Magothy River Watershed Assessment

Comprehensive Study Summary Report

Prepared By:

Anne Arundel County
Department of Public Works
Bureau of Engineering
Watershed Ecosystem and Restoration Services Division
Watershed Assessment and Planning Program

In association with:
LimnoTech
Magothy River Association

May 2010

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Under:

NPDES Section II. F – Watershed Assessment and Planning

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EXECUTIVE SUMMARY

The Magothy River Watershed is one of twelve major watersheds in Anne Arundel County. Situated in the northeastern portion of the County, north of Annapolis and south of Baltimore, much of the watershed is suburban in character. Water-based recreational activities are very popular in the tidal portions of the Magothy River.

This report describes a comprehensive assessment of current conditions in the Magothy River Watershed. Data collection, data compilation, and modeling were used to rate and prioritize restoration and protection activities in the watershed. The watershed assessment, findings, and recommendations of this report will be used by Anne Arundel County to identify specific capital environmental restoration projects and to guide land use management planning and policy. The report was developed consistent with standard permit conditions within the permit (99-DP-3316 MD0068306) for the County's municipal separate storm sewer system (MS4). This permit was issued by the Maryland Department of the Environment (MDE) on November 8, 2004, under the National Pollution Discharge Elimination System (NPDES).

The work described in this summary report consisted of data collection and compilation, followed by the application of hydrologic and pollutant loading models to assess existing and future conditions in the watershed. Stream reaches and subwatersheds were ranked and prioritized according to their calculated need for restoration or preservation. From this prioritization, an implementation plan was developed to conceive and guide specific restoration and preservation activities in the watershed. As a first step toward implementation, the County also developed concept design plans for specific proposed restoration projects. The collected field data associated with this study are available for review on the County's website (http://gis-world.aacounty.org/WERS/).

Data Collection and Compilation. The assessment included extensive data collection and compilation efforts to support the County's stream reach and subwatershed condition assessment and rating efforts. The chief elements of collected data from streams and immediate riparian areas were:

- Stream classification/verification
- Habitat condition assessment
- Infrastructure/environmental features
- Habitat scores
- Channel geomorphology
- Road crossing flood potential
- Bioassessments
- Aquatic resource indicators

The chief elements collected from uplands areas within the watershed were:

- Impervious cover
- Urban stormwater best management practices (BMPs)
- Agricultural land management practices
- Onsite sewage disposal systems
- Soil indicators
- Landscape indicators

Hydrologic and Pollutant Load Modeling. Data collection and compilation provides inputs to the County's hydrologic and pollutant models within the Watershed Management Tool (WMT). These analytical models were used to assess existing and future conditions in the watershed. The hydrologic modeling is centered on estimation of peak flow rates and volumes during storms associated with bankfull conditions. Water quality modeling is used to estimate current pollutant loads within the watershed, trends in watershed loading, and the level of pollution control required to meet watershed goals and regulatory requirements. The models were applied to support the rating of subwatersheds for restoration and preservation need and the evaluation of restoration and retrofit activities across priority subwatersheds.

Rating and Prioritization. The County performed rating and prioritization in order to characterize current conditions within the watershed, to guide decisions that impact waterways, and to assist with land use management planning. Three rating and prioritization assessments are used: stream restoration; subwatershed restoration; and subwatershed preservation. Each of the three assessments uses a suite of indicator scores or ratings that are weighted and combined to obtain a single rating for each stream or subwatershed. The ratings used are "Low," "Medium," "Medium High," or "High," depending on the relative need for either restoration or preservation.

Six of the 29 subwatersheds with assessed perennial streams had greater than one-third of their streams rated as "High" or "Medium High" priority for restoration. Ten of 68 subwatersheds were rated as "High" priority for restoration. Similarly, 14 of the 68 subwatersheds were rated as "High" priority for preservation. Table ES.1 provides a summary of these priority subwatersheds.

Table ES.1 – Summary of High Priority Subwatersheds

Subwatersheds with the Largest Number of High Priority Streams Based on Stream Restoration Assessment	High Priority Subwatersheds Based on Subwatershed Restoration Assessment	High Priority Subwatersheds Based on Subwatershed Preservation Assessment
Cypress Creek (MGC)	Cypress Creek (MGC)	Blackhole Creek (MRG)
Forked Creek (MGL)	Deep Creek (MGT)	Otter Pond (MGE)
Little Magothy River (MGV)	Little Magothy River (MGV)	Magothy Narrows (MRM)
Dividing Creek (MGH)	Indian Village Branch (MGW)	Cornfield Creek (MR0)
Magothy Branch 1 (MR3)	Hunters Harbor (MRD)	Cockey Creek (MR6)
Magothy Narrows (MRM)	Mill Creek (MGI)	Broad Creek (MGJ)
	Cattail Creek 2 (MRO)	Magothy Branch 1 (MR3)
	Beechwood Branch (MR5)	Magothy River Tidal (MGX)
	Magothy River Tidal (MGF)	Nannys Branch (MGY)
	Unnamed Tributary (MGA)	James Pond (MRJ)
		Rouses Branch (MRA)
		Brookfield Branch (MR4)
		Sillery Bay (MG8)
		Podickery Creek (MGZ)

These subwatersheds become candidate locations for capital projects based on the rating and prioritization.

The County also performed a preservation assessment at the parcel level to identify the highest priority parcels for preservation throughout the Magothy River Watershed. A list of the top 200 parcels is provided in Appendix C.

Restoration and Preservation Implementation Plan. The Restoration and Preservation Implementation Plan for the Magothy River Watershed considers aspirational goals as well as goals based on regulatory mechanisms (including the NPDES permit and total maximum daily load (TMDL) programs), stormwater flow and pollutant load reduction, impervious cover, and other measures of watershed health. The County developed a detailed list of options for restoration activities that will move the watershed towards achieving these watershed goals.

The assessment process included evaluation of the performance and cost-effectiveness of different types of restoration and retrofit activities. The County's water quality model was used to calculate potential pollutant removal from six types of restoration projects identified for priority subwatersheds. These six project types include shallow marsh and regenerative wetland seepage systems, regenerative step pool outfall sand filtration devices, dry pond retrofits, concrete ditch retrofits to water quality swales, enhanced stormwater retrofits (bioretention facilities), and onsite sewage discharge system retrofits. These restoration and retrofit projects were then fed into a cost-benefit analysis. One finding of the watershed assessment is that wetland/marsh systems are the most cost-effective restoration activity in the Magothy River Watershed.

Key Recommendations. The data collection, modeling, assessment, and implementation planning activities for the Magothy River Watershed led to the following recommendations:

- Implement all restoration and retrofit projects identified by the County in order to move towards water quality goals, focusing first on the most cost-effective projects.
- Advocate for updates in regulatory stream width requirements and Federal Emergency Management Agency (FEMA) floodplain estimation methods in the County's Stormwater Management Policy and Procedure Manual. This will ensure that preservation and restoration priorities are reflected in zoning and planning decisions, and to promote synergies across County departments.
- Augment programs that support routine maintenance of BMPs to keep BMPs performing at design efficiencies.
- Document and quantify the effectiveness of restoration projects through additional data collection to validate cost-benefit analysis, demonstrate progress towards watershed goals, and improve the basis for costing.
- Work with community organizations such as the Magothy River Association, the Magothy River Land Trust, and the Anne Arundel County Master Steward Academy to organize volunteer-based activities that contribute to watershed health through restoration, education, and land acquisition.

Concept Design Plans. As a first step toward implementation, the County developed concept design plans for six of the proposed restoration projects. Each concept plan contained a narrative description of the issue to be addressed, the purpose of the restoration activity, a site location map, hydrologic and hydraulic volumes, a plan view of the conceptual design, existing condition photos, design and construction cost estimates, and a feasibility assessment. The concept plans were developed following a thorough analysis of existing site conditions and consultation with key stakeholders.

1. INTRODUCTION

1.1 PURPOSE AND SCOPE

The Anne Arundel County, Maryland, Watershed Assessment and Planning Program within the Department of Public Works initiated a comprehensive assessment of the Magothy River Watershed, depicted on Map 1.1, in March 2008. The main purpose of the assessment was to characterize current stream and upland conditions in the watershed in support of watershed planning activities. This assessment of current conditions (referred to as the 2008 assessment) helps the County to determine where to focus resources to maintain those waterbodies that are in good condition and to help determine where mitigation of potential problems is necessary to improve the overall watershed health and quality of tidal and non-tidal resources. The study also fulfills requirements of National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) permit issued to the County by the Maryland Department of the Environment (MDE). Similar watershed studies were initiated by the County in the Severn River Watershed, the South River Watershed, the Upper Patuxent River Watershed and, more recently, in the non-tidal portion of the Patapsco River Watershed.

The scope of the Magothy River Watershed study included collection of field and stream assessment data and supporting Geographic Information System (GIS) data, followed by analysis and modeling using the County's customized watershed assessment and modeling tools. The data collected as part of the Magothy watershed assessment were compiled and stored in the County's GIS-interfaced Watershed Management Tool (WMT). Assessment data stored in the WMT are available for review via the County's Watershed Mapping Application (http://gis-world.aacounty.org/WERS/)

The WMT and other analysis tools were used to perform a synthesis of assessment data for further evaluation:

- Engineering models evaluate existing and future hydrologic, hydraulic and water quality conditions.
- Statistical models explore possible correlations between watershed stressors and select watershed health indicators.
- Rating and prioritization result in ranked identification of stream reaches and subwatersheds for restoration and preservation.

Assessment and modeling efforts were performed collaboratively by County staff, with assistance from their consultants and community stakeholders. A Professional Management Team (PMT) comprised of County staff, LimnoTech project staff and technical advisors, and representatives of the Magothy River Association provided peer review and input on the County assessments and modeling efforts. Specific watershed goals and recommendations for implementation derived from the PMT meetings are provided in this report.

The County's assessment and modeling efforts and findings are detailed in Sections 2, 3, and 4. Recommended watershed management goals and recommendations for implementation are described in Section 5. The remainder of Section 1 presents the regulatory context for the assessment, introduces previous studies, and describes the physical setting for the Magothy River Watershed.

1.2 REGULATORY AND PLANNING CONTEXT

The regulatory and planning context for the watershed assessment includes state regulatory activities, legislative requirements, County actions, and programs aimed at restoration and protection of water quality impairment in the Magothy River Watershed and the greater Chesapeake Bay system.

1.2.1 NPDES

Anne Arundel County holds NPDES MS4 permit issued by the Maryland Department of the Environment (MDE). This permit (99-DP-3316, MD0068306) covers all stormwater discharges to and from the MS4 owned and operated by the County. Section III.F the County's MS4 permit requires the County to develop watershed management plans for all watersheds in Anne Arundel County that:

- Determine current water quality problems;
- Identify and rank water quality problems;
- Identify all structural and non-structural water quality improvement opportunities;
- Include the results of 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 of the permit requires the County to implement restoration efforts in one or more watersheds to restore ten percent of the County's impervious surface area within the 5-year permit cycle. The Magothy River Watershed Assessment has been conducted in partial fulfillment of these requirements.

1.2.2 Total Maximum Daily Load

Total maximum daily loads (TMDLs) are a requirement of the Clean Water Act for waters out of compliance with water quality standards that call on states to list its impaired water bodies [303(d) list] and develop a plan to reduce the pollutant load to these water bodies. The 303(d)-listed streams within the Magothy River Watershed are presented in Map 1.2. MDE is the designated regulatory authority by EPA for TMDLs in Maryland.

The 1996 303(d) list indicated that the Magothy River (basin number 02-13-10-01) was impaired by nutrients, sediments, and fecal coliform. Biological impacts in the non-tidal portions were added to the 2002 303(d) list, and biological impacts in the tidal portions were added to the 303(d) list in 2004. Also in the 2004 303(d) list, the fecal coliform impairment was clarified with the identification of four specific restricted shellfish harvesting areas within the basin (Magothy River; Tar Cove; Forked Creek; and Deep Creek). The 2010 Integrated Report, or IR, combines the 303(d) list with the 305(b) Water Quality report, and it listed the Magothy River as impaired for toxics based on PCBs in fish tissue.

MDE completed a TMDL study for fecal coliform in the Magothy River, Tar Cove, and Forked Creek that was accepted by EPA Region 3 on February 20, 2006 (this study also included an analysis that indicated that Deep Creek was meeting water quality standards for fecal coliform, so a TMDL was not needed). The TMDL states that Phase I general MS4 permits are considered point sources subject to waste load allocations (WLAs) under the TMDL. Fecal coliform WLAs for the Magothy River, Tar Cove, and Forked Creek were included in the TMDL report. MDE is in the process of conducting a bacterial source tracking study in order to verify the nonpoint source loading estimates contained in the TMDL report, and will use the results of this study to begin an iterative process to implement the TMDL. The TMDL report states that MDE will focus first on those sources with the largest impact on water quality, and that it will consider the relative ease of implementation and cost. MDE further notes that the source contributions estimated from the watershed analysis may be used as a tool to target and prioritize initial TMDL implementation efforts.

The TMDL for fecal coliform for the Magothy River can be found on MDE's TMDL website[1]. The 2010 IR indicates that a TMDL for the nutrients impairment is likely within two years. The suspended sediment, toxics, and biological impairments within the Magothy River basin will be addressed at a future date.

1.2.3 Chesapeake 2000 Agreement

The Chesapeake 2000 agreement adopted in June 2000 called for watershed planning in the region through development and implementation of locally supported watershed management plans[2]. This report meets the description for watershed management plans described above and fulfills part of Anne Arundel County's obligation under this agreement.

1.2.4 Baywide Tributary Strategies

Baywide tributary strategies detail the specific actions needed to reduce the amount of nutrients and sediment flowing into the Chesapeake Bay, from both point and nonpoint sources. Pollutant reduction goals were set for the entire watershed by the Bay states in 2003, with annual allocations for nitrogen, phosphorus, and sediment. The allocations were further subdivided into nine major river basins, and then allocated to each Bay state. The Magothy River falls under the responsibility of the Lower Western Shore Tributary Team. The Lower Western Shore Tributary Strategy included a series of agricultural, urban, and septic system best management practices that needed to be implemented in order to meet Maryland's nutrient goals under the Chesapeake 2000 Agreement.

[1] http://www.mde.state.md.us/Programs/WaterPrograms/TMDL/ApprovedFinalTMDL/TMDL_final_magothy_fc.asp
[2] http://dnrweb.dnr.state.md.us/bay/res_protect/c2k/index.asp

Maryland's Chesapeake Bay Statewide Implementation Plan (January 2008) included a stormwater strategy with the following elements, among other strategies:

- One hundred percent of newly developed and redeveloped lands (2003-2010) will address stormwater management in accordance with Maryland's existing stormwater management regulatory requirements; and
- Up to 40 percent of untreated developed land (*e.g.*, developed pre-1985) will be retrofitted (e.g., construct new and/or modify existing stormwater management practices including nonstructural and structural designs, reducing impervious cover, reducing runoff, pollution prevention measures, etc.) as funding is available.

The Statewide Implementation Plan states that MDE's "MS4 permits are consistent with and support the Maryland Tributary Strategy, specifically the goal to retrofit up to 40 percent of existing developed lands with stormwater management measures. Through the MS4 permit, watershed restoration requirements have been set using an incremental approach to identify and begin to retrofit 10 percent of the existing impervious area within a 5-year permit term. MS4 permits are currently in the third generation, and the effected local jurisdictions are required to identify another 10 percent for the new permit cycle. Local jurisdictions will systematically address the need to restore and treat the stormwater runoff from the most populated impervious areas." Statements by MDE at recent public meetings related to the Chesapeake Bay TMDL for nitrogen, phosphorus and suspended solids have raised the possibility that these requirements may be increased in future permit cycles in order to meet Chesapeake Bay goals.

1.2.5 Maryland House Bill 1141

The Maryland General Assembly passed House Bill 1141 in 2006. This Bill 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[3].

Chapter 10 (Water Resources Plan) of Anne Arundel County's 2009 General Development Plan (April 2009) addresses these requirements. The Water Resources Plan describes the County's current planning framework for watershed protection and provides a summary of the County's water supply and wastewater treatment capacities, septic systems, and stormwater management capacity. The Water Resources Plan also summarizes the analysis that was conducted to show the impact of nutrient loads on the watersheds for existing conditions, conditions based on the current land use plan, and conditions based on the proposed land use plan. In addition, the Water Resources Plan outlines a mitigation plan that is consistent with the watershed protection goals and strategies.

The Water Resources Plan includes discussions of the role that the County's Watershed Management Plans play in evaluating the current status of each of the County's watersheds, and prioritizing them to determine which are most in need of restoration or protection. The

[3] Maryland House Bill 1141, http://www.mde.state.md.us/ResearchCenter/Publications/General/eMDE/vol2no2/growth.asp

Water Resources Plan indicates that the County's Watershed Management Plans provide technical support for the development, implementation, management, and refinement of the other programs, plans and requirements that protect the County's watersheds, including the General Development Plan, County stormwater regulations, and the County erosion and sediment control program.

1.2.6 Chesapeake Bay TMDL-related Requirements

EPA and states in the Chesapeake Bay Watershed are in the process of developing TMDLs for nitrogen, phosphorus and suspended solids. The pending TMDLs for river segments in the Chesapeake Bay Watershed have generated numerous discussions of potential future regulatory actions, including potential new stormwater regulatory requirements, increased enforcement of requirements, and suggested "consequences" for the failure to implement requirements, ranging from reductions in state revolving fund (SRF) funding to bans on the issuance of new permits. Specific legislation has been offered in the U.S. Congress to implement President Obama's Executive Order on the Chesapeake Bay, including the Chesapeake Bay Ecosystem Restoration Act of 2009 introduced by Senator Benjamin Cardin of Maryland. The bill would establish as law the EPA's proposed requirements for the states' development and implementation of cleanup plans for the Chesapeake Bay and sets a firm deadline of 2025 for all restoration efforts to be in place. If states fail to develop plans or make progress, the bill requires the EPA to intervene. Among the Cardin Bill's requirements are a "no net increase" of nitrogen and phosphorus from new development, increases in impervious surfaces, or septic systems. It would require that all new construction projects of more than 5,000 square feet create no additional runoff to streams.

1.2.7 Maryland Stormwater Regulations

Maryland's Stormwater Management Act of 2007 became effective on October 1, 2007. The Act requires that environmental site design (ESD) be implemented to the maximum extent practicable through the use of nonstructural best management practices and other better site design techniques. As part of its implementation of the Act, MDE has published the 2009 Model Standard Stormwater Management Plan (October 2009) and the 2009 Model Stormwater Management Ordinance (June 2009). Changes to Maryland's stormwater management regulations (COMAR 26.17.02) to address the Act became effective in May of 2009. Anne Arundel County's draft updates to County Code Article 16 (Floodplain Management, Sediment Control, and Stormwater Management) incorporate requirements for ESD as required by the Act. The draft update of County Code section 16.4.202.a states that "the planning techniques, nonstructural practices and design methods specified in the Design Manual shall be used to implement ESD to the maximum extent practicable (MEP). The use of ESD planning techniques and treatment practices must be exhausted before any structural BMP is implemented."

1.2.8 Onsite Sewage Disposal System Considerations

Anne Arundel County published the *Onsite Sewage Disposal System (OSDS) Evaluation Study and Strategic Final Repor*t in March 2008. This study is part of an effort to develop an

OSDS Strategic Plan for cost-effective reduction of nitrogen loads from OSDSs consistent with County goals. The OSDS Study recommended a number of options for OSDSs depending on the proximity of the OSDS to a sanitary sewer, the density of OSDSs, nitrogen delivery ratios, and other relevant factors. These options included extending sanitary sewer systems to the homes using OSDSs, replacing the OSDSs with cluster systems, upgrading the OSDSs to remove nitrogen, or taking no action. As part of its overall strategy to mitigate the effects of OSDSs, the County will also evaluate the feasibility of code revisions to require all new or replacement private septic systems to utilize the latest standards for denitrification. Currently, this requirement applies only within the Critical Area (*i.e.*, all lands within 1,000 feet of tidal waters or adjacent tidal wetlands). The County plans to determine whether this approach is feasible in other areas.

1.3 PREVIOUS STUDIES

The County initiated a field study to support the 2005 *Magothy River Watershed Restoration Strategy* in 2004. This study was carried out in partnership with the Magothy River Association in cooperation with the Maryland Department of Natural Resources. A grant from the National Fish and Wildlife Foundation was used to fund the study. Condition assessments of Magothy River non-tidal tributary streams as well as tidal shorelines were included in the study.

The condition assessments utilized rapid data collection with Stream Corridor Assessment and Tidal Shoreline Survey methods that were supplemented by field-collected water quality and hydraulic measurements. These data were synthesized to identify and prioritize impaired areas in need of restoration and pristine or sensitive areas in need of preservation. A watershed restoration strategy was developed that included a prioritized list of restoration and preservation projects and recommendations for additional future actions. Many of these recommendations were addressed as part of the 2008 Magothy River Watershed Assessment. This included evaluating drainage areas above impaired reaches, performing biological assessments and water quality assessments throughout the watershed, and investigating additional restoration and preservation opportunities.

1.4 PHYSICAL SETTING

The Magothy River Watershed is one of twelve major watersheds in Anne Arundel County, Maryland, and it is situated in the northeastern portion of the County (see Map 1.1 for orientation of the watershed within the County). The drainage area of the Magothy River Watershed is approximately 22,800 acres. The Magothy River feeds into the Chesapeake Bay and both the tidal portion of the Magothy River and the Chesapeake Bay are popular recreation areas for boating, fishing and other outdoor activities.

1.4.1 Physiography

The Magothy River Watershed is situated in the Atlantic Coastal Plain Physiographic Province. The watershed covers portions of the Crownsville Upland District and the Annapolis Estuaries and Lowlands District. The Crownsville Upland District is an undulating landform with flat-lying to gently southeast-dipping sedimentary beds (Maryland Geological Survey, 2008) that is found within the northern portion of the Magothy River Watershed. The Annapolis Estuaries and Lowlands District is relatively featureless lowland over essentially flat-lying sedimentary beds (Natural Resources Conservation Service [NRCS], 2009) that is found throughout the rest of the Magothy River Watershed.

The majority of slopes within the watershed are less than 14%. The western and southern upstream portions of the Magothy River Watershed are highest in elevation. The southeastern tip of the watershed is an area of low elevation and little topographic variation. Maps 1.3 and 1.4 depict the steep slopes and topography found in the Magothy River Watershed.

1.4.2 Soils and Geology

Soils within the Magothy River Watershed are varied in their hydrologic properties and expected erodibility. All four hydrologic soil groups are present. As shown in Table 1.1, the majority of soils (62%) 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 20% of the soils in the watershed. These soils have low runoff potential when thoroughly wet and water is transmitted freely through the soil. Soils categorized in hydrologic soil groups C and D, which are the soils with the highest runoff potential, are less prominent in the watershed.

Table 1.1 – Hydrologic Soils Groups in the Magothy River Watershed

Hydrologic Soil Group	Percent of Watershed
A	20%
B	62%
C	13%
D	5%

Soil erodibility varies across the Magothy River Watershed. As shown in Table 1.2, 66% of the soils in the watershed are classified as potentially highly erodible land and another 24% are classified as highly erodible land. Soils classified as not highly erodible lands are found in small pockets across the watershed and make up 10% of its area. A map of hydrologic soil groups and soil erodibility factors is presented as Map 1.5.

Table 1.2 – Soil Erodibility in the Magothy River Watershed

Soil Erodibility	Percent of Watershed
Not highly erodible land	10%
Highly erodible land	24%
Potentially highly erodible land	66%

1.4.3 Surface Water

The Magothy River Watershed contains approximately 28 miles of perennial stream reaches, draining 41 non-tidal and 27-tidal subwatersheds. The 68 subwatersheds range in size from 3 to 1,429 acres. A map of the subwatersheds, including the subwatershed three digit code and name, is presented as Map 1.6.

1.4.4 Sensitive Environmental Features

Many sensitive environmental features including bogs, wetlands, Greenways, and Critical Areas are present within the Magothy River Watershed. Each of these features is important because they provide hydrologic, water quality, and habitat benefits. Wetlands are found throughout the Magothy River Watershed, while bogs are primarily located in the north portion of the watershed. In Maryland, bogs are home to several rare, threatened, or endangered species. Greenways are important because they have been identified for preservation or recognized for their ecological value as natural habitat and connecting corridors for wildlife. Critical Areas are important because they reduce pollution, provide habitat, and protect shoreline and near-shoreline areas from development. A map of these sensitive environmental features is presented as Map 1.7.

1.4.5 Land Use, Land Cover and Land Ownership

The mix of land use and land cover in the Magothy River Watershed is summarized in Table 1.3. As shown, the residential categories collectively represent nearly 54% of the watershed. Woods occupy a substantial area of 31.7%. The areas covered by commercial areas, transportation uses, industry, open space, and agricultural activities are all individually less than 5%. A map depicting the land cover breakdown in the watershed is presented as Map 1.8.

Table 1.3 – Land Use and Land Cover

Land Use/Land Cover	Acres	Percent of Watershed
Commercial	1,115.0	4.9%
Forested Wetland	3.0	<0.1%
Industrial	35.1	0.2%
Open Space	970.0	4.3%
Open Wetland	19.5	0.1%
Pasture/Hay	20.4	0.1%
Residential 1-acre	753.8	3.3%
Residential 1/2-acre	5,326.3	23.4%
Residential 1/4-acre	5,640.9	24.7%
Residential 1/8-acre	535.3	2.3%
Residential 2-acre	49.0	0.2%
Row Crops	92.7	0.4%
Transportation	896.9	3.9%
Water	118.1	0.5%
Woods	7,221.9	31.7%

Impervious surfaces represented by roads, building footprints, parking lots and other hard surfaces cover approximately 22% of the Magothy River Watershed. Imperviousness within individual subwatersheds ranges from 0 to 39%. A map depicting the impervious cover in the watershed is presented as Map 1.9.

Approximately 76% of the land within the Magothy River Watershed is privately owned. The County owns 9.4% of the land, and the State and Federal government own smaller percentages. Right-of-ways, mostly along transportation corridors, account for a significant portion of the land (13.4%). Lands designated as right-of-ways are owned by both the County and State. A map of property ownership in the watershed is presented as Map 1.10. The percentage of impervious cover owned by each of these primary land owners is presented in Table 1.4. A map of impervious cover ownership in the watershed is presented as Map 1.11.

Table 1.4 – Impervious Land Cover and Ownership

Land Use and Ownership	Land Cover (acres)	Impervious Cover (acres)	Impervious % of Land Cover	% of Total Impervious Cover
Commercial & Industrial (Private Lands)	787	534	68%	11%
Residential (Private Lands)	10,897	2511	23%	50%
Agriculture (Private Lands)	92	1	1%	<0.1%
Other (Private Lands)	5,541	139	3%	3%
County Lands	4,311	1497	35%	30%
State Lands	1,164	295	25%	6%
Federal Lands	11	6	51%	0.1%
Total	**22,805**	**4,982**	**22%**	**---**

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2. DATA COLLECTION AND COMPILATION

Field data were collected and compiled to support the County's stream reach and subwatershed condition assessment and rating efforts. Field crews verified and classified the Magothy River tributary stream network, assessed physical habitat conditions, and collected data on infrastructure, environmental features, road crossing flood potential, and channel geomorphology. This data collection field work was performed from April to June 2008. Additional existing data were also used to support the County's assessment efforts. These additional data include bioassessment monitoring results, land use cover, impervious areas, best management practices (BMPs) characteristics, septic system impacts, soil characteristics, and various other aquatic and landscape indicators. Each of these data components is discussed in more detail in this section. The discussion is organized by pertinent ecosystem zone, including the tributary streams and their associated riparian areas (Section 2.1) and upland areas (Section 2.2).

2.1 STREAM DATA COLLECTION AND COMPILATION

The following subsections present and summarize the collected and compiled data within the Magothy River 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.

2.1.1 Stream Classification and Verification

A watershed assessment is predicated on an accurate understanding of stream location and character (*e.g.*, perennial, intermittent, ephemeral, underground, wetland, *etc*.). The actual position, alignment, and character of all tributary streams in the Magothy River Watershed were field verified. A stream planimetric dataset based on 2002 aerial photography along with drainage lines derived from a digital elevation model (DEM) (with a 2 meter by 2 meter grid size) were used as a guide for directing field assessment and verification efforts. Based on field verification activities, a stream reach GIS layer representing all of the tributary streams that contribute flow to the tidal portion of the Magothy River was constructed.

Field teams confirmed the location of the stream channel and made a determination of the stream character. Additions to and deletions from the existing stream planimetric dataset were recorded and updated as necessary to match observed field conditions. Modifications to the channel alignment in the dataset were made only when significant inconsistencies were noted. Field teams used best professional judgment to evaluate a number of field indicators of perenniality, including hydrologic indicators (*e.g.*, seeps, leaf litter presence, sediment deposition), geomorphic indicators (*e.g.*, riffle pool sequence, substrate sorting, sinuosity, bankfull bench presence), soil indicators (*e.g.*, redox-morphic features, chroma), and biological indicators (*e.g.*, vegetation, benthic macroinvertebrates).

Approximately 74 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 more commonly found in the southern portion of the watershed between Little Magothy River and Dividing Creek and the headwater portion of the watershed between Rouses Branch and Cockey Creek. The northern portion of the watershed is dominated by intermittent channels and wetland areas.

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. Physical features, such as stream confluences, bridges, and culverts, were also used to sub-divide reaches. A total of 557 individual reaches were identified within the Magothy River Watershed. The average reach length was approximately 700 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 Character Types

Type	Number of Reaches	Stream Miles	Percent of Total Stream Miles
Ephemeral	96	14.3	19.3%
Intermittent	97	14.6	19.7%
Perennial	205	28.1	38.0%
Pond/Lake	47	4.1	5.6%
Underground	8	1.1	1.5%
Wetland	104	11.8	15.9%
TOTAL	**557**	**74.0**	**---**

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.

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). 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.

Physical habitat condition assessment reaches were created based on observed changes in habitat conditions along a stream. For the Magothy River Watershed, approximately 27 of the 28 miles of perennial streams were assessed and scored. Approximately one 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 168 individual reaches with an average assessed stream reach length of approximately 0.16 miles (or 845 feet).

Figure 2.1 – Examples of Assessed Stream Reaches

Stream Reach in the Bailys Branch Subwatershed (MR1) with Minimally Degraded Habitat Condition

Stream Reach in the Cypress Creek Subwatershed (MGC) with Severely Degraded Habitat Condition

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 Magothy River Watershed is 76.46, which corresponds to a "Partially Degraded" condition. Approximately 62% of perennial stream miles in the Magothy River Watershed were rated as "Partially Degraded." "Minimally Degraded" streams comprised roughly 28% of the perennial streams, followed by "Degraded" and "Severely Degraded" streams at 6.8% and 2.6%, respectively. The Magothy Branch and Cypress Creek subwatersheds had the highest number (three) of stream reaches that are either "Degraded" or "Severely Degraded." The Deep Creek and Bailys Branch subwatersheds had the highest percentage of perennial stream miles that were considered "Minimally Degraded" with 84% and 72%, respectively. A summary of MPHI condition categories by stream mile and number of reaches is provided in Table 2.2. A map of the MPHI conditions throughout the watershed is presented as Map 2.2. Examples of assessed stream reaches are depicted in Figure 2.1.

Table 2.2 – MPHI Condition Category

Condition	Number of Reaches	Stream Miles	Percent of Total Stream Miles
Minimally Degraded	47	7.5	28.2%
Partially Degraded	104	16.6	62.4%
Degraded	13	1.8	6.8%
Severely Degraded	4	0.7	2.6%
TOTAL	**168**	**26.6**	**---**

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 was compiled within each perennial reach and associated riparian area. These features included riparian buffer deficiencies, excessive in-stream erosion, stream obstructions, stream crossings, utilities, dumpsites, head cuts, and tributary 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.

These infrastructure and environmental features can be critical to the health of the Magothy River tributary streams for different reasons discussed below.

- 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.

Figure 2.2 – Examples of Environmental and Infrastructure Features

Deficient Buffer (Residential Lawn Encroachment) with Moderate Impact in the Little Magothy River Subwatershed (MGV)

Pipe and Ditch Contributing Flow with Moderate Impact in the Forked Creek Subwatershed (MGL)

Stream Crossing with Moderate Impact in the Deep Creek Subwatershed (MGT)

A summary of the impacts for each infrastructure or environmental feature is presented in Table 2.3. The distribution of these features throughout the watershed is presented in Map 2.3. Stream crossings, which typically include culverted segments of stream, accounted for the largest number of inventory features and the highest cumulative impact score. Riparian buffer impacts and pipe and ditch impacts were the next most common inventory features identified in the Magothy River Watershed. Riparian buffer impacts were most often associated with encroachment from residential lawns. Pipes and drainage ditches that contribute flow and erosive forces to the Magothy River Watershed streams were most often associated with stormwater outfalls. The relative abundance of these three infrastructure features (*i.e.*, stream crossings, deficient buffers, and pipes and ditches) is consistent with a more urbanized watershed like the Magothy River. The remaining features (*i.e*, dumpsites, eroded areas, obstructions, utilities, and head cuts) were encountered less frequently, but certainly contributed lo cally to areas of stream degradation throughout the watershed. Examples of environmental and infrastructure features encountered in the Magothy River Watershed are depicted in Figure 2.2.

Table 2.3 – Infrastructure and Environmental Feature Impact Scores

Type	Number of Features with Impact Score:				Total Cumulative Impact Score
	Minor	Moderate	Severe	Extreme	
Buffers	---	40	0	1	210
Crossings	82	14	2	0	248
Dumpsites	13	3	0	---	28
Erosion	---	10	1	1	67
Obstructions	24	2	0	---	58
Pipes/Ditches	40	19	3	---	125
Utilities	3	0	1	0	16
Head Cuts	---	---	---	---	61.5*

* Head cut impact score corresponds to cumulative height of head cuts
--- Not considered as an impact score for associated feature

Managing the impacts from many of these features can be difficult as doing so requires modifications to existing infrastructure or stream restoration. The County identified a number of restoration projects that are discussed in more detail in Section 5. In addition to these capital projects, the Professional Management Team for this study also identified other potential projects and initiatives that utilize the resources of community organizations like the Magothy River Association. These include public outreach campaigns on water quality and land management issues in the watershed and mobilization of volunteers to restore riparian buffers and clean up dumpsites. These opportunities are discussed in more detail in Section 5 as well.

As discussed briefly in Section 1.3, a previous assessment of erosion areas, dumpsites, and deficient buffers was conducted by MDNR during the 2004 field work to support the *Magothy River Watershed Restoration Strategy*. Many of the environmental features identified in this 2004 survey were reassessed during the 2008 Magothy River Watershed Assessment. Although the assessment and scoring scheme was different for the 2004 dataset, an attempt was made to compare the results of the 2004 and the 2008 assessments. A breakdown of impact changes from the two assessments is presented in Table 2.4. This simple comparison shows that most impacts remained unchanged. Of the impacts that did change, more impacts showed improved versus worsened conditions. It is important to note that the differences in assessment and scoring protocols between the two studies make it difficult to make definitive statements about whether actual impacts improved or got worse in the ensuing four year period.

Table 2.4 – Comparison of Infrastructure and Environmental Feature Impact Scores from 2004

Type	Number of Features with Impact Scores Between 2004 and 2008:		
	Impact Improved	Impact Unchanged	Impact Worsened
Buffers	4	18	0
Dumpsites	3	0	0
Erosion	2	5	2

2.1.4 Final Habitat Score

A Final Habitat Score for each perennial stream reach was calculated using the MPHI scores generated from the physical habitat condition assessment (Section 2.1.2) and the sum of the impact scores generated from the inventory of infrastructure and environmental features (Section 2.1.3). The Final Habitat Score is calculated as follows (Anne Arundel Co., 2006):

$$\textit{Final Habitat Score} = \textit{MPHI Score} - 0.5\left(\sum \textit{Total impact scores}\right)$$

The Final Habitat Score is utilized in the County's subwatershed prioritization assessments, which are discussed in more detail in Section 4. Final Habitat Scores for individual reaches are combined using a reach length-weighted average to assess the physical habitat conditions of perennial streams at the subwatershed level. Similar to the MPHI scoring, each weighted stream reach and consequently each subwatershed is assigned a condition category of "Minimally Degraded," "Partially Degraded," "Degraded," or "Severely Degraded." A breakdown of Final Habitat Scores for the 29 Magothy River subwatersheds that contain perennial streams is presented in Table 2.5. The Final Habitat Scores found throughout the watershed are presented in Map 2.4. Greater than 75% of the habitats at the subwatershed level within the Magothy River Watershed are "Partially Degraded." Two subwatersheds, Cypress Creek (MGC) and Magothy Narrows (MRM), were rated as "Severely Degraded."

Table 2.5 – Final Habitat Scores at Subwatershed Level

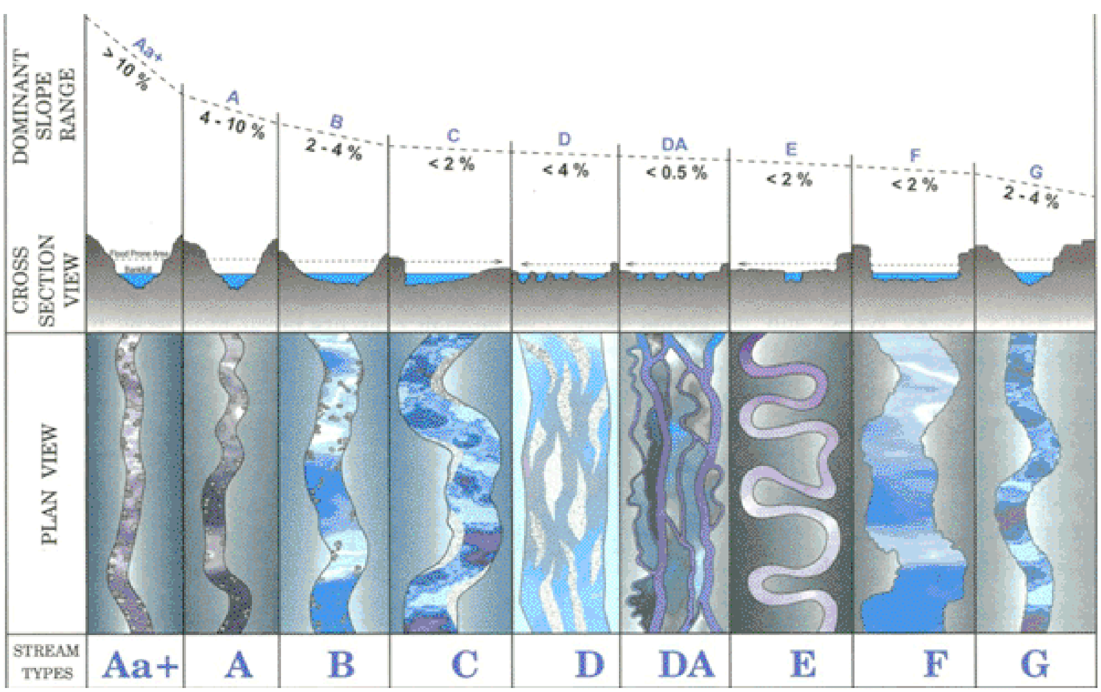
Rating	Number of Subwatersheds	Percent of Subwatersheds
Minimally Degraded	4	13.8%
Partially Degraded	22	75.9%
Degraded	1	3.4%
Severely Degraded	2	6.9%
TOTAL	**29**	**---**

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 location. The Rosgen classification system has four levels. The Level I classification is a geomorphic characterization that groups streams 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 is presented in Figure 2.3.

Figure 2.3 – Representation of Rosgen Level I Classifications of Major Stream Types



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

The County utilizes Rosgen Level I geomorphic classifications in its watershed modeling and analysis as indicators of stream stability and channel entrenchment. In the Magothy River Watershed, 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.

The distribution of Rosgen Level I classifications across the watershed is depicted in Map 2.5 and summarized in Table 2.6. As shown, approximately 32% of perennial, single-threaded reaches were classified as Type "B" channels, which are typically characterized as predominantly stable, moderate gradient channels with low sinuosity and low erosion rates. More than 25% of reaches were classified as Type "F" channels, which are generally low gradient, incised channels with high erosion rates. Some reaches were not assessed because they were inaccessible. Other reaches were determined in the field to be anastomosed or multi-threaded and were automatically assigned to the Type "DA" classification.

Table 2.6 – Rosgen Level I Classifications

Classification	Number of Reaches	Stream Miles	Percent of Total Stream Miles
A	2	0.4	1.4%
B	57	8.4	31.7%
C	29	4.6	17.4%
DA	30	4.8	18.0%
F	38	6.7	25.1%
Not Classified	12	1.7	6.4%
TOTAL	**168**	**26.6**	**---**

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 Magothy River 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. This subset of crossings included those roads owned by the County that were within 20 vertical feet of the stream bed, older than five-years in age, and classified as a "Freeway," "Principal Arterial," "Minor Arterial," or "Collector." These crossings were analyzed further to determine whether flooding or overtopping could result in a community or business area being cut off from emergency services. The results of this analysis showed that no single crossing or combination of crossings met this criterion. As such, the analysis was expanded to consider overtopping of "Local" roads as well. Six crossings were identified that would limit access by emergency services with the consideration of this new class of road. A technical memorandum with a more detailed description of the road crossing selection process is included in Appendix A. The locations of the analyzed road crossings are presented in Map 2.6.

Field surveys were performed on five of these road crossings to obtain data on stream channel and roadway geometry. The sixth crossing was inaccessible and was not surveyed. The 1-year, 2-year, 10-year, and 100-year discharges from each associated drainage area were calculated using NRCS's TR-20 single event runoff and routing model. The culverts associated with each crossing were modeled using the survey data and the Federal Highway Administration's HY8 model to determine the water level height and associated discharge required to overtop each of the crossings. This overtopping discharge was then compared to the range of return period discharges to determine the expected frequency that the road crossing would flood. One crossing at Armiger Drive in Bailys Branch (MR1) was determined to have an overtopping recurrence probability of between 1 and 2 years. A second road crossing in Bailys Branch on Sagamore Way was determined to have an expected overtopping recurrence of between 10 and 100 years. Three other road crossings were determined to have an overtopping recurrence of greater than 100 years. A summary of the discharge and flooding frequency data is presented in Table 2.7.

Table 2.7 – Flooding Potential of Selected Road Crossings

Crossing	Sub-watershed ID	Drainage Area (sq mi)	Discharge (cfs)				Overtopping Discharge (cfs)	Overtopping Return Period
			1 year	2 year	10 year	100 year		
Armiger Drive	MR1	0.1444	17	30	86	163	**20**	**Less than 2 years**
Sagamore Way	MR1	0.1247	51	78	173	294	**240**	**Between 10 and 100 years**
Seaborne Drive	MR5	0.2668	19	34	94	177	**210**	**Over 100 years**
Glencrest Road	MRG	0.5623	13	26	89	186	**402**	**Over 100 years**
Lake Shore Drive	MRL	0.0922	0	1	13	38	**65**	**Over 100 years**

2.1.7 Bioassessments

In an aquatic environment, benthic macroinvertebrates are typically the most sensitive of aquatic organisms to deleterious changes to water quality and physical habitat. Given this, the capacity of an ecosystem to support and maintain a healthy benthic community is a good measure of stream health. In April 2007, the County conducted biological field assessments at 27 targeted sites distributed throughout the Magothy River Watershed. Benthic macroinvertebrates were collected and analyzed at these sites using methods developed by MBSS as outlined in the *New Biological Indicators to Better Assess the Condition of Maryland Streams* (MDNR, 2005). These sampling data were supplemented with additional biological assessment data collected from the County-wide random sampling program conducted in 2006 and 2007.

The County used the Benthic Index of Biotic Integrity (BIBI) developed by MBSS to facilitate analysis of biological communities. The BIBI utilizes metrics that quantify biological diversity and the presence or absence of pollution sensitive taxa in a biological sample set. The metrics specifically include:

- Total number of taxa
- Number of EPT (Ephemeroptera, Plecoptera, Trichoptera) taxa
- Number of Ephemeroptera taxa
- Percent of urban intolerant individuals
- Percent Ephemeroptera
- Number of scraper taxa
- Percent of climbers

Raw values from each metric were assigned a score of 1, 3, or 5 based on ranges of values for each metric. These individual scores were then combined into a scaled BIBI score ranging from 1 to 5 and an associated narrative (ranging from "Very Poor" to "Good") was assigned.

The BIBI results from the targeted and random sampling events show that 22 of the 38 sites (58%) were rated as "Very Poor" or "Poor." No sites were rated "Good" and 16 sites (42%) were rated as "Fair." Targeted subwatersheds with "Very Poor" scores included Podickery Creek (MGZ), Cornfield Creek (MR0), Gray's Creek (MRE), and Black Hole Creek (MRG). A number of the more impaired bioassessment locations lacked many of the taxa (*e.g.*, Ephemeroptera, Plecoptera, Trichoptera) typically considered sensitive to pollutants and other biological stressors. Conversely, there was a relative abundance of traditionally pollution tolerant taxa, including *Caecidotea* and *Calopteryx*.

Habitat assessments and water quality sampling were conducted at each bioassessment location to provide context for the bioassessment scores. Of the four targeted bioassessment locations with "Very Poor" biological conditions, three locations (Podickery Creek, Gray's Creek, and Black Hole Creek) were characterized by relatively small drainage areas with minimal tributary impervious cover, minimal flow, and low pH values associated with leaf litter and organic matter decomposition. Cornfield Creek was also characterized by low pH, but was slightly more urbanized with nearly 20% impervious cover associated with residential and commercial land uses.

A summary of the bioassessment results for both the targeted and random datasets is presented in Table 2.8. A map of the bioassessment sample locations and BIBI results is presented in Map 2.7. Full bioassessment data and results from the targeted study can be found in the *Magothy River Watershed Year 2007 Targeted Biological Monitoring and Assessment* report, which is included in Appendix B.

Table 2.8 – Biological Assessment Summary

Subshed	Sample ID	Study	BIBI Score	Ranking
MG1	MAGO-13-2007	2007 Targeted	3.9	Fair
MGC	MAGO-20-2007	2007 Targeted	2.1	Poor
MGC	MAGO-21-2007	2007 Targeted	2.7	Poor
MGH	MAGO-22-2007	2007 Targeted	3.0	Fair
MGI	MAGO-23-2007	2007 Targeted	2.1	Poor
MGL	MAGO-24-2007	2007 Targeted	3.3	Fair
MGT	MAGO-25-2007	2007 Targeted	2.7	Poor
MGV	MAGO-26-2007	2007 Targeted	2.7	Poor
MGW	MAGO-06-2007	2007 Targeted	2.1	Poor
MGY	MAGO-05-2007	2007 Targeted	3.3	Fair
MGZ	MAGO-27-2007	2007 Targeted	1.9	Very Poor
MR0	MAGO-01-2007	2007 Targeted	1.6	Very Poor
MR1	MAGO-09-2007	2007 Targeted	3.9	Fair
MR2	MAGO-11-2007	2007 Targeted	2.7	Poor
MR3	MAGO-12-2007	2007 Targeted	3.6	Fair
MR4	MAGO-08-2007	2007 Targeted	2.7	Poor
MR5	MAGO-07-2007	2007 Targeted	2.4	Poor
MR6	MAGO-04-2007	2007 Targeted	3.9	Fair
MR7	MAGO-10-2007	2007 Targeted	3.6	Fair
MR9	MAGO-14-2007	2007 Targeted	2.1	Poor
MRA	MAGO-15-2007	2007 Targeted	2.1	Poor
MRB	MAGO-16-2007	2007 Targeted	3.6	Fair
MRE	MAGO-02-2007	2007 Targeted	1.6	Very Poor
MRF	MAGO-17-2007	2007 Targeted	2.7	Poor
MRG	MAGO-03-2007	2007 Targeted	1.6	Very Poor
MRI	MAGO-18-2007	2007 Targeted	2.1	Poor
MRO	MAGO-19-2007	2007 Targeted	3.9	Fair
MG1	07-04	2006-2007 Random	3.0	Fair
MR3	07-09	2006-2007 Random	3.9	Fair
MR7	07-10	2006-2007 Random	3.0	Fair
MR7	07-10	2006-2007 Random	1.9	Very Poor
MR9	07-05	2006-2007 Random	2.1	Poor
MRA	07-07	2006-2007 Random	2.7	Poor
MRA	07-12A	2006-2007 Random	2.1	Poor
MRB	07-14A	2006-2007 Random	1.9	Very Poor
MRI	07-03	2006-2007 Random	3.6	Fair
MRO	07-02	2006-2007 Random	3.0	Fair
MRO	07-08	2006-2007 Random	3.3	Fair

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 Magothy River Watershed were provided by 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 subwatersheds in the Magothy River Watershed contained areas identified as trout spawning habitat. Twenty subwatersheds were found to serve as areas for anadromous fish spawning, while 28 subwatersheds were determined to contain SSPRA habitat. Ten subwatersheds were noted to contain both anadromous fish spawning habitat and 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 Magothy River subwatersheds is presented in Table 2.9. No subwatersheds rate "High" for aquatic resources. Approximately 15% of subwatersheds are prioritized "Medium High" for this indicator. Subwatershed ratings for aquatic resources are presented in Map 2.8.

Table 2.9 – Aquatic Resource Indicator Ratings

Rating	Number of Subwatersheds	Percent of Subwatersheds
High	0	0%
Medium High	10	14.7%
Medium	28	41.2%
Low	30	44.1%
TOTAL	**68**	**---**

2.2 UPLAND DATA COLLECTION AND COMPILATION

The following subsections on impervious cover, urban stormwater BMPs, agricultural land management practices, OSDSs, soil indicators, and landscape indicators summarize the collected and compiled data in the upland areas associated with Magothy River tributary streams. This information is crucial for determining the land use conditions that influence the health of the tributary streams and the tidal portion of the Magothy River. As with the data presented in the previous section, the following upland data are used to identify and formulate restoration activities and land management decisions to improve conditions throughout the watershed.

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 36% of the stream reaches in the Magothy River Watershed were rated "Non-supporting." A summary of impervious cover ratings is provided in Table 2.10. As described earlier, a map depicting impervious cover throughout the watershed is presented in Map 1.8.

Table 2.10 – Impervious Cover Ratings

CWP Rating Category (% impervious cover)	Number of Reaches	Percent of Reaches
Sensitive (0-10%)	8	4.8%
Impacted (10-19%)	46	27.4%
Impacted (19-25%)	54	32.1%
Non-supporting (>25%)	60	35.7%
TOTAL	**168**	**---**

2.2.2 Urban Stormwater Best Management Practices

Urban stormwater BMPs are utilized throughout the County to intercept, detain, retain, and/or treat stormwater runoff before it reaches receiving water bodies. The installation of structural or nonstructural BMPs is required in all new development areas and in certain individual lot developments. The level of requisite stormwater management (*e.g.*, recharge volume, water quality volume, channel protection volume, *etc*.) is dependent on development size, proximity to Critical Areas, and downstream conditions among other considerations. Redevelopment sites also have stormwater management requirements, which can be met by actual reductions in impervious cover or effective reductions in impervious cover through BMP implementation, BMP upgrades, or other restoration activities (Anne Arundel County OPZ, 2006). In addition to these BMPs triggered by development or redevelopment, the County also regularly implements BMP retrofits of publicly owned property as part of its capital improvement program and its watershed management planning activities.

To facilitate understanding of the level of stormwater management provided by BMPs in the Magothy River Watershed, a spatially-accurate GIS inventory dataset was developed for all existing public and private stormwater BMPs. This analysis is critical for identifying areas within the watershed that are under-managed and for guiding future retrofit and BMP implementation efforts. The BMP inventory dataset contained accurate and up-to-date information on the locations, type, drainage area, and ownership of stormwater BMPs. The effort to develop the dataset entailed compiling existing data from multiple County and State sources, narrowing the dataset to eliminate those BMPs outside of the Magothy River Watershed, confirming or updating the spatial locations of the remaining BMPs, removing duplicate records, and performing research to fill any data gaps. A technical memorandum with a more detailed description of this work is presented in Appendix A.

BMPs in the Magothy River Watershed are grouped by the County into six major categories according to their primary mechanism of action. These categories include “Dry Detention,” “Dry Extended Detention,” “Filtration,” “Infiltration,” “Wet Structures,” and “Other.” A list of general BMP types that fall under each of these categories is included in Appendix B. A total of 1,764 BMPs were confirmed to be located within the Magothy River Watershed boundary as part of the compilation and research process. The sum of the drainage areas for these BMPs in the Magothy River Watershed is 2,913 acres. A breakdown of BMP types and their drainage areas is presented in Table 2.11. A map of BMPs located throughout the watershed is presented as Map 2.9.

Table 2.11 – Summary of Magothy River BMPs by Type

BMP Category	Quantity	Percent by Quantity	Drainage Area (acres)	Percent by Drainage Area
Dry Detention	36	2%	630.6	22%
Dry Extended Detention	64	4%	504.3	17%
Filtration	87	5%	83.4	3%
Infiltration	1,293	73%	710.1	24%
Wet Structures	77	4%	901.6	31%
Other	207	12%	83.0	3%
TOTAL	**1,764**	**100%**	**2,913.1**	**100%**

Approximately 13% of the area of the Magothy River Watershed receives water quantity management or water quality treatment through a BMP. Some of this area is receiving treatment by a series of BMPs because there is some overlap of BMP drainage areas. The BMP drainage areas range in size from 0.01 to 188 acres, with a mean drainage area of 1.65 acres, and a median drainage area of 0.10 acres. This indicates that many of the BMPs are very small in size. Over 81% of the BMPs treat less than one acre, but there are 34 BMPs that treat drainage areas over twenty acres.

The stormwater BMPs in the Magothy River Watershed are typically owned by private land owners, the County, or other State agencies, such as the Maryland State Highway Administration (MSHA). A breakdown of BMP types and ownership is presented in Table 2.12. The majority of the BMPs in the watershed (83%) are privately owned. Publicly owned BMPs comprise another 13% of the BMPs. However, when evaluated by the percent of the drainage area that they manage or treat in the watershed, private BMPs cover 38% and public BMPs cover 57% of the managed area. Many of the privately-owned BMPs are dry wells that serve to manage runoff from single rooftops or other impervious areas associated with residential properties. All of the MSHA-owned BMPs located along State-owned roadways are categorized as infiltration trenches.

Table 2.12 – Summary of Magothy River BMPs by Owner

BMP Category	Publicly Owned BMPs		Privately Owned BMPs		MSHA Owned BMPs	
	Drainage Area (acres)	Percent Drainage Area	Drainage Area (acres)	Percent Drainage Area	Drainage Area (acres)	Percent Drainage Area
Dry Detention	171.0	10%	448.2	40%	0.0	0%
Dry Ext Detention	389.8	23%	109.0	10%	0.0	0%
Filtration	21.0	1%	44.8	4%	0.0	0%
Infiltration	331.7	20%	323.1	29%	28.0	100%
Other	27.4	2%	45.7	4%	0.0	0%
Wet Structure	729.3	44%	146.2	13%	0.0	0%
TOTAL	**1,670.2**	**100%**	**1,117.0**	**100%**	**28.0**	**100%**

To function as designed, BMPs need to be properly maintained. Some of the older BMPs in the County are no longer functioning or effective for a variety of reasons. Some are failing due to a lack of maintenance. Others are failing due to inadequate original design or changes in development intensity within a drainage area that exceeds the original design capacity of the BMP. Many of the failed or failing BMPs in the Magothy River Watershed consist of overwhelmed infiltration systems or detention ponds that have become clogged. Other BMPs, such as dry ponds were designed primarily for water quantity management and as such offer very little water quality benefit. Examples of poorly performing BMPs are presented in Figure 2.4.

The basic strategy for improving BMP performance across the watershed on County-controlled land is expected to entail a combination of the targeted placement of new BMPs and the retrofitting of failing BMPs. This would include the conversion of dry ponds to wet ponds or other practices with greater water quality management potential. Details of this strategy are discussed further in Section 5.

Figure 2.4 – Examples of Poorly Performing BMPs

Poorly Performing Infiltration Basin near Dunkeld Court in the Cypress Creek Subwatershed (MGC)

Poorly Performing Extended Detention Pond near Leelyn Drive in the Cypress Creek Subwatershed (MGC)

2.2.3 Agricultural Land Management Practices

Agricultural land use with the Magothy River Watershed is fairly limited, with row crop or pasture/hay land cover making up less than 1% (92 acres) of the watershed's total area. Nonetheless, an effort was undertaken to identify and account for the contributions of agricultural land management or conservation practices on pollutant loading within the watershed. Two windshield surveys were conducted to collect data on agricultural land use practices. The data obtained during the windshield surveys indicated that approximately half of the agricultural land is comprised of soybean crop. Horse farms comprise approximately one quarter of the agricultural land and there is a small amount of corn farmed in the watershed as well. These data were used to update the County's land use map. Acquisition of more detailed site-specific information regarding agricultural practices was not possible as these data are protected by privacy laws.

Some aggregated data on land management practices were provided by the Maryland Department of Agriculture. This information includes the number of acres covered by a Nutrient Management Plan (NMP) and the number of acres under a Soil Conservation and Water Quality (SCWQ) program plan. This information is summarized in Table 2.13 along with expected nutrient removal rates and expected pounds of nutrients removed per year. NMPs are plans that help farmers manage crop nutrients and animal waste, grow crops more efficiently, and protect water quality. All farm operators in the State that meet certain minimum criteria are required to have an NMP. SCWQ plans are a large part of Maryland's resource conservation and protection efforts. In general, the plans help farmers manage natural resources and identify and solve potential environmental problems while reaching optimal but sustainable production goals. The plans contain a menu of BMPs to help farmers prevent sediment, nutrients, and fertilizers from impacting nearby waterways. A technical memorandum with a more detailed description of the agricultural land practices assessment work during this study and some of the issues encountered is provided in Appendix A.

Table 2.13 – Aggregated Agricultural Conservation Practices

Conservation Practice	Acres in Watershed	Expected Nutrient Removal Rates*		Nutrient Removal/year	
		N (lbs/ac)	P (lbs/ac)	N (lbs)	P (lbs)
Nutrient Management Plan	42.3	3.11	0.3	132	13
SCWQ Plan	465	0.93	0.14	432	65
			TOTAL	**564**	**78**

2.2.4 Onsite Sewage Disposal Systems

OSDSs or septic systems can contribute high levels of nutrients, particularly nitrogen, and bacteria to downgradient 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, the locations and basic characteristics of OSDSs throughout the County were identified. This information was used with data on per capita loading to quantify aggregate pollutant loads from OSDSs across the Magothy River Watershed.

The 2008 OSDS study noted that the Magothy River Watershed has approximately 9,626 OSDSs, which represents approximately 24% of the OSDS County-wide. These systems contribute approximately 178,500 lbs of total nitrogen annually to streams within the watershed. The study identified 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 Magothy River Watershed, approximately 66% of OSDSs are recommended for connection to a sewer extension, 20% are recommended for cluster treatment, and 8% 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 142,200 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 "Low," "Medium," "Medium High," or "High" 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 Magothy River subwatersheds is presented in Table 2.14 and in Map 2.11. Approximately 76% of subwatersheds within the Magothy River Watershed are rated "Low" or "Medium." Three subwatersheds, Cockey Creek (MR6), Gray's Creek (MRE), and Old Man Creek (MRF), are rated "High" for total nitrogen contributions from OSDSs. Collectively, the estimated annual total nitrogen contribution from these three subwatersheds is 40,090 lbs/year. This represents approximately 22% of the watershed-wide total nitrogen contribution from OSDSs.

Table 2.14 – Total Annual Nitrogen Load Rating from OSDS

Rating	Number of Subwatersheds	Percent of Subwatersheds
Low	28	41.2%
Medium	24	35.3%
Medium High	13	19.1%
High	3	4.4%
TOTAL	**68**	**---**

2.2.5 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 data across subwatersheds. A summary of subwatershed ratings for soil erodibility is presented in Table 2.15 and depicted in Map 2.12. Approximately 7% of Subwatersheds are prioritized “High” for susceptibility to soil erosion.

Table 2.15 – Subwatershed Ratings for Soil Erodibility

Rating	Number of Subwatersheds	Percent of Subwatersheds
High	5	7.4%
Medium High	13	19.1%
Medium	33	48.5%
Low	17	25.0%
TOTAL	**68**	**---**

2.2.6 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 Areas 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 Magothy River 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. The GIS analyses associated with wetland cover were performed using GIS datasets obtained from MDNR.

As with previous indicator categories, subwatersheds are prioritized “Low,” “Medium,” “Medium High,” or “High” based on natural breaks in the data. Summaries of these ratings for Magothy River subwatersheds are presented in Tables 2.15 and 2.16 and depicted on Maps 2.13, 2.14, and 2.15.

Table 2.15 – Landscape Indicator Ratings (Subwatershed Restoration)

Rating	Number of Subwatersheds	Percent of Subwatersheds
Percent Impervious Cover		
High	20	29.4%
Medium High	19	27.9%
Medium	19	27.9%
Low	10	14.7%
Percent Forest within the 100-foot Stream Buffer		
High	11	22.0%
Medium High	18	36.0%
Medium	16	32.0%
Low	5	10.0%
Ratio of Existing to Potential Wetlands		
High	8	11.8%
Medium High	17	25.0%
Medium	16	23.5%
Low	27	39.7%
Acres of Developable Critical Area		
High	7	10.3%
Medium High	13	19.1%
Medium	21	30.9%
Low	27	39.7%

Table 2.16 – Landscape Indicator Ratings (Subwatershed Preservation)

Rating	Number of Subwatersheds	Percent of Subwatersheds
Percent Forest Cover		
High	13	19.1%
Medium High	21	30.9%
Medium	17	25.0%
Low	17	25.0%
Percent Wetland Cover		
High	6	8.8%
Medium High	8	11.8%
Medium	17	25.0%
Low	37	54.4%
Density of Headwater Streams		
High	8	11.8%
Medium High	11	16.2%
Medium	11	16.2%
Low	38	55.9%

Table 2.16 – Landscape Indicator Ratings (Subwatershed Preservation)

Rating	Number of Subwatersheds	Percent of Subwatersheds
Percent of Land within the Greenway Master Plan		
High	5	7.4%
Medium High	5	7.4%
Medium	9	13.2%
Low	49	72.1%
Presence of Bog Wetlands		
High	4	5.9%
Low	64	94.1%
Acres of RCA lands with the Critical Area		
High	8	11.8%
Medium High	7	10.3%
Medium	11	16.2%
Low	42	61.8%
Percent of Protected Lands		
High	3	4.4%
Medium High	4	5.9%
Medium	12	17.6%
Low	49	72.1%
Presence of Wellhead Protection Areas		
High	10	14.7%
Low	58	85.3%

Percent impervious cover was the most evenly distributed of the landscape indicator ratings for subwatershed restoration. The indicator associated with percent forest within the 100-foot stream buffer had most subwatersheds rated “Medium” or “Medium High.” The ratio of existing wetlands to potential wetlands and acres of developable land within the Critical Area were predominantly rated “Low” to “Medium.” Between 10 and 12% of subwatersheds were rated “High” for these latter two indicators of restoration need.

Most subwatersheds were rated on the “Low” end of the rating scale for the landscape indicators used to assess the need for preservation. Percent forest cover was the most evenly distributed of the preservation indicators with the subwatersheds apportioned equally between “High”/”Medium High” and “Medium”/”Low.” For the remaining indicators, between 4 and 15% of the subwatersheds were rated in the “High” category for preservation.

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3. HYDROLOGIC AND POLLUTANT LOAD MODELING

The data collection efforts described in Section 2 provide a solid basis for assessing the current status of the Magothy River Watershed and identifying potential stressors that may contribute to observed impairments. Modeling, which is the computer simulation of natural processes, serves to extend the utility of the collected data by allowing 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.

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 Magothy River 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 hydrologic and water quality model for the Magothy River 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, total phosphorus, total suspended solids, and fecal coliforms under current and ultimate build-out conditions. These loadings are used in the restoration and preservation prioritization assessment discussed in Section 4. The model is also used to calculate loading for pristine conditions for comparison purposes and to calculate other alternative land use and management scenarios as discussed in Section 5.

The model's basic elements are polygons determined in GIS by the geometric intersection of land use and hydrologic (subwatershed) boundaries. Table 3.1 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. Detailed information on the development and application of the County's water quality model were provided in previous watershed reports (Anne Arundel County, 2006).

Table 3.1 – 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
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
Federal Emergency Management Agency (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 Magothy River 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 Magothy River 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.

3.1.3 Modeling of Current and Ultimate Build-out Conditions

The County applied its hydrologic and water quality models to evaluate current and ultimate build-out conditions, which are reflected in the subwatershed assessments discussed in Section 4. Existing conditions were based on 2007 land cover data. Future conditions were based on an analysis of ultimate build-out conditions in the watershed. Pristine (pre-development) conditions were modeled for contextual purposes. Each modeled scenario began with the geometric intersection of the GIS layers described in Table 3.1, followed by application of various rules about 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. A summary of the modeled scenarios is presented in Table 3.2.

Table 3.2 – Modeled Water Quality Scenarios

Modeled Scenario	Purpose
A. Pristine Conditions	Baseline, all-forested condition representing pre-development state
B. Existing Conditions 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.

3.2 MODELING RESULTS

This subsection presents and discusses results from application of the hydrological and water quality models to the Magothy River Watershed.

3.2.1 Hydrologic Modeling

The hydrologic model results consisted of four hydrologic indicators for each Magothy River subwatershed:

- 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 Magothy River subwatersheds is presented in Table 3.3. For 65 of the 68 Magothy River 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 to lower priorities. Approximately 75% of subwatersheds within the Magothy River Watershed are rated “Low” for the two peak flow indicators. One subwatershed, Magothy River Tidal (MGU), was rated “High” for peak flow associated with both the one-year and two-year storm events. Another subwatershed, Indian Village Branch (MGW), was rated “High” for the one-year storm peak flow. The hydrologic indicator ratings for surface runoff yield were more evenly distributed among the rating categories. Approximately 53% of the subwatersheds were rated “Low” or “Medium” for the runoff indicator for both evaluated storm events. The remaining 47% of the subwatersheds were rated “High” or “Medium High.”

3.2.2 Water Quality Modeling Results

Water quality modeling results are summarized in Table 3.4, which lists the model-predicted annual loadings for the entire Magothy River 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 3.3 – Hydrologic Indicator Ratings

Rating	Number of Subwatersheds	Percent of Subwatersheds
Peak Flow (one-year storm)		
High	1	1.5%
Medium High	4	5.9%
Medium	12	17.6%
Low	51	75.0%
Peak Flow (two-year storm)		
High	2	2.9%
Medium High	3	4.4%
Medium	13	19.1%
Low	50	73.5%
Surface Runoff Yield (one-year storm)		
High	12	17.6%
Medium High	20	29.4%
Medium	14	20.6%
Low	22	32.3%
Surface Runoff Yield (two-year storm)		
High	12	17.6%
Medium High	20	29.4%
Medium	15	22.1%
Low	21	30.9%

Table 3.4 – Magothy River Watershed Annual Loads for Various Scenarios

Scenario	Total Phosphorus (lb/yr)	Total Nitrogen (lb/yr)	Total Suspended Solids (tons/yr)	Fecal Coliforms (cfu/yr)
A. Pristine	1,496	11,472	249	5.0E+06
B. Current	13,935	293,403	5,882	2.5E+13
C. Future	14,339	298,935	6,221	2.7E+13

Note: cfu = colony forming units

Additional detail about the sources of pollutant loadings watershed-wide under each scenario is provided in Table 3.5. 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 3.5 – Detailed Watershed Annual Loads for Various Scenarios

Scenario	Total	Loading Source			
		Urban	OSDS	Other	Agricultural
Total Phosphorus (lb/year)					
A. Pristine	1,496	---	---	1,496	---
B. Current	13,935	13,141	---	746	48
C. Future	14,339	13,956	---	376	7
Total Nitrogen (lb/year)					
A. Pristine	11,472	---	---	11,472	---
B. Current	293,403	108,869	178,496	5,956	82
C. Future	298,935	119,625	178,496	801	13
Total Suspended Solids (tons/year)					
A. Pristine	249	---	---	249	---
B. Current	5,882	5,715	---	158	9
C. Future	6,221	6,132	---	88	1
Fecal Coliform (cfu/year)					
A. Pristine	5.0E+06	---	---	5.0E+06	---
B. Current	2.5E+13	2.4E+13	---	4.8E+11	2.4E+09
C. Future	2.7E+13	2.7E+13	---	2.8E+11	3.6E+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 Magothy River subwatersheds is presented in Table 3.6. A visual representation of the existing condition pollutant loads within Magothy River 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. Between 13 and 22% of the subwatersheds were rated “High” for the two indicator categories.

Table 3.6 – Water Quality Indicator Ratings (Subwatershed Restoration)

Rating	Number of Subwatersheds	Percent of Subwatersheds
Total Nitrogen Load from Runoff		
High	15	22.0%
Medium High	21	30.9%
Medium	21	30.9%
Low	11	16.2%
Total Phosphorus Load from Runoff		
High	9	13.2%
Medium High	21	30.9%
Medium	27	39.7%
Low	11	16.2%

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 Magothy River subwatersheds is presented in Table 3.7 and is shown visually on Map 3.4. For the percent future departure of total nitrogen loading, over 85% of the subwatersheds were rated as “Low” or Medium” priorities. For the percent future departure of total phosphorus loads, “Low” or Medium” priorities comprise 69% of the total.

Table 3.7 – Water Quality Indicator Ratings (Subwatershed Preservation)

Rating	Number of Subwatersheds	Percent of Subwatersheds
Percent Future Departure of Total Nitrogen Load		
High	5	7.4%
Medium High	5	7.4%
Medium	10	14.7%
Low	48	70.6%
Percent Future Departure of Total Phosphorus Load		
High	7	10.3%
Medium High	14	20.6%
Medium	9	13.2%
Low	38	55.9%

4. RATING AND PRIORITIZATION

The County performs three detailed prioritization assessments to characterize current conditions within the watershed, to guide decisions that impact waterways, and to assist with land use management planning. The three assessments (stream restoration, subwatershed restoration, and subwatershed preservation) are presented in more detail in the following subsections. Each prioritization assessment relies on indicators derived from the data collected and compiled in Section 2 and the model results generated in Section 3.

4.1 STREAM RESTORATION ASSESSMENT AND RATING

The County's stream restoration assessment is intended to identify and rate the impaired stream reaches in the Magothy River Watershed to prioritize future stream restoration and capital improvement projects and to guide future land use management and development decisions. Methods and findings for the stream restoration assessment and rating are presented in this subsection.

4.1.1 Methods

The stream restoration assessment uses a suite of indicator scores or ratings that are weighted and combined to obtain a single stream restoration rating for each perennial reach. The indicators are grouped into one of five categories: stream habitat; stream morphology; land cover; infrastructure; and hydrology and hydraulics. As shown in Table 4.1, each category is comprised of one to six different indicators and each indicator has a relative weigh assigned by the County.

Table 4.1 – Stream Restoration Assessment Indicators

Category	**Indicator**	**Weight**
Stream Habitat	MPHI score	31.6%
Stream Morphology	Rosgen Level I classifications	5.3%
Land Cover	Imperviousness (%)	5.3%
Infrastructure	Stream 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, and obstructions)	15.8%
Hydrology and Hydraulics	Crossing flooding likelihood	15.8%

Among the indicators for stream restoration, the MPHI is utilized to represent the quality of physical stream habitat characteristics. Rosgen Level I classifications are used as an indicator of the degree of stability and entrenchment of each stream reach. The percentage of imperviousness contributes to increased stormwater volumes and thermal and chemical pollutant loading. The presence and impacts associated with stream buffers, channel erosion, head cuts, dumpsites, and other indicators (*i.e.*, pipes, ditches, stream crossings, and obstructions) are a sign of potential channel degradation, excessive pollution and sedimentation, and habitat impairment. Flooding and overtopping of road stream crossings pose an inconvenience and safety hazard to nearby residents.

4.1.2 Findings

Of the 168 assessed stream reaches in the Magothy River Watershed, 13 were rated "High" priorities for restoration. Of the 29 subwatersheds with assessed perennial streams, six had greater than one-third of their perennial streams rated as "Medium High" or "High" for restoration:

- Cypress Creek (MGC) had three assessed streams; all three were prioritized as "High"
- Magothy Narrows (MRM) had one assessed stream; it was prioritized "High"
- Little Magothy River (MGV) had 7 assessed stream reaches; three were prioritized "Medium High" and two were prioritized "High"
- Dividing Creek (MGH) had 15 assessed streams; eight were prioritized as "Medium High"
- Magothy Branch 1 (MR3) had ten assessed stream reaches; one was prioritized "Medium High" and three were prioritized "High"
- Forked Creek (MGL) had 16 assessed streams; five were prioritized "Medium High" and one was rated "High"

Otherwise, the majority of stream reaches in the Magothy River Watershed were assessed to be predominantly "Low" (48.8%) or "Medium High" (26.8%) on the prioritization scale for restoration. A breakdown of results by subwatershed is presented in Table 4.2. See Map 4.1 for a map of the stream restoration assessment results.

Table 4.2 – Stream Restoration Assessment Results

Subwatershed Name	Subwatershed Code	Number of Reaches with Rating				
		Low	Medium	Medium High	High	Total
Bailys Branch	MR1	4	2	3	0	9
Beechwood Branch	MR5	5	0	1	0	6
Blackhole Creek	MRG	2	1	0	0	3
Brookfield Branch	MR4	3	0	2	0	5
Cattail Creek 1	MRI	2	0	0	0	2
Cattail Creek 2	MRO	2	1	0	0	3
Cockey Creek	MR6	5	0	2	0	7
Cornfield Creek	MR0	1	0	0	0	1
Cypress Creek	MGC	0	0	0	3	3
Deep Creek	MGT	6	9	4	0	19
Dividing Creek	MGH	7	0	8	0	15
Forked Creek	MGL	6	4	5	1	16
Indian Village Branch	MGW	1	0	0	0	1
Kinder Branch	MR9	0	0	1	1	2
Little Magothy River	MGV	2	0	3	2	7
Magothy Branch	MR7	4	0	1	0	5
Magothy Branch 1	MR3	2	4	1	3	10
Magothy Branch 2	MG1	3	1	1	0	5
Magothy Narrows	MRM	0	0	0	1	1
Magothy River Tidal	MGR	1	0	0	0	1
Magothy River Tidal	MGP	1	1	0	0	2
Mill Creek	MGI	11	1	3	2	17
Muddy Run	MR2	1	1	1	0	3
Nannys Branch	MGY	4	1	3	0	8
Nannys Creek	MRB	0	0	3	0	3
Old Man Creek	MRF	2	0	0	0	2
Ross Cove	MRL	1	1	0	0	2
Rouses Branch	MRA	6	0	3	0	9
Scheides Cove	MGM	0	1	0	0	1
Total		**82 (48.8%)**	**28 (16.7%)**	**45 (26.8%)**	**13 (7.7%)**	**168**

4.2 SUBWATERSHED RESTORATION ASSESSMENT AND RATING

The County's subwatershed restoration assessment is intended to identify and rate those subwatersheds where conditions warrant consideration for restoration activities. Methods and findings for the subwatershed restoration assessment and rating are presented in this subsection.

4.2.1 Methods

Like the stream restoration assessment, the subwatershed restoration assessment uses a suite of indicator ratings that are weighted and combined to obtain a single restoration rating for each subwatershed. The indicators are grouped into one of six categories: stream ecology; OSDSs; BMPs; water quantity; water quality; and landscape. Each category is comprised of one to four different indicators. A summary of the indicators and their relative weighting assigned by the County are presented in Table 4.3.

Table 4.3 – Subwatershed Restoration Assessment Indicators

Category	Indicator	Weight
Stream Ecology	Final habitat score	8.4%
	Bioassessment score	8.4%
OSDSs	Total nitrogen load from OSDSs (lbs)	6.7%
BMPs	Impervious area treated by BMPs (%)	6.7%
Water Quantity	Peak flow from 1-year storm (cfs/ac)	4.6%
	Peak flow from 2-year storm (cfs/ac)	4.6%
	Runoff volume from 1-year storm (in)	5.8%
	Runoff volume from 2-year storm (in)	5.8%
Water Quality	Total nitrogen load from runoff (lbs/acre/yr)	7.0%
	Total phosphorus load from runoff (lbs/acre/yr)	7.0%
Landscape	% Impervious cover	9.6%
	% Forest within the 100 ft stream buffer	10.4%
	% of existing wetlands to potential wetlands	9.6%
	Acres of developable Critical Area	5.4%

Among the indicators for the subwatershed restoration assessment, the final habitat and bioassessment scores are used as indicators of the quality of the physical and biological characteristics of stream reaches in the subwatershed. Peak flow and runoff volume are indicators of hydrology changes due to increased development and urbanization. The relative magnitude of total nitrogen loading from septics and total nitrogen and total phosphorus loading from runoff are indicative of potential water quality degradation in each subwatershed. BMP and landscape indicators including percent imperviousness, percent BMP treatment, and percent forested buffer influence stormwater volumes, peak flows, and pollutant loading. The presence of potential wetland areas and acres of developable Critical Area serve as indicators of restoration potential.

4.2.2 Results

The subwatersheds in the Magothy River Watershed were assessed to identify restoration needs. Of the 68 subwatersheds assessed, 10 were rated "High," which makes them high priorities for restoration. These 10 subwatersheds rated "High" include:

- Cypress Creek (MGC)
- Deep Creek (MGT)
- Little Magothy River (MGV)
- Indian Village Branch (MGW)
- Hunters Harbor (MRD)
- Cattail Creek 2 (MRO)
- Beechwood Branch (MR5)
- Mill Creek (MGI)
- Magothy River Tidal (MGF)
- Unnamed Tributary (MGA)

Otherwise, the majority of the subwatersheds were assessed to be predominantly "Medium High" (29.4%) or "Medium" (32.4%) on the prioritization scale for restoration needs. A smaller group of 16 subwatersheds (23.5%) were assessed to show a "Low" need for restoration. The breakdown of rating results by subwatershed is presented in Table 4.4. See Map 4.2 for a map of the subwatershed restoration assessment results.

Table 4.4 – Subwatershed Restoration Assessment Results

Rating	Number of Subwatersheds	Percent of Subwatersheds
High	10	14.7%
Medium High	20	29.4%
Medium	22	32.4%
Low	16	23.5%
TOTAL	**68**	**---**

4.3 SUBWATERSHED PRESERVATION ASSESSMENT AND RATING

The County's subwatershed preservation assessment is intended to identify and rate those subwatersheds where conditions warrant consideration for preservation activities. Methods and findings for the subwatershed preservation assessment and rating are presented in this subsection.

4.3.1 Methods

The subwatershed preservation assessment uses a suite of indicator ratings that are weighted and combined to obtain a single preservation rating for each subwatershed. The indicators are grouped into one of five categories: stream ecology, future departure of water quality conditions, soils, landscape, and aquatic living resources. Each category is comprised of one to eight different indicators. A summary of the indicators and the relative weighting assigned by the County are provided in Table 4.5.

Table 4.5 – Subwatershed Preservation Assessment Indicators

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 phosphorus	11.1%
Soils	NRCS soil erodibility factor	7.4%
Landscape	Percent forest cover	11.1%
	Percent wetland cover	11.1%
	Density of headwater streams (ft/ac)	7.4%
	Percent of land within the Greenway Master Plan	3.7%
	Presence of bog wetlands	3.7%
	Acres of RCA lands within 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 subwatersheds in the Magothy River Watershed were well distributed on the preservation rating scale. Subwatersheds were apportioned equally between "High"/"Medium High" and "Medium"/"Low" ratings. Of the 68 subwatersheds assessed, 14 were rated "High" priorities for preservation. These 14 subwatersheds include:

- Blackhole Creek (MRG)
- Otter Pond (MGE)
- Magothy Narrows (MRM)
- Cornfield Creek (MR0)
- Cockey Creek (MR6)
- Broad Creek (MGJ)
- Magothy Branch 1 (MR3)
- Magothy River Tidal (MGX)
- Nannys Branch (MGY)
- James Pond (MRJ)
- Rouses Branch (MRA)
- Brookfield Branch (MR4)
- Sillery Bay (MG8)
- Podickery Creek (MGZ)

A breakdown of rating results by subwatershed is presented in Table 4-6. Map 4.3 depicts the subwatershed preservation assessment results.

Table 4.6 – Subwatershed Preservation Assessment Results

Rating	Number of Subwatersheds	Percent of Subwatersheds
High	14	20.6%
Medium High	20	29.4%
Medium	15	22.1%
Low	19	27.9%
TOTAL	**68**	**---**

The County recognized that finer resolution was needed with the identification of areas in need of preservation. The ability to identify high priorities for preservation at the subwatershed level was useful, but somewhat limiting in that many land management decisions are often made on much smaller scales. As such, the County performed the preservation assessment again, but applied it at the parcel level. The result, depicted on Map 4.4, is a ranking of the highest priority parcels for preservation throughout the Magothy River Watershed. A list of the top 200 parcels is provided in Appendix C.

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5. RESTORATION AND PRESERVATION IMPLEMENTATION PLAN

As discussed in detail in the previous sections, the County performed extensive data collection and compilation (Section 2); applied hydrologic and water quality models (Section 3); and prioritized stream reaches and subwatersheds based on the need for restoration and preservation (Section 4). These steps were critical for developing a better understanding of watershed conditions and identifying priorities in the watershed. The information developed during these steps was instrumental in formulating the restoration and preservation implementation plan for the watershed.

This section identifies and describes a specific restoration and preservation implementation plan for the Magothy River Watershed. The components of this plan rest on watershed goals, the development of potential restoration activities, the modeling of future restoration scenarios, and a cost-benefit analysis of restoration scenarios. These components are discussed in detail in this section along with a set of specific recommendations for implementation. In addition, concept design plans for a subset of prioritized sites within the Magothy River Watershed are also presented.

5.1 WATERSHED GOALS

An implementation plan for restoration and preservation of a watershed needs to consider aspirational goals while setting realistic targets that can be met through complete implementation of the plan. For the Magothy River Watershed, the aspirational goals advocated by stakeholders include restoration of the watershed and its waterbodies to pre-development clarity levels, and the return of extensive and diverse populations of aquatic life such as turtles and fish. These types of goals are useful to consider in community settings to define a common vision and to build support for difficult implementation strategies.

Realistic targets for an implementation plan are typically based on measures established through County programs and other regulatory mechanisms, such as NPDES permits or TMDL plans. These goals should be measurable, defensible, reasonable, and feasible.

Much of the data and analyses discussed in the previous sections were designed to support the establishment of specific numeric goals, the achievement of which would result in improvements in watershed health and continued progress in regulatory compliance. The following approaches were considered in setting numeric goals:

- Benthic Index of Biotic Integrity – Relationships between BIBI values and other watershed characteristics such as septic system density or water quality loadings were examined, as some correlations had been found in other County watersheds. Single and multivariate regression analyses were used to develop predictive relationships that describe the BIBI in terms of known watershed stressors. In the Magothy River Watershed, a relationship was established between Final Habitat Scores, percent of wetland loss, and nitrogen loading from OSDS. This suggests that implementation of associated restoration activities (*i.e.,* habitat restoration, wetland creation, and septic system retrofits) could potentially result in the restoration or improvement of biological functions within the watershed.

The regression relationship produced from the multivariate analysis was:

$$BIBI = 0.18 + 0.004(Final\ Habitat\ Score) - 0.002(\%Wetland\ \ Loss) - 0.0025(TN_{sep})$$

Using this relationship, a target BIBI goal (*e.g.,* "Fair" or 3) could potentially be achieved through a combination of restoration activities that increase the Final Habitat Score, increase the percentage of wetlands, and/or decrease the total nitrogen loading (lbs/acre/year) from septic systems.

- TMDL – Since the TMDL in the Magothy River is currently limited to bacteria, the County elected to use the approved Baltimore Harbor TMDL for nutrients as surrogate waste load targets.
- Ultimate Condition with 10% Impervious Cover – Target loadings were set equivalent to loads expected with full future build-out development, but with effective impervious surface limited to 10% of the developed area. This impervious surface limit is consistent with that observed by the Center for Watershed Protection (discussed in Section 2.2.1) as the inflection point for degradation of habitat, aquatic life, and water quality.
- 2004 NPDES Permit – This target reflects the reduction in pollutant loads associated with the 10% reduction in impervious surface required by the County's MS4 permit. Load reduction is assumed to be 10% for this analysis. An associated metric is the total area of uncontrolled impervious surface that can come under future control.
- Pristine Condition – For reference purposes, land use for the entire watershed was set to pre-development conditions, assumed here to be forest throughout. Loadings under pristine conditions are not used as a goal for the implementation plan.

5.2 DEVELOPMENT OF POTENTIAL RESTORATION ACTIVITIES

The development of potential restoration scenarios is accomplished through an analysis of restoration need followed by the identification of options for specific restoration activities. The County established priorities for restoration need through its stream and subwatershed restoration assessments discussed in Section 4. From these assessments, the County selected the 13 highest ranking subwatersheds in need of restoration. This includes the subwatersheds that scored as a "High" or "Medium High" priority for restoration. These subwatersheds include:

- Magothy Branch 2 (MG1)
- Cypress Creek (MGC)
- Magothy River Tidal (MGF)
- Dividing Creek (MGH)
- Mill Creek (MGI)
- Deep Creek (MGT)
- Little Magothy River (MGV)
- Indian Village Branch (MGW)
- Nannys Branch (MGY)
- Cockey Creek (MR6)
- Hunters Harbor (MRD)
- Old Man's Creek (MRF)
- Cattail Creek (MRI/MRO)

In general, the County considers a number of specific activities to restore stream health and function and to improve management of stormwater runoff and pollutants from upland areas. In reality, the number of potential restoration project types far exceeds what is reasonable to consider for a planning level analysis such as this. As such, the County has selected the following six generalized restoration projects that represent a wide range of commonly used options with proven effectiveness in terms of implementability, cost, and performance.

- <u>Shallow Marsh and Regenerative Wetland Seepage System</u> – This restoration activity is used to rehabilitate destabilized stream channels. Typically through the installation of these systems, an incised stream will be reconnected with its flood plain (via bank cuts or bed grade adjustments) and a series of riffle weirs and sand filters will be used to create shallow flood plain marshes and wetland areas. This regenerative technique serves to slow down overall stream flow, promote establishment of aquatic habitat, and improve water quality.
- <u>Regenerative Step Pool Outfall Sand Filtration Device</u> – This restoration activity is employed as a stormwater outfall retrofit. The device utilizes a series of shallow pools, riffle weir grade controls, native vegetation, and underlying sand and compost filters to treat, detain, and safely convey drainage area runoff. These outfall retrofits increase infiltration and dampen flow velocities, which enhances removal of suspended particles and associated nutrients and decreases downstream bed and bank erosion in receiving waterbodies.
- <u>Dry Pond Retrofit</u> – This restoration activity entails converting dry ponds or dry extended detention ponds that are typically designed for water quantity management to wet ponds or other vegetated systems that are designed for water quality management.
- <u>Concrete Ditch Retrofit to Water Quality Swale</u> – This restoration activity involves replacing concrete or asphalt-lined ditches used to convey storm flow with a water quality swale. These swales typically contained vegetation features designed to dampen flow and promote pollutant removal.
- <u>Enhanced Stormwater Retrofit (Bioretention Facility)</u> – This restoration activity involves installing bioretention facilities or other vegetated practices with equivalent high pollutant removal efficiencies. These facilities can either be used to replace poorly performing BMPs or as new installation where improved stormwater management is needed.
- <u>Onsite Sewage Discharge System Retrofits</u> – This restoration activity includes the recommendations set out in the 2008 OSDS Study; namely sewer extension to an existing WRF, clustering of community sewer services, and OSDS upgrades with enhanced total nitrogen removal. These retrofits primarily reduce subsurface nitrogen loading to streams.

With general restoration areas identified and an arsenal of restoration activities, the County developed specific projects to meet restoration needs. The County utilized a combination of desktop GIS analyses, hydrologic modeling, and field visits to confirm suitability of the potential restoration projects. Desktop GIS analyses included evaluation of existing infrastructure and BMPs, land use, property ownership, and accessibility among other considerations. The County also reviewed upcoming capital improvement projects to ensure that there were no conflicts with existing projects and to identify potential future projects where leveraging could occur to provide additional stormwater management benefit.

The County initially performed this analysis to support a Local Implementation Grant application submitted in August 2008 to the Chesapeake and Atlantic Coastal Bays 2010 Trust Fund (Magothy 2010 Grant). This successful grant application included the identification of 32 projects within the Cypress Creek (MGC), Dividing Creek (MGH), and Mill Creek (MGI) subwatersheds. Additional restoration projects were subsequently conceived within the remaining ten priority subwatersheds. To date, the County has identified 67 specific retrofit/restoration projects within the 13 priority subwatersheds.

5.3 MODELING FUTURE RESTORATION SCENARIOS

The County applied its hydrologic and pollutant load modeling (previously discussed in Section 3) to evaluate the potential for the identified restoration projects to reduce pollutant loading and meet the various numeric goals established in Section 5.1. To do this, the County developed and modeled future restoration scenarios based on the six generalized restoration project groups and the aggregate characteristics of the 67 specific restoration projects. The methods and results of this modeling effort are discussed in the following subsections.

5.3.1 Methods

The County applied the water quality model to evaluate a variety of alternate scenarios with the intent of characterizing water quality and potential for improvements. Each scenario was modeled in the same manner as the three conditions evaluated in Section 3. The modeled scenarios are presented in Table 5.1. For each scenario, the County used pollutant removal efficiencies identified in Table 5.2 and determined the resultant pollutant loading for total nitrogen, total phosphorus, total suspended solids, and fecal coliform.

Table 5.1 – Modeled Water Quality Scenarios

Modeled Scenario	Purpose
A. Pristine Conditions	Baseline, all-forested condition representing pre-development state
B. Existing Conditions	Current land use and existing BMPs fully maintained
C. Future Conditions	Expected future land use with existing BMPs; development informed by future stormwater regulations and sewer master plan.
D. Existing Conditions with Dry Pond Retrofits	Same as Scenario B with the addition of dry pond retrofit projects (*e.g.*, Trinity Farm Pond)
E. Existing Conditions with Concrete Ditch Retrofit to Water Quality Swales	Same as Scenario B with the addition of concrete ditch retrofit to water quality swale projects (*e.g.*, McKinsey Road)
F. Existing Conditions with Enhanced Stormwater Retrofit (Bioretention Facilities)	Same as Scenario B with the addition of bioretention facility projects (*e.g.*, Severna Park Elementary School)
G. Existing Conditions with Regenerative Step Pool Outfall Sand Filtration Devices	Same as Scenario B with the addition of regenerative step pool outfall projects (*e.g.*, Community College outfalls)
H. Existing Conditions with Shallow Marsh and Regenerative Wetland Seepage Systems	Same as Scenario B with the addition of shallow marsh and regenerative wetland seepage systems (*e.g.,* Severna Park Golf Coastal Plain Outfall)
I. Existing Conditions with OSDS Retrofits	Same as Scenario B with the implementation of retrofits identified in the OSDS Study
J. Existing Conditions with All Retrofits and Restoration Projects Implemented	Same as Scenario B with the inclusion of all BMPs identified in Scenarios D through I.

Table 5.2 – Restoration/Retrofit Pollutant Reduction Assumptions

Retrofit Scenario	Performance
Shallow Marsh and Regenerative Wetland Seepage Systems	45% reduction in Total Phosphorus 20% reduction in Total Nitrogen
Regenerative Step Pool Outfall Sand Filtration Device	60% reduction in Total Phosphorus 40% reduction in Total Nitrogen
Dry Pond Retrofit	60% reduction in Total Phosphorus 40% reduction in Total Nitrogen
Concrete Ditch Retrofit to Water Quality Swales	60% reduction in Total Phosphorus 40% reduction in Total Nitrogen
Enhanced Stormwater Retrofits (Bioretention Facilities)	60% reduction in Total Phosphorus 50% reduction in Total Nitrogen
OSDS Retrofits	50% reduction in Total Nitrogen

5.3.2 Water Quality Modeling Results

Water quality modeling results are summarized in Table 5.3, which lists the model-predicted annual loadings for the entire Magothy River Watershed of total phosphorus, total nitrogen, total suspended solids, and fecal coliforms for all modeled scenarios. The results from the pristine, current, and future condition scenarios from Section 3 are repeated here for comparison purposes.

Table 5.3 – Magothy River Watershed Annual Loads for Alternate Scenarios

Scenario	Total Phosphorus (lb/yr)	Total Nitrogen (lb/yr)	Total Suspended Solids (tons/yr)	Fecal Coliforms (cfu/yr)
A. Pristine	1,496	11,472	249	5.0E+06
B. Current	13,935	293,403	5,882	2.5E+13
C. Future	14,339	298,935	6,221	2.7E+13
D. Dry Pond Retrofit	13,897	293,192	5,858	2.5E+13
E. Water Quality Swales	13,787	292,585	5,791	2.4E+13
F. Bioretention	13,862	292,897	5,837	2.5E+13
G. Step Pool Outfalls	13,537	291,205	5,637	2.4E+13
H. Marsh/Wetlands	12,577	289,290	5,095	2.0E+13
I. OSDS Retrofits	13,935	151,099	5,882	2.5E+13
J. All Projects (D-I)	11,920	143,252	4,689	1.8E+13

Table 5.4 shows the percent change in loading for Scenarios C through J as compared to current conditions (Scenario B). Several points of interest can be seen in review of this table:

- Development , even with strict enforcement of aggressive stormwater regulations (Scenario C), will result in increases in loadings of all pollutants.
- Total nitrogen and total phosphorus in stormwater runoff are generally more difficult to remove than total suspended solids or fecal coliforms.
- The Shallow Marsh and Regenerative Wetland Seepage System scenario is the most effective at removing total phosphorus, total suspended solids, and fecal coliforms due in part to the large drainage areas of the proposed projects.
- Total nitrogen loadings are most effectively reduced with actions addressing septic systems, such as sewer extensions and septic system repairs or replacements. The cumulative effectiveness of this scenario is driven by the large number of OSDSs proposed to be replaced or retrofitted.

It is important to note that the specific restoration activities represented in Scenarios D through H do not represent an exhaustive list of associated restoration opportunities within the watershed. For planning and short-term implementation purposes, restoration activities under these scenarios were limited to public lands and other areas with minimal implementation challenges. Higher loading reductions could be possible as broader areas are considered for these types of restoration activities.

Charts showing the watershed-wide total loadings and the loading components are included in Figures 5.1 through 5.4. Table 5.5 provides more detail about the sources of pollutant loadings watershed-wide under all modeled scenarios. Urban runoff continues to be the primary loading component for total phosphorus, total suspended solids, and fecal coliforms, while septic loads are the primary loading component for total nitrogen. Under future conditions, loads from urban areas generally grow while loads from agricultural and other lands decrease, reflecting changes in land use with development. The water quality model results were also reviewed for the 13 priority subwatersheds identified in Section 5.2. Similar patterns were observed in the results across the modeled scenarios except where particular types of restoration or retrofit were not applicable for the particular subwatershed.

Table 5.4 – Change In Watershed Annual Loads Compared to Current Conditions

Scenario	Total Phosphorus	Total Nitrogen	Total Suspended Solids	Fecal Coliforms
C. Future	+2.9%	+1.9%	+5.8%	+8.8%
D. Dry Pond Retrofit	-0.3%	-0.1%	-0.4%	-0.4%
E. Water Quality Swales	-1.1%	-0.3%	-1.6%	-1.7%
F. Bioretention	-0.5%	-0.2%	-0.8%	-0.8%
G. Step Pool Outfalls	-2.9%	-0.7%	-4.2%	-4.5%
H. Marsh/Wetlands	-9.7%	-1.4%	-13.4%	-19.1%
I. OSDS Retrofits	0.0%	-48.5%	0.0%	0.0%
J. All Projects (D-I)	-14.5%	-51.2%	-20.3%	-26.5%

Figure 5.1 – Water Quality Modeling Results for Existing and Future Scenarios – Total Phosphorus

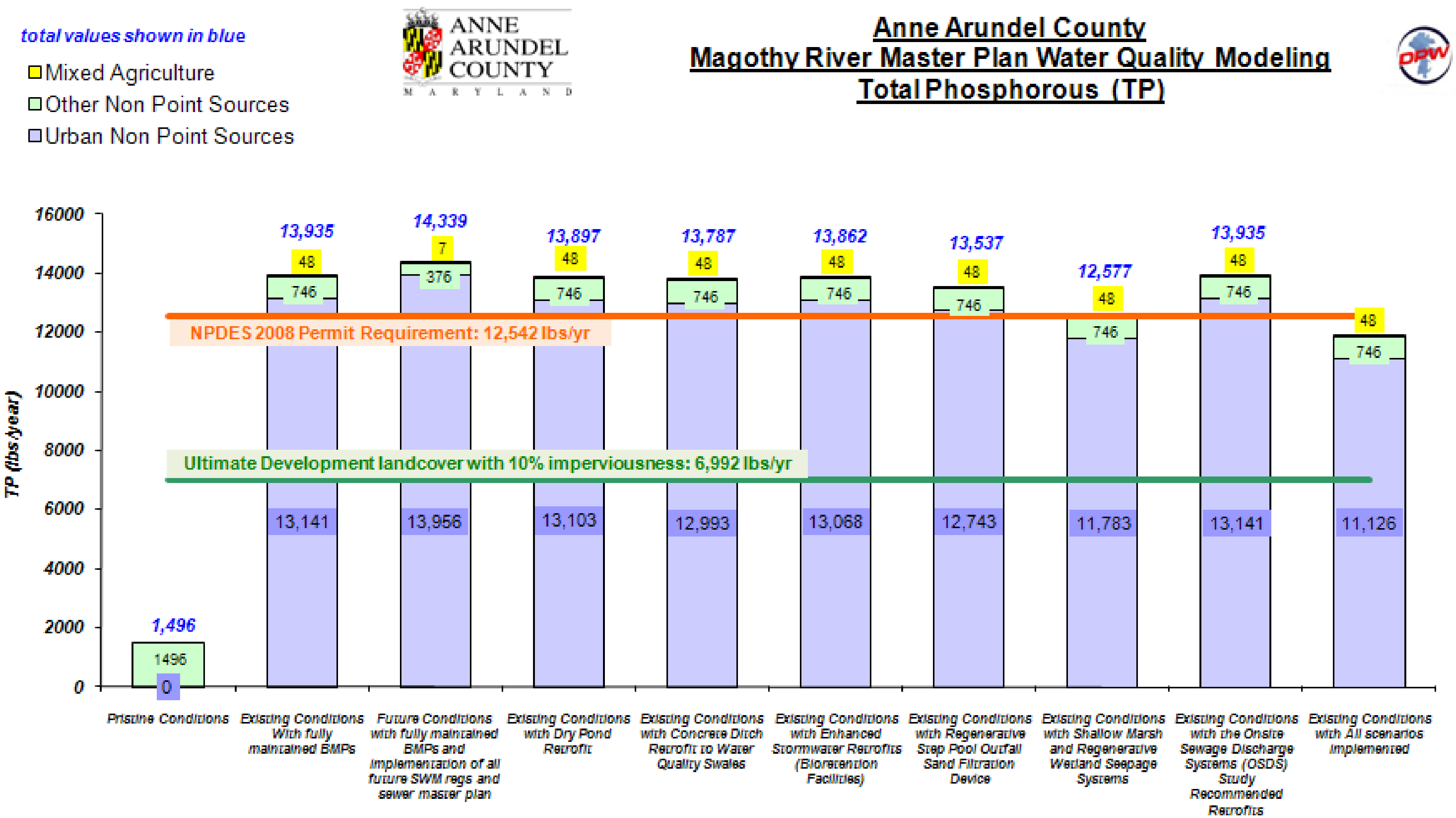

Figure 5.2 – Water Quality Modeling Results for Existing and Future Scenarios – Total Nitrogen

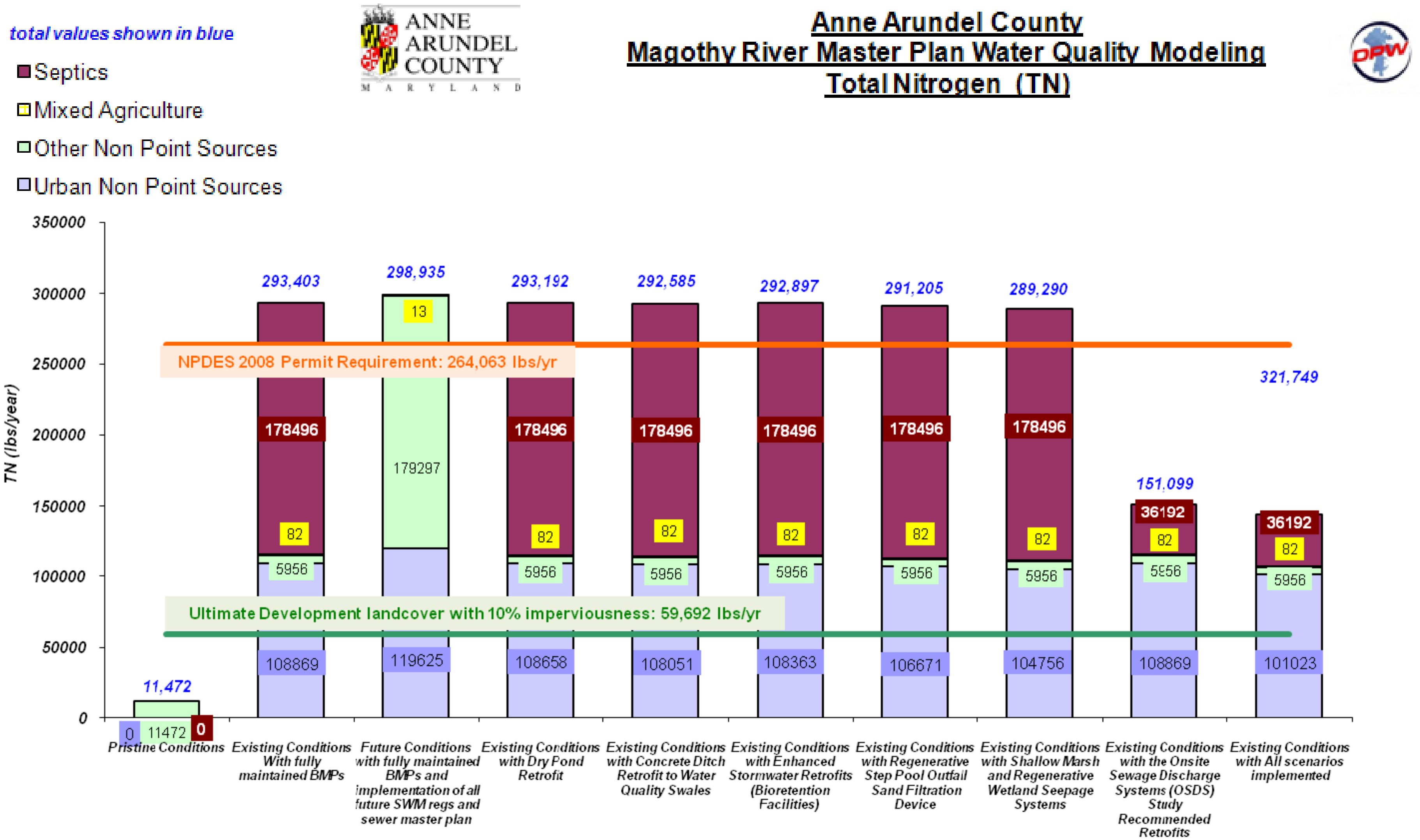

Figure 5.3 – Water Quality Modeling Results for Existing and Future Scenarios – Total Suspended Solids

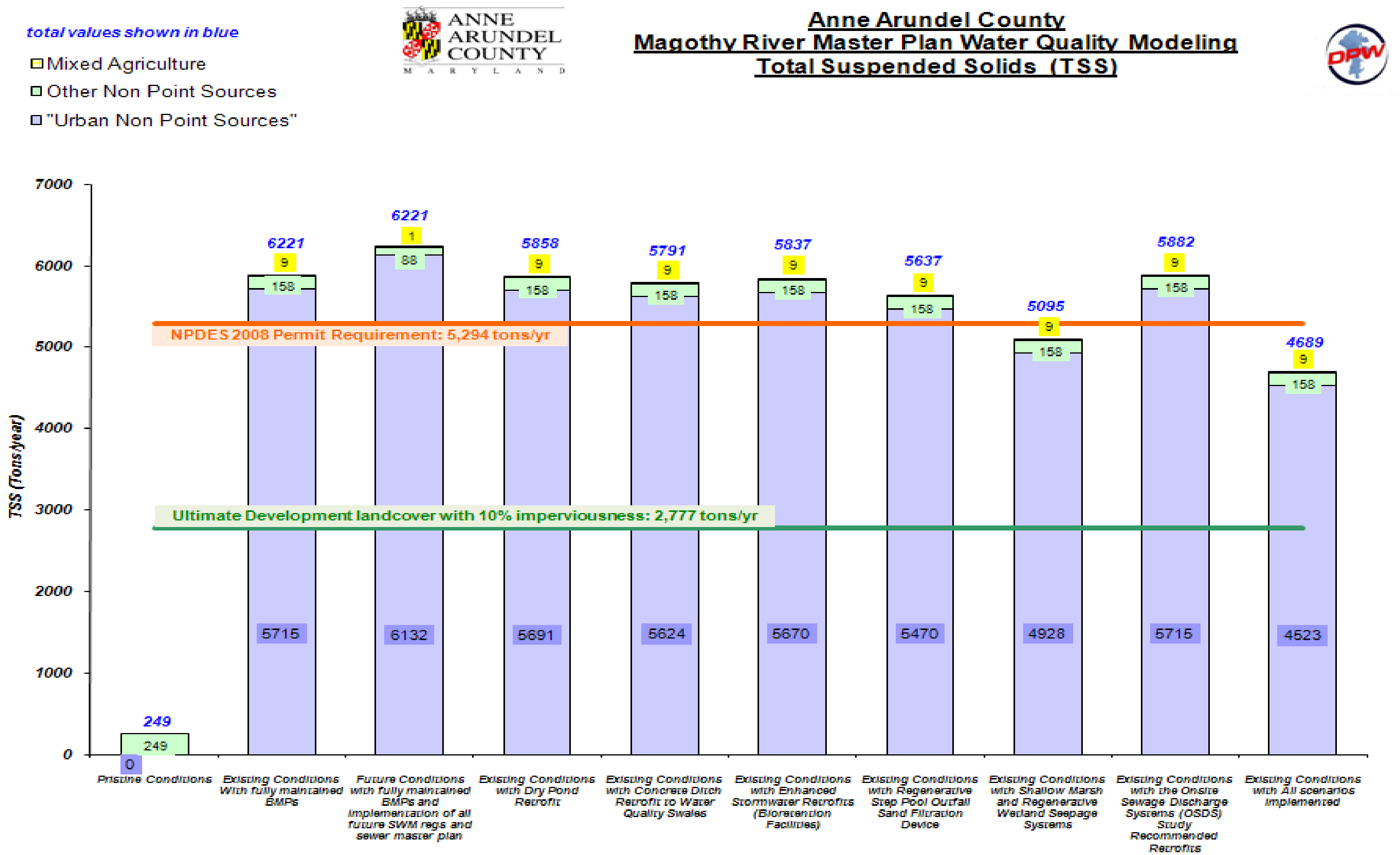

Figure 5.4 – Water Quality Modeling Results for Existing and Future Scenarios – Fecal Coliform

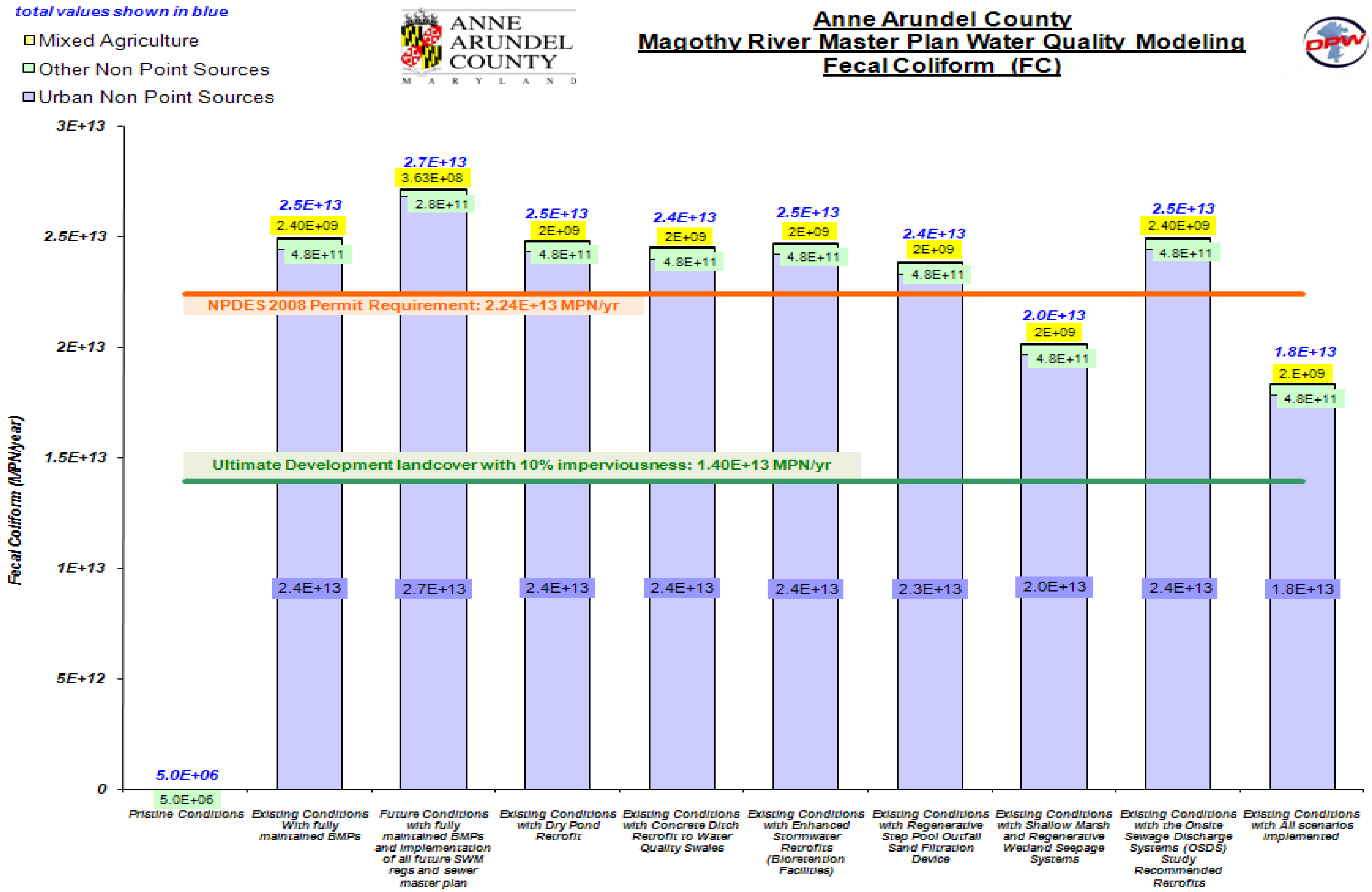

Table 5.5 – Detailed Watershed Annual Loads for Alternate Scenarios

Scenario	**Total**	**Change from Current**	**Loading Source**			
			Urban	Septic	Other	Agricultural
Total Nitrogen (lb/year)						
A. Pristine	11,472	---	---	---	11,472	---
B. Current	293,403	---	108,869	178,496	5,956	82
C. Future	298,935	(+1.9%)	119,625	---	801	13
D. Dry Pond Retrofit	293,192	(-0.1%)	108,658	178,496	5,956	82
E. Water Quality Swales	292,585	(-0.3%)	108,051	178,496	5,956	82
F. Bioretention	292,897	(-0.2%)	108,363	178,496	5,956	82
G. Step Pool Outfalls	291,205	(-0.7%)	106,671	178,496	5,956	82
H. Marsh/Wetlands	289,290	(-1.4%)	104,756	178,496	5,956	82
I. OSDS Retrofits	151,099	(-48.5%)	108,869	36,192	5,956	82
J. All Projects (D-I)	143,252	(-51.2%)	101,023	36,192	5,956	82
Total Phosphorus (lb/year)						
A. Pristine	1,496	---	---	---	1,496	---
B. Current	13,935	---	13,141	---	746	48
C. Future	14,339	(+2.9%)	13,956	---	376	7
D. Dry Pond Retrofit	13,897	(-0.3%)	13,103	---	746	48
E. Water Quality Swales	13,787	(-1.1%)	12,993	---	746	48
F. Bioretention	13,862	(-0.5%)	13,068	---	746	48
G. Step Pool Outfalls	13,537	(-2.9%)	12,743	---	746	48
H. Marsh/Wetlands	12,577	(-9.7%)	11,783	---	746	48
I. OSDS Retrofits	13,935	---	13,141	---	746	48
J. All Projects (D-I)	11,920	(-14.5%)	11,126	---	746	48

Table 5.5 – Detailed Watershed Annual Loads for Alternate Scenarios (continued)

Scenario	Total	Change from Current	Loading Source			
			Urban	Septic	Other	Agricultural
Total Suspended Solids (tons/year)						
A. Pristine	249	---	---	---	249	---
B. Current	5,882	---	5,715	---	158	9
C. Future	6, 221	(-55.4%)	6,132	---	88	1
D. Dry Pond Retrofit	5,858	(-58.0%)	5,691	---	158	9
E. Water Quality Swales	5,791	(-58.4%)	5,624	---	158	9
F. Bioretention	5,837	(-58.1%)	5,670	---	158	9
G. Step Pool Outfalls	5,637	(-59.5%)	5,470	---	158	9
H. Marsh/Wetlands	5,095	(-63.4%)	4,928	---	158	9
I. OSDS Retrofits	5,882	(-57.8%)	5,715	---	158	9
J. All Projects (D-I)	4,689	(-66.3%)	4,523	---	158	9
Fecal Coliform (cfu/year)						
A. Pristine	5.0E+06	---	---	---	5.0E+06	---
B. Current	2.5E+13	---	2.4E+13	---	4.8E+11	2.4E+09
C. Future	2.7E+13	(+8.8%)	2.7E+13	---	2.8E+11	3.6E+08
D. Dry Pond Retrofit	2.5E+13	(-0.4%)	2.4E+13	---	4.8E+11	2.4E+09
E. Water Quality Swales	2.4E+13	(-1.7%)	2.4E+13	---	4.8E+11	2.4E+09
F. Bioretention	2.5E+13	(-0.8%)	2.4E+13	---	4.8E+11	2.4E+09
G. Step Pool Outfalls	2.4E+13	(-4.5%)	2.3E+13	---	4.8E+11	2.4E+09
H. Marsh/Wetlands	2.0E+13	(-19.1%)	2.0E+13	---	4.8E+11	2.4E+09
I. OSDS Retrofits	2.5E+13	---	2.4E+13	---	4.8E+11	2.4E+09
J. All Projects (D-I)	1.8E+13	(-26.5%)	1.8E+13	---	4.8E+11	2.4E+09

5.4 COST-BENEFIT ANALYSES OF RESTORATION SCENARIOS

When considering opportunities to reduce pollutant loading, it is helpful to appreciate the relative value of implementing one restoration scenario over another in terms of setting financial priorities. Comparing retrofit and restoration activity costs relative to their pollutant removal effectiveness is one of the important considerations in the County's decision-making process. An evaluation of the costs relative to pollutant removal was performed as part of this study. For this analysis, the County applied cost factors from existing projects within the County to develop an appreciation for relative costs and benefits of the proposed retrofit/restoration opportunities. The evaluation methods are described below along with the results and discussion.

5.4.1 Methods

The benefits (in terms of pollutant load reductions) for each restoration scenario were calculated using the water quality model as described above. The County estimated costs for each scenario were based on known previous project costs or from development of unit costs based on treatment of a defined drainage area (which could then be extrapolated to smaller or larger drainage areas) (*i.e*., quantity takeoff). For OSDS retrofits, the County utilized the implementation costs outlined in the 2008 OSDS report. Cost assumptions are presented in Table 5.6.

Table 5.6 – Restoration/Retrofit Unit Cost Assumptions

Retrofit Scenario	Unit Cost/Assumptions
Shallow Marsh and Regenerative Wetland Seepage Systems	$800 per linear foot of restoration. Based on average estimates from historic projects
Regenerative Step Pool Outfall Sand Filtration Device	$500 per linear foot of restoration. Based on average estimates from historic projects
Dry Pond Retrofit	Average $50,000 per facility. EPA cost equation based on volume. Http://cfoyb.epa.gov/npdes/stormwater/menufbmp/post_26.cfm
Concrete Ditch Retrofit to Water Quality Swales	$750 per linear foot of restoration. Based on quantity takeoff.
Enhanced Stormwater Retrofits (Bioretention Facilities)	$60,000 per impervious acre treated. Based on quantity takeoff.
OSDS Retrofits	$13,000 - $38,000 per system

5.4.2 Results and Discussion

The results of the cost/benefit calculations are presented in both tabular and graphical format. Figure 5.5 compares the modeled cost effectiveness across the entire watershed of different scenarios that correspond to different retrofit and restoration types. Figures 5.6 through 5.8 compare the total removal and the cost-effectiveness for total phosphorus (TP), total nitrogen (TN), and total suspended solids (TSS) in the priority subwatersheds. Table 5.7 summarizes the calculated unit costs for removal of these pollutants assuming all retrofit and restoration projects are implemented.

Figure 5.5 – Cost/Benefit Ratio of Retrofit and Restoration Scenarios for Pollutant Removal

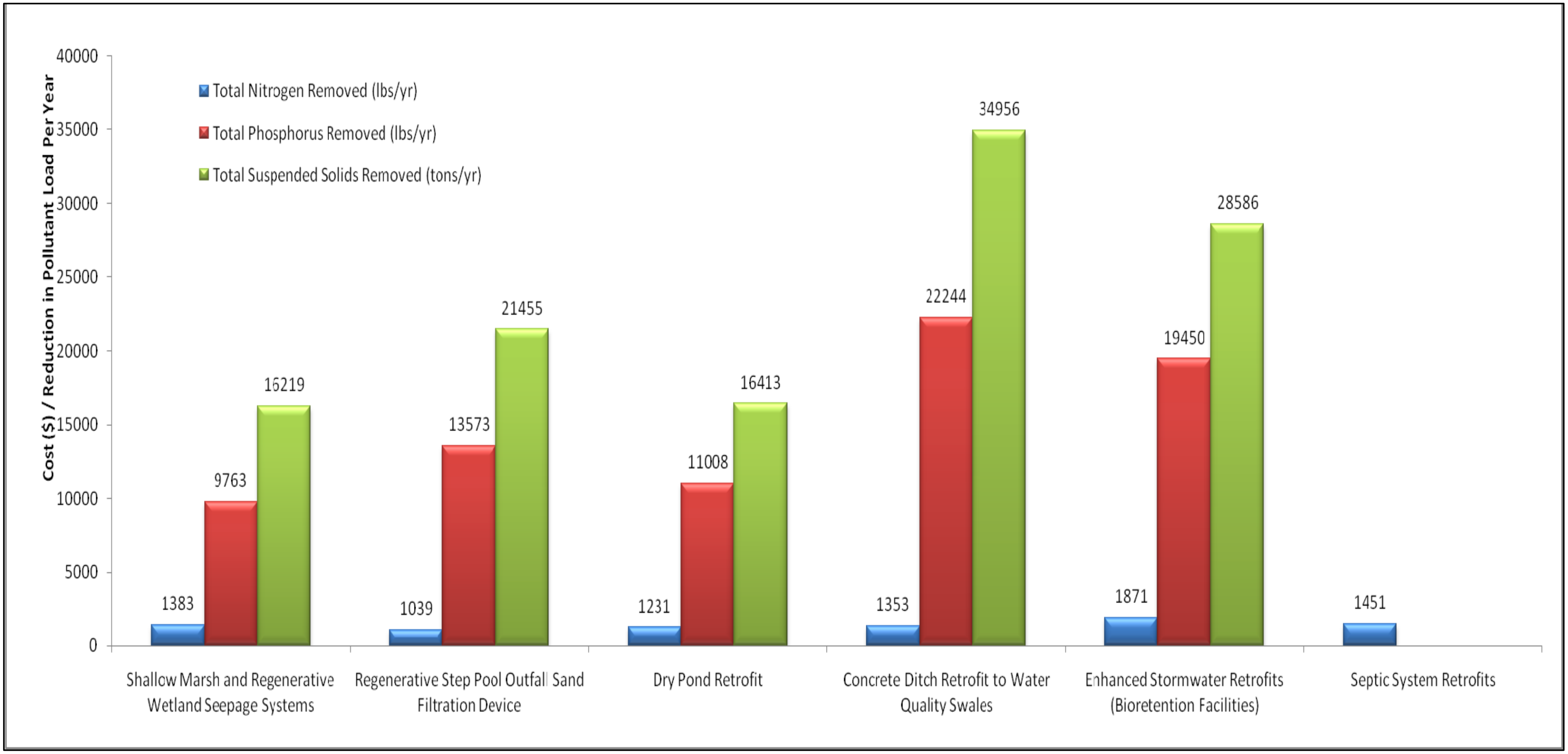

Figure 5.6 – Cost Effectiveness Analysis by Subwatershed of Total Phosphorus Removal

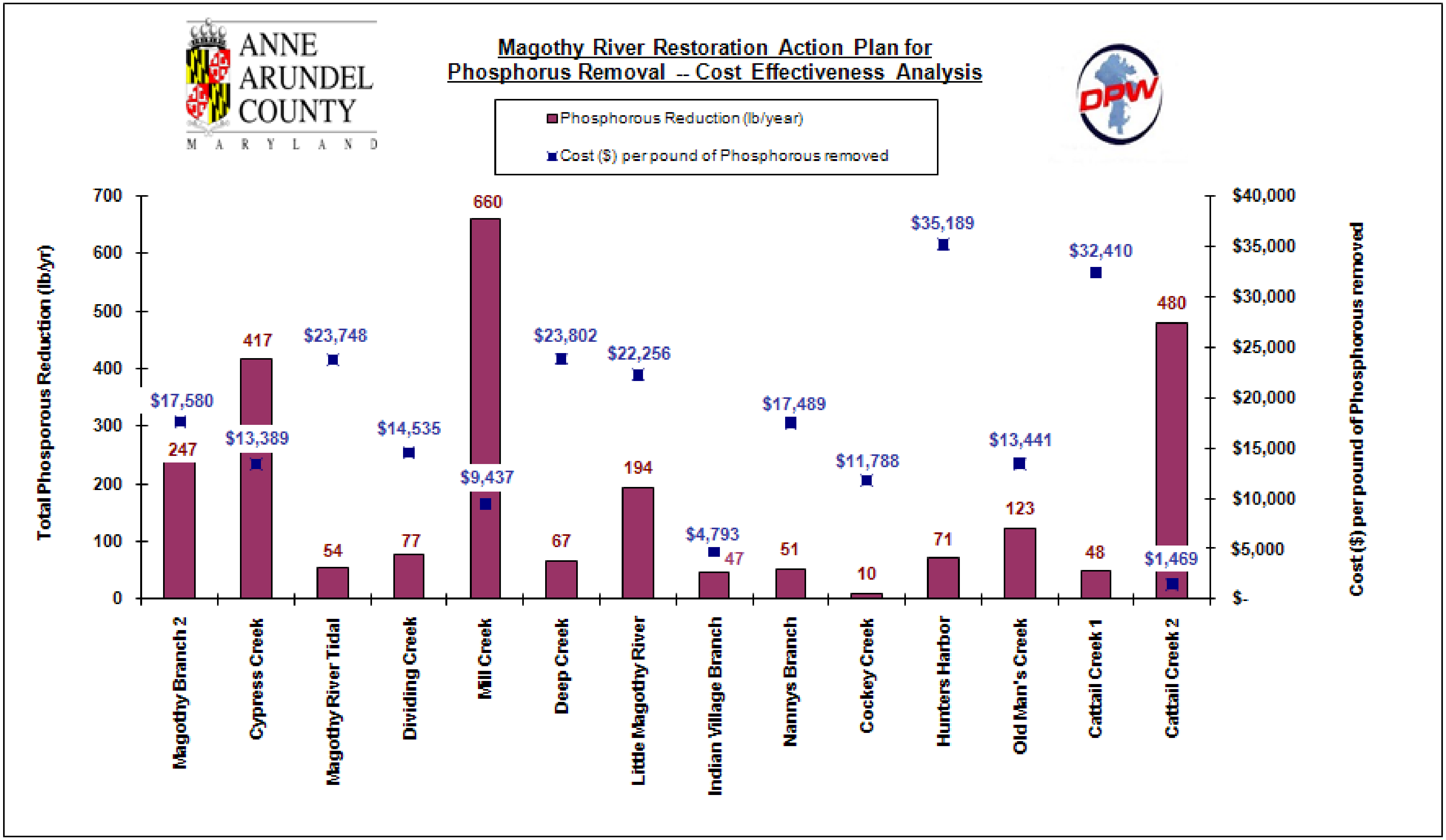

Figure 5.7 – Cost Effectiveness Analysis by Subwatershed of Total Nitrogen Removal

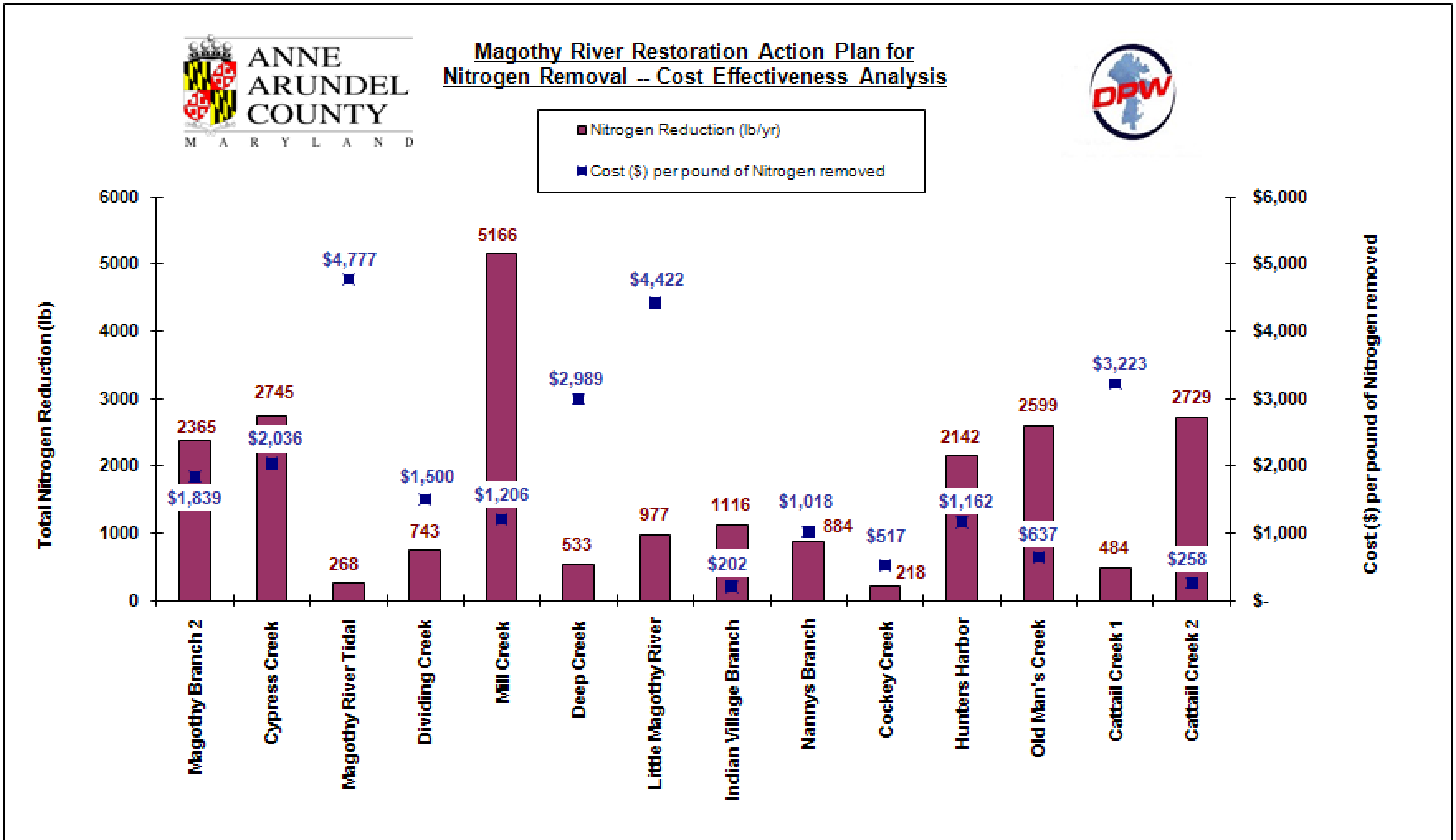

Figure 5.8 – Cost Effectiveness Analysis by Subwatershed of Total Suspended Solids Removal

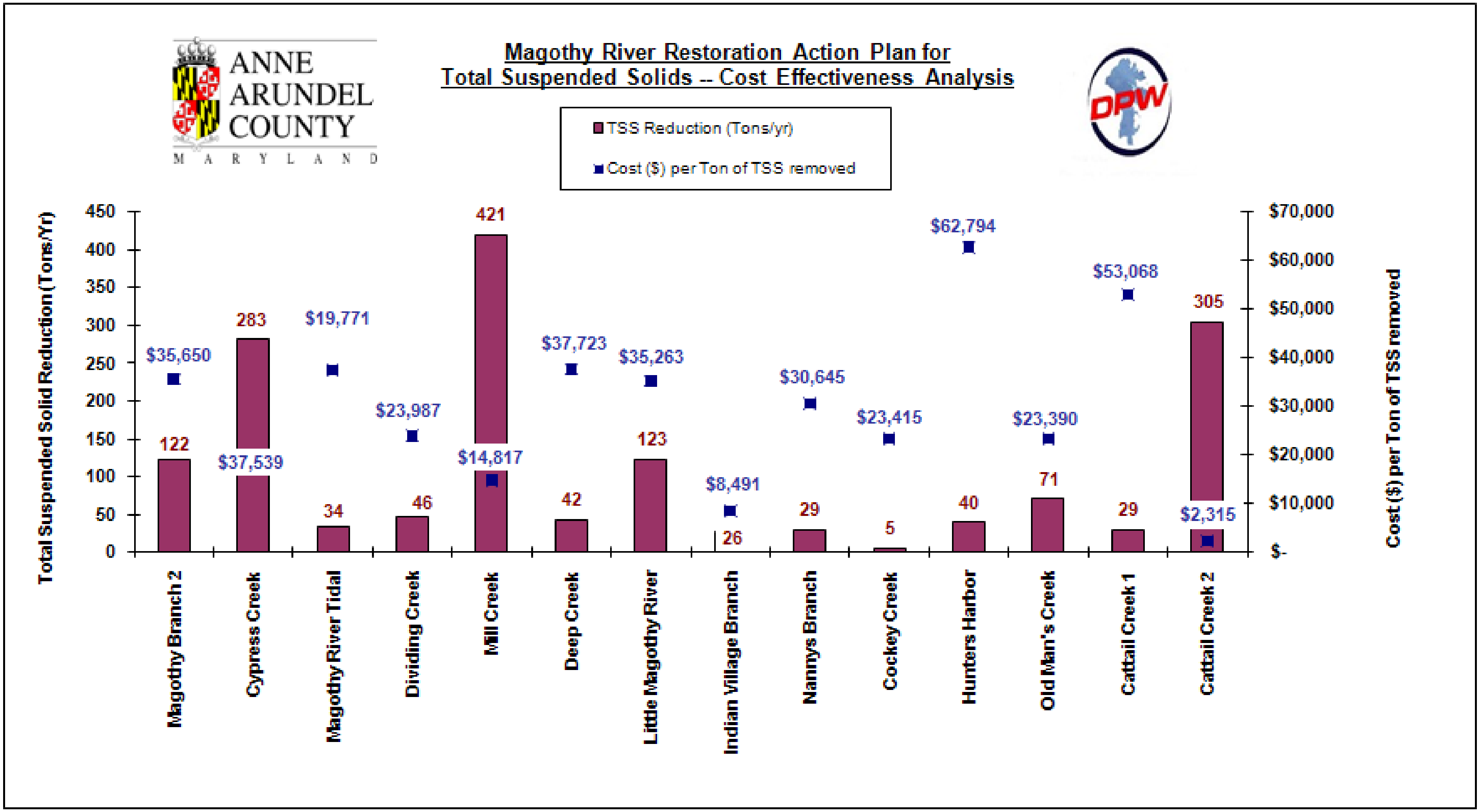

Table 5.7 – Total Cost of Restoration/Retrofits and Unit Cost-Effectiveness

Subwatershed	Restoration/Retrofits				OSDS Retrofits	
	Total Cost	$/lb TP	$/ton TSS	$/lb TN	Total Cost	$/lb TN
Magothy Branch 2 (MG1)	$4,347,914	$17,580	$35,650	$1,839	$11,970,000	$3,751
Cypress Creek (MGC)	$5,364,500	**$13,196**	**$19,500**	$2,014	$4,066,000	$1,564
Magothy River Tidal (MGF)	$322,471	$32,832	$49,401	$4,082	$266,000	$2,128
Dividing Creek (MGH)	$1,114,650	**$14,535**	**$23,987**	$1,500	$8,284,000	$1,463
Mill Creek (MGI)	$6,119,476	**$9,355**	**$14,695**	$1,199	$13,452,000	$2,138
Deep Creek (MGT)	$1,451,250	$22,881	$36,316	$2,945	$9,690,000	$1,927
Little Magothy River (MGV)	$4,321,920	$22,256	$35,263	$4,422	$2,166,000	$1,817
Indian Village Branch (MGW)	$225,000	**$4,793**	**$8,491**	**$202**	$6,688,000	$2,975
Nannys Branch (MGY)	$900,000	$17,489	$30,645	**$1,018**	$798,000	$187
Cockey Creek (MR6)	$112,500	**$11,788**	**$23,415**	**$517**	---	---
Hunters Harbor (MRD)	$2,025,000	$35,451	$63,262	**$1,186**	---	---
Old Man's Creek (MRF)	$1,296,500	$20,917	$35,334	**$828**	$25,498,000	$2,167
Cattail Creek (MRI/MRO)	$1,666,500	$26,817	$42,925	$2,769	$9,994,000	$2,107
All priority subwatersheds	$29,267,678	$15,077	$24,446	$1,581	$92,872,000	$1,451

Note: - Five lowest unit removal costs for Restoration/Retrofit projects are in **bold.**
- Cost of pollutant removal expressed as lifetime or total cost per lb removed annually.

Observations of note based on this analysis are as follows:

- Stream restorations with shallow marsh and wetland seepage systems are the most cost-effective single type of restoration activity on the watershed scale.
- Among the priority subwatersheds, Indian Village Branch shows the lowest unit costs for pollutant removal. This is due primarily to the fact that a single outfall restoration project manages almost 90% of the land area in this small subwatershed.
- Cost-benefit analysis indicates that, among the subwatersheds, Cypress Creek (MGC), Mill Creek (MGI), Dividing Creek (MGH), and Cockey Creek (MR6) have lower unit costs for total phosphorus and total suspended solids removal.
- Based on watershed-wide comparisons of cost efficiency for different scenarios (Figure 5.5), removal of total nitrogen through OSDS management is competitive with other restoration/retrofit projects. As shown in Table 5.7, removal of total nitrogen in the priority subwatersheds through septic systems retrofits is slightly less expensive on a unit-cost basis ($1,451/lb of total nitrogen removed) than removal through restoration/retrofit projects ($1,581/lb).
- The logistics of administering 2,400 OSDS retrofits at a cost of $92,000,000 may be less attractive than administering 67 restoration/retrofit projects.

- Restoration/retrofit projects will provide benefits from the removal of total phosphorus and total suspended solids as well as total nitrogen, while the OSDS retrofits address only total nitrogen.

The process discussed herein provides a valuable quantitative metric for direct comparison between restoration and retrofit types. However, the County does not base decisions solely on these modeled benefits and pollutant removal costs. The County also considers, in parallel, qualitative benefits such as habitat restoration, accessibility, local stakeholder investments, and others. For example, shallow marsh/regenerative wetlands are shown to be cost-effective by this analysis. However, they also provide high qualitative benefit through restoration of habitat and stream character.

Table 5.8 summarizes different numeric targets for watershed-wide loadings, and compares these targets to the loading results from the most effective water quality model scenario for load reduction (Scenario J). The analysis shows that implementation of all 67 identified restoration/retrofit projects (J. All Projects) will meet the estimated TMDL goal and the 2004 NPDES loading goals for total phosphorus, total nitrogen, and fecal coliform as well as the 2004 NPDES target for total suspended solids.

Table 5.8 – Watershed–wide Loading Targets and Scenario J Loading Results

Target	Total Phosphorus (lbs/year)	Total Nitrogen (lbs/year)	Total Suspended Solids (lbs/year)	Fecal Coliform
Pristine	1,496	11,472	249	5.0E+06
Ultimate Conditions with 10% Impervious Cover	6,992	56,692	2,777	1.4E+13
TMDL Goal	***11,956***	***277,059***	399	***2.1E+13***
2004 NPDES Goal	***12,542***	***264,063***	***5,294***	***2.2E+13***
J. All Projects (D-I)	**11,920**	**143,252**	**4,689**	**1.8E+13**

5.5 RECOMMENDATIONS

Based on the analysis outlined above and detailed in preceding sections, the following activities are recommended to restore and protect the Magothy River Watershed.

5.5.1 Restoration Activities

- Fully implement the restoration and retrofit projects discussed in Section 5.2. A full list of the proposed projects is included in Appendix D. As the implementation of the full set of proposed projects hinges on the availability of funding, a step-wise approach should be taken. Prioritization of projects should consider cost-benefits, ease of implementation, potential for partnerships, and ancillary benefits of implementation (*e.g.*, increased property values, air quality improvements, recreational opportunities, *etc*.).
- Work with community organizations such as the Magothy River Association to organize volunteer-based activities like dumpsite cleanups and buffer plantings. As discussed in Section 2.1.3, the locations and relative impacts of dumpsites and deficient buffers was established through the County's data collection efforts. This information along with other resources can be shared with the community organization spearheading the restoration activities. Dumpsite cleanups and buffer plantings could theoretically take place on both County-owned and privately-owned property provided that the proper outreach was performed and permissions granted.
- Measure the effectiveness of restoration projects through additional targeted data collection. The County routinely monitors retrofit and restoration projects following completion to ensure that they are functioning as designed. Additional data collection could include MPHI assessments and bioassessment monitoring at downstream reaches expected to benefit from the project.
- Consider innovative programs to augment County maintenance of certain BMPs (*e.g.*, Adopt-a-Rain Garden program). Routine maintenance is a critical step to ensuring that BMPs function effectively over long periods. This is evidenced by the number of failing BMPs discussed in Section 2.2. While some maintenance activities require specialized equipment or expertise, simple activities like trash and debris removal can be handled by volunteers provided that some safety guidance was provided.

5.5.2 Preservation Activities

- Continue advocating for modifications to regulatory stream buffer widths and FEMA floodplain estimation methods in the County Stormwater Management Manual and associated County codes. The County's Watershed Assessment and Planning Program has previously recommended, and it is reiterated here, that 100-year floodplain estimation methods should take into account the non-incised channel geometry when evaluating hydraulic capacity and establishing 100-year flooding elevations (Flores et al, 2009). By estimating floodplain widths using existing incised channel dimensions, the resultant floodplain buffers can be dramatically underestimated. Parallel to this, the County has also advocated for expanding minimum regulatory stream buffers to 330 feet in unsewered areas and in areas covered by the Greenway Master Plan. This buffer expansion represents the minimum width necessary to provide pollutant removal and promote groundwater recharge. A map of the 330-foot buffer zone is presented as Map 5.1.

- Continue working with the Office of Planning and Zoning and other County offices to ensure that preservation and restoration priorities established in this study are reflected in all development decisions and other land-use related considerations.
- Work with community organizations to educate the public about water resources and their role in preservation. Outreach activities could be targeted to those areas identified as most critical for preservation.
- Work with non-profit organizations like the Nature Conservancy and The Conservation Fund to acquire and set aside priority lands and resources for preservation. Approach large landowners identified in the parcel level preservation assessment (see Appendix C) about considering conservation easements on their properties.

5.5.3 Other Activities

- Promote cooperation and partnership amongst County agencies (*e.g.,* schools) to identify educational opportunities as well as leverage future retrofit projects on County-owned property.

5.6 CONCEPT PLANS

As a first step toward implementation, the County developed concept design plans for six of the 67 proposed restoration projects discussed in Section 5.2. Each concept plan contained a narrative description of the issue to be addressed, the purpose of the restoration activity, a site location map, hydrologic and hydraulic volumes, a plan view of the conceptual design, existing condition photos, design and construction cost estimates, and a feasibility assessment.

The concept plans were developed following a rigorous analysis of existing site conditions and were done in consultation with community stakeholders from the Magothy River Association. For each of the key projects, field crews conducted site visits to assess the full suitability and feasibility of the selected restoration activity and to collect any necessary field measurements and photos. GIS and modeling data were used to identify project area characteristics, determine project drainage areas, and calculate hydraulic and pollutant load benefits. County-approved design specifications were used to site and size each of the project elements. Standard construction cost guides were used in tandem with County-specific unit costs to develop preliminary design and construction cost estimates. An assessment was also undertaken to identify and address conceptually important constructability issues such as land ownership, construction access, erosion and sediment controls, and potential utility conflicts.

The six projects and a brief description of each are provided below. The full concept design plans are included in Appendix E.

- Anne Arundel County Community College Stream Restoration and Outfall Stabilization (Dividing Creek) – This conceptual plan consists of three separate projects related to restoring a portion of Dividing Creek located within the Anne Arundel Community College grounds: (1) remove an existing outfall to the stream that originates at a stormwater management pond, relocate the pond outlet, and convey the pond outlet flow via a staggered regenerative storm conveyance system; (2) retrofit an additional downstream stormwater outfall with another regenerative storm conveyance system; and (3) restore the incised stream and reconnect it with the natural floodplain using a wetland seepage regime with a series of shallow pools and riffle weir grade controls.
- Park Plaza Concrete Ditch Retrofit (Cypress Creek) – A concrete lined ditch located within the Park Plaza parking lot conveys vast quantities of untreated runoff from a large commercial and residential area to the headwaters of a poorly rated tributary of Cypress Creek. The ditch is approximately 360 feet long. This project will retrofit the ditch with a regenerative storm conveyance system to improve water quantity and water quality management to Cypress Creek.
- Leelyn Drive/North Cypress Linear BMP Retrofit (Cypress Creek) – An existing extended detention BMP located south of Leelyn Drive and north of the Village Square Shopping Center drains a largely residential area and is not functioning as designed. This project will retrofit the BMP with a regenerative storm conveyance system to improve water quantity and water quality management to Cypress Creek.
- Cypress Creek Recreation Area Bioretention Facility (Cypress Creek) – This project will install a bioretention facility near an existing storm drain on the north side of the overflow parking for the Cypress Creek Recreation Area. Poor drainage currently contributes to frequent flooding events of portions of the parking lot.
- Arundel Beach Road Park and Ride Bioretention Facility (Cypress Creek) – The drainage around an existing County-owned Park n Ride parking lot is poorly managed. The parking lot contributes drainage to the headwaters of a poorly rated tributary of Cypress Creek. This project will install two bioretention facilities near the parking lot to limit drainage and improve runoff water quality.
- Dunkeld Manor Stormwater Retrofit (Cypress Creek) –An existing infiltration basin in a residential area is no longer functioning as designed and is detaining water beyond an acceptable residence time. In addition, properties located downgradient of the basin reportedly experience occasional flooding issues. This project will retrofit the basin with a regenerative storm conveyance system to improve water quantity and water quality management to Cypress Creek and alleviate downgradient residential flooding issues.

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6. REFERENCES

Anne Arundel County. 2002. Severn River Watershed Management Master Plan Current Conditions Report, December 2002. Prepared by KCI Technologies, Inc. and CH2M HILL for Anne Arundel County Department of Public Works Watershed Management Program. Anne Arundel County, Maryland.

Anne Arundel County. 2006. Severn River Watershed Management Master Plan, Final Report. Prepared by KCI Technologies, Inc. and CH2M HILL for Anne Arundel County Department of Public Works Watershed Management Program. Anne Arundel County, Maryland.

Anne Arundel County, Office of Planning and Zoning (OPZ), 2006. *Stormwater Management Practices and Procedures Manual*, July 2001, Revised July 2006. Prepared by: Office of Planning and Zoning, in conjunction with Department of Public Works, Department of Inspections and Permits, Anne Arundel Soil Conservation District

Anne Arundel County. 2008. Onsite Sewage Disposal Systems: Evaluation Study and Strategic Plan, March 2008. Prepared by CH2M HILL, John E. Harms, Jr. & Associates, and Stearns and Wheeler LLC.

Cowan, W.L. 1956. Estimating Hydraulic Roughness Coefficients. *Agricultural Engineering*. Vol. 37, no.7. pp. 473–47

EPA, 2001. PLOAD Version 3.0, An ArcView GIS Tool to Calculate Nonpoint Sources of Pollution in Watershed and Stormwater Projects. January 2001. Developed by CH2M HILL

Flores, H. et al., Watershed Assessment and Planning Program. *Floodplains and Regulatory Stream Buffers – Recommendations for Inclusion in the County Stormwater Management Manual.* September 15, 2009

Maryland Department of Natural Resources (MDNR). October 2005. Volume 16, New Biological Indicators To Better Assess The Condition Of Maryland Streams. EA-05-13 (DNR #12-10282005-74)

Maryland Geological Survey. 2008. James P. Reger and Emery T Cleaves. "Explanatory Text for the Physiographic Map of Maryland". Open-File Report 08-03-1. Available at: http://www.mgs.md.gov/coastal/maps/physio.html.

NRCS. 2009. "Chapter 7: Hydrologic Soil Groups". Part 630 Hydrology, National Engineering Handbook. Available at: http://policy.nrcs.usda.gov/OpenNonWebContent.aspx?content=22526.wba.

Schueler, T. 1987. Controlling urban runoff: a practical manual for planning and designing urban BMPs. Metropolitan Washington Council of Governments. Washington, DC

Schueler, T.R. 1992. Mitigating the Adverse Impacts of Urbanization on Streams: A Comprehensive Strategy for Local Government. In Watershed Restoration Sourcebook. Publication #92701 of the Metropolitan Washington Council of Governments. P. Kimble and T. Schueler, editors.

OVERSIZED MAPS