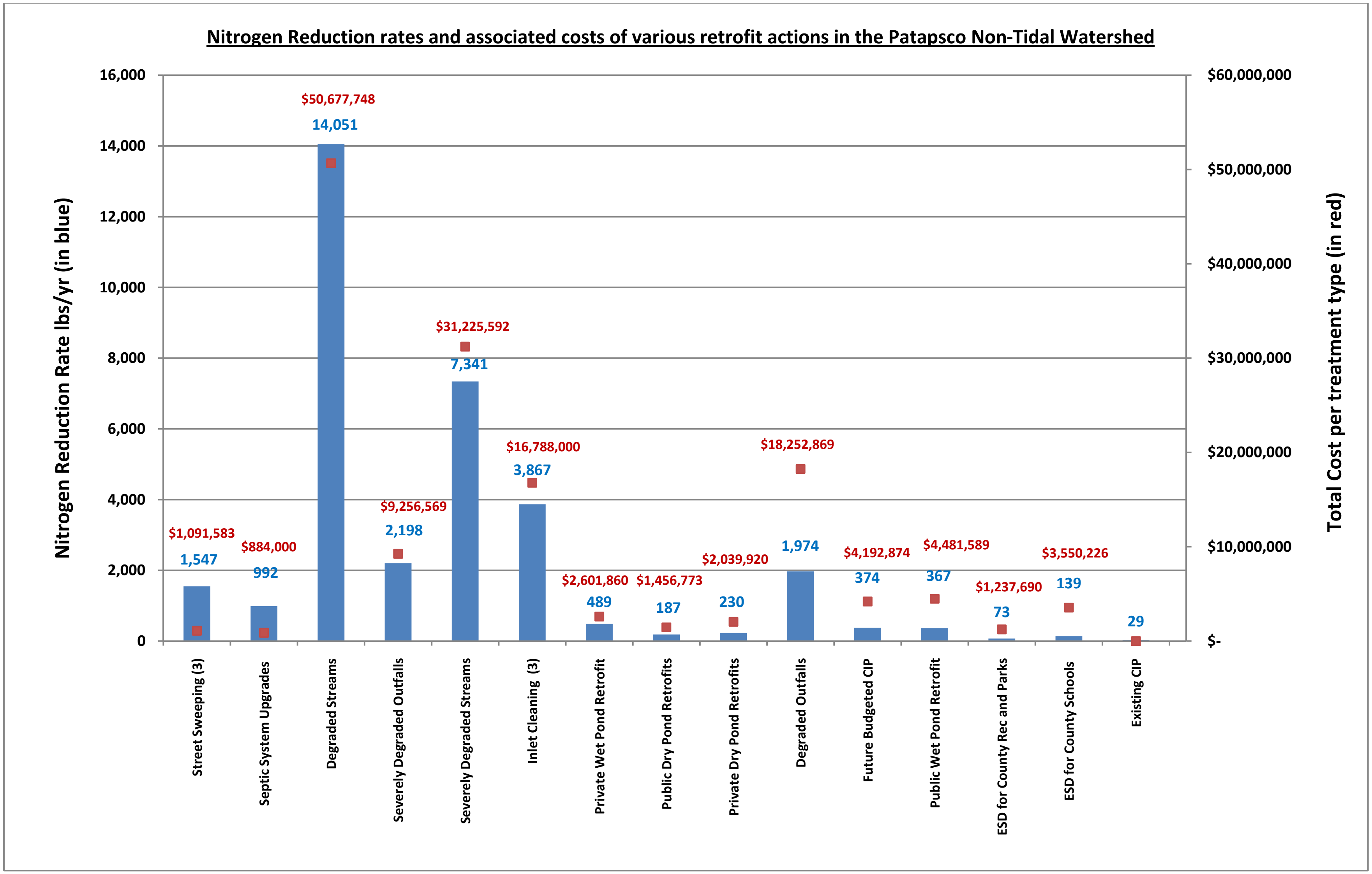


FIGURE 5-2: COST BENEFIT RATIO SUMMARY

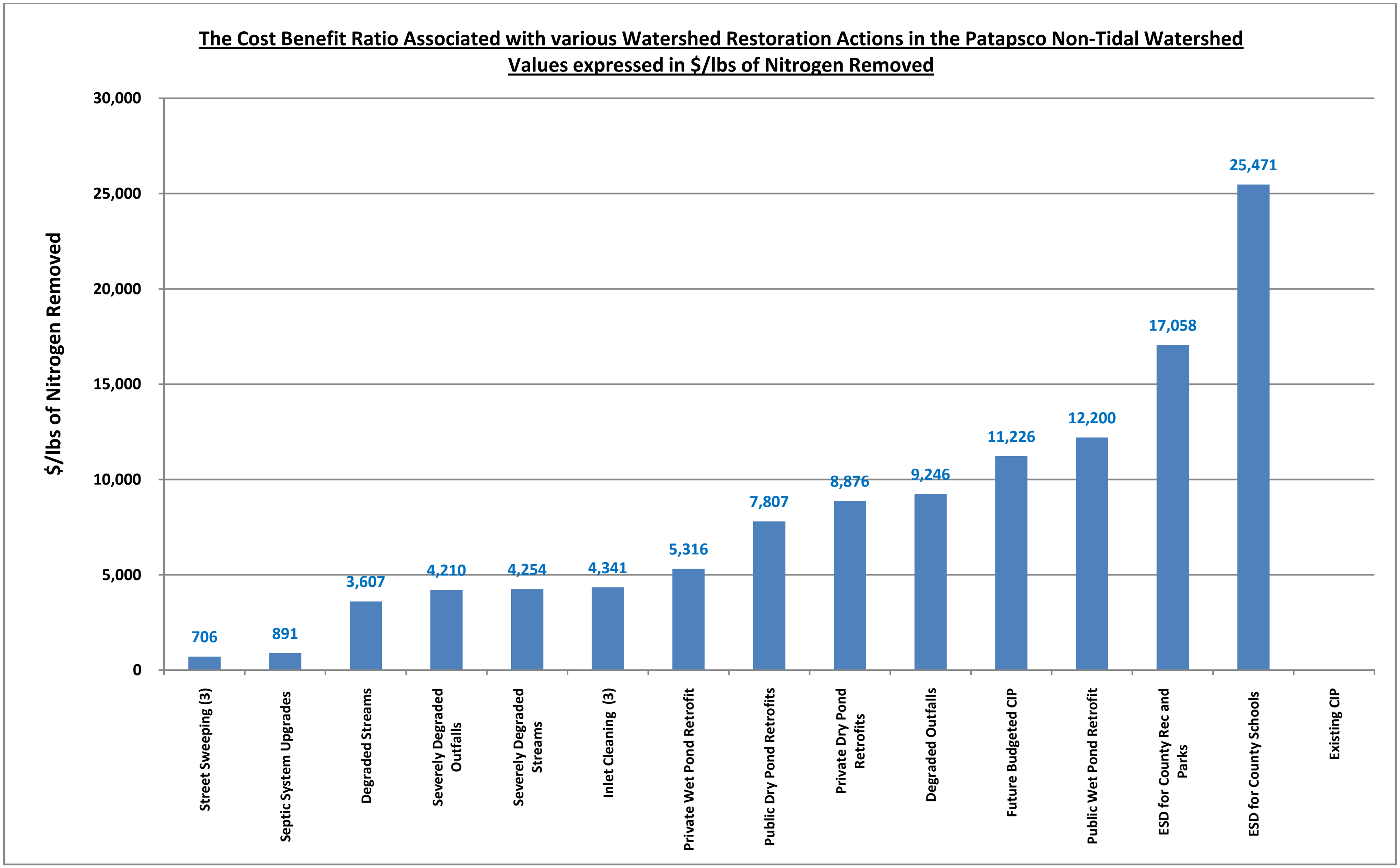


TABLE 5-4: PATAPSCO NON-TIDAL WIP SUMMARY OF STRATEGIES

Retrofit Type	Quantity	Units	Description	Total Drainage (acres)	Impervious Acres Retrofit at limit of technology	Pollutant Reduction			Preliminary Cost ($)	TN Cost ($)/lb	TP Cost ($)/lb
						TN lbs/yr	TP lbs/yr	TSS tons/yr			
Street Sweeping[3]	148[2]	Miles	Monthly Street Sweeping of Curbed County Roads	440	355	1,547	188	97	$1,091,583	**706**	**5,799**
Inlet Cleaning	1,399	Inlets	Cleaning of curb opening inlets semi-annually	3,204	1,421	3,867	94	247	$16,788,000	**4,341**	**178,357**
Private Wet Pond Retrofit	13	# of Ponds	Retrofit of all extended detention public ponds approved prior to 2002.	290	178	489	60	11	$2,601,860	**5,316**	**43,556**
Public Wet Pond Retrofit	14	# of Ponds	Retrofit of all extended detention public ponds approved prior to 2002.	499	218	367	84	12	$4,481,589	**12,200**	**53,341**
Septic System Upgrades	68	Septic Systems	Conversion of Septic Systems outside the Sewer Service Area (OSDS BIN=3) to Enhanced Nitrogen Removal Systems	N/A	N/A	992	N/A	N/A	$884,000	**891**	**N/A**
Degraded Streams	5	Miles	Retrofit of **degraded** channels based on physical habitat assessment	6,253	1,943	14,051	2,791	291	$50,677,748	**3,607**	**18,160**

Retrofit Type	Quantity	Units	Description	Total Drainage (acres)	Impervious Acres Retrofit at limit of technology	Pollutant Reduction			Preliminary Cost ($)	TN Cost ($)/lb	TP Cost ($)/lb
						TN lbs/yr	TP lbs/yr	TSS tons/yr			
Severely Degraded Streams	4	Miles	Retrofit of **severely degraded** channels based on physical habitat assessment	3,853	1,043	7,341	1,712	166	$31,225,592	**4,254**	**18,237**
Severely Degraded Outfalls	10	# of Outfalls	Retrofit of outfalls within the **1st quartile** subwatersheds ranked for restoration using filtering BMP (SPSC system).	573	272	2,198	431	49	$9,256,569	**4,210**	**21,459**
Degraded Outfalls	62	# of Outfalls	Retrofit of outfalls within the **2nd quartile** subwatersheds ranked for restoration using filtering BMP (SPSC system).	1,130	488	1,974	688	103	$18,252,869	**9,246**	**26,541**
Public Dry Pond Retrofits	9	# of Ponds	Retrofit of all extended detention public ponds approved prior to 2002.	162	60	187	73	12	$1,456,773	**7,807**	**19,999**
Private Dry Pond Retrofits	9	# of Ponds	Retrofit of all extended detention private ponds approved prior to 2002.	227	61	230	79	12	$2,039,920	**8,876**	**25,899**

Retrofit Type	Quantity	Units	Description	Total Drainage (acres)	Impervious Acres Retrofit at limit of technology	Pollutant Reduction TN lbs/yr	TP lbs/yr	TSS tons/yr	Preliminary Cost ($)	TN Cost ($)/lb	TP Cost ($)/lb
Future Budgeted CIP	7	Projects	This scenario quantifies the benefits of implementing future CIP restorations with approved budget	256	100	374	155	16	$4,192,874	**11,226**	**27,060**
ESD for County Schools	7	Schools	Pervious pavement and bioretention	93	30	139	50	5	$3,550,226	**25,471**	**70,365**
ESD for County Rec and Parks	23	Facilities	Pervious pavement and bioretention	57	10	73	18	2	$1,237,690	**17,058**	**69,361**
Existing CIP	2	Projects	This scenario quantifies the benefit for CIP restorations performed since 2002 and up to 2009	75	32	29	19	2	Completed /Expended	**N/A**	**N/A**
Existing County Public BMPs	70	BMPs	Maintenance and Retrofit of existing BMPs	849	255	2,023	397	80	N/A	**N/A**	**N/A**
Existing County Private BMPs	512	BMPs	Maintenance and Retrofit of existing BMPs	2,749	825	4,685	698	163	N/A	**N/A**	**N/A**
Total				**11,095**(1)	**3,471**(1)	**39,019**	**7,349**	**1,169**	**$146,645,709**	**N/A**	

(1) Totals for land and impervious acres do not reflect the total sum due to overlapping treatment areas for the various strategies.

(2) Street Sweeping mileage was multiplied by 2 to account for both directions.

(3) Street Sweeping assumes an annual cost multiplied by a 30 year planning horizon.

5.4 Recommendations

Plan recommendations are organized in two parts. The first is general recommended strategies based on the cost benefit analysis and the results of the plan. The second is the selection of potential retrofit sites for conceptual design, and completion of conceptual designs from a cross-section of project types.

5.4.1 Recommended Activities

Begin implementation of the plan based on forthcoming Chesapeake Bay TMDL load allocations and impervious surface treatment targets; while not losing site of public safety, protection of infrastructure and the protection and enhancement of local habitat functionality. Projects when possible should be targeted in the highest priority subwatersheds (PN1, PN3, PN8, PN4 and PN9) and the highest priority reaches. Mapping of identified projects is included in Appendix I. A list of projects organized by type is also included in Appendix G (Table G.1) for dry and wet pond retrofits, outfall retrofit, degraded streams, and ESD/LID retrofits.

Enhancements to the current street sweeping and inlet cleaning programs are recommended based on the cost-benefit analysis and the known effectiveness of these maintenance activities. Because the County currently has programs in place, the resources to enhance the programs could be easier to obtain and general implementation could be easier than adopting new techniques and technologies. Street sweeping has been preliminarily recommended in the following subwatersheds (Table 5-5).

TABLE 5-5: STREET SWEEPING AND INLET CLEANING SUMMARY

Subwatershed	Street Sweeping Miles treated	Inlets Cleaning, Number of Inlets	Inlet Cleaning, Drainage Area treated (acres)
PN1	31.4	569	1315.5
PN2	11.3	155	552.3
PN4	23.5	458	1053.8
PN6	8.1	217	283.0
Total	**74.3**	**1399**	**3204.6**

Continue to plan and implement upgrades to septic systems based on the OSDS recommendations (Anne Arundel County, 2008) and the forthcoming Bureau of Utilities Plan. The septic retrofits in this plan are summarized in table 5-6.

TABLE 5-6: SEPTIC SYSTEM UPGRADES SUMMARY

Subwatershed	Number of Systems	Existing TN Load (lbs/yr)	Reduction in TN (lbs/yr)
PN1	2	39.5	19.8
PN4	1	126.7	63.4
PN5	38	1283.1	641.6
PN6	5	128.6	64.3
PN8	9	178.0	89.0
PNA	13	227.4	113.7
Total	**68**	**1983.3**	**991.6**

Wet pond retrofits should be investigated further to ensure that their inclusion will be acceptable treatment according to MDE and the EPA. Conduct pilot implementation study including water quality analysis to verify pollutant removal estimates.

Continue the implementation of SPSC at degraded outfalls. Sites can be prioritized through a cross-reference with the environmental features inventory to determine the best candidates. The highest priority sites will not only have high pollutant loads, but will also be outfalls that are compromised structurally with undermining, failing end sections, headcuts, and channel erosion present.

Continue to monitor the effectiveness of implemented projects, in terms of the pollutant reduction, habitat improvement, and changes in biological condition. Particularly newer technologies and solutions such as floating wetlands, SPSCs, LID/ESD, and stream restoration. Additionally a full analysis of costs associated with projects – including capital expenditures, internal program management, monitoring and maintenance will be invaluable information for future planning.

Identify strategies, funding opportunities, and partnerships with organizations and programs for preserving lands in the highest priority subwatersheds (PNA, PN5, PN6, PN7, PNC and PNB) beginning with those parcels identified through this plan and listed in Appendix F. Organizations and programs include: Maryland Environmental Trust (MET), the Maryland Land Trust Alliance, the North County Land Trust, Program Open Space (POS), Maryland Agricultural Land Preservation Foundation (MALPF), Rural Legacy Program, Maryland Green Print, and Maryland Historical Trust.

5.4.2 Development of Concept Plans

Potential restoration sites were identified by the County through a desktop inspection of the subwatershed and reach rankings coupled with the environmental and infrastructure inventory data. A listing of 23 potential sites were developed along with descriptions of the site and drainage area, the type of restoration activity proposed, and the potential project benefits. The 23 sites were ranked against one another based on the following factors: design construction, existing BMP treatment, property ownership, facility access, public outreach potential and whether or not the project was identified through a citizen complaint. Fact sheets for each of the 23 candidates are included in Appendix G. The project team met to review the sites and based on the rankings and identified a list of top candidates for field reconnaissance. Six sites were visited and field reviewed to determine project viability. A technical memorandum was developed to document the site conditions and team findings. Based on the field review and additional desktop analysis, four sites were ultimately selected for completion of detailed conceptual design plans. The remaining sites provide a backlog of candidate sites for further investigation and possible implementation.

The resulting concept plans are included in Appendix H. Details on the conceptual design process and the cost estimation procedure are included in the introduction to Appendix H. Summaries of each concept are included here.

Concorde Circle Dry Pond Retrofit

An existing dry pond is currently the only stormwater management provided for the 60-acre drainage area with a mix of commercial and residential land cover. The pond drains to unnamed Patapsco River

Tributary PN4. Currently, there are 16 acres of impervious surface within the drainage area to the facility. A retrofit of this facility is proposed, to convert this dry pond to a shallow wetland. This will increase water quality treatment within the facility.

SHIPLEY ROAD STEP POOL STORM CONVEYANCE

An existing drainage channel connecting the Shipley Road cul de sac to a Patapsco River tributary is inadequate. The existing rip rap and gabion basket channel protection measures are failing, creating an incised channel and delivering sediment to downstream reaches. The project will retrofit the site with a step pool storm conveyance (SPSC) which will provide water quantity and quality management. The project is located in subwatershed PN4 and has a drainage area of 18 acres in a residential setting.

BROOKLYN PARK GREEN ALLEYWAYS

This project takes a community approach to the reduction of stormwater runoff and pollutant loading. It encompasses several green infrastructure techniques, including green alleys, porous pavement, and rain gardens (bioretention) within a neighborhood in Brooklyn Park. This neighborhood is within subwatershed PN1 and is bounded on the North by the City of Baltimore, on the West by the Patapsco River, on the East by Belle Grove Road, and on the south by Riverview Road. The green infrastructure measures presented here are chosen for a pilot project within the Brooklyn Park neighborhood; however these efforts could be expanded across the whole neighborhood and/or watershed. The concept evolved out of the Old Riverside Road candidate concept included in Appendix G.

SCIENCE DRIVE STREAM RESTORATION AND STEP POOL STORM CONVEYANCE

This project includes 950 linear feet of existing channel that is degraded and entrenched with several utility impacts. The channel has a forested buffer to the south with development encroaching upon the channel to the north. This project would include a 520-foot Step Pool Storm Conveyance (SPSC) in the upstream portion of the site and regrading and stabilization of the stream banks to allow access to the floodplain in the downstream 430-foot portion of the site. The existing buffer can be enhanced through the removal of invasive species and the establishment of native species. The concept evolved from the Amtrak Station Stream Restoration candidate concept included in Appendix G.

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