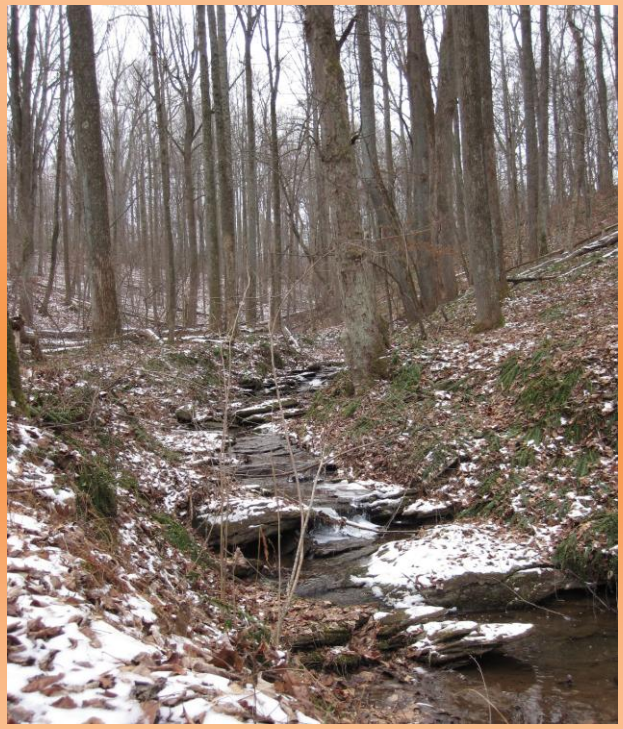
BEAVERDAM RUN, BAISMAN RUN, AND OREGON BRANCH

SMALL WATERSHED ACTION PLAN

FINAL REPORT



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Baltimore County Executive Kevin Kamenetz and the Baltimore County Council

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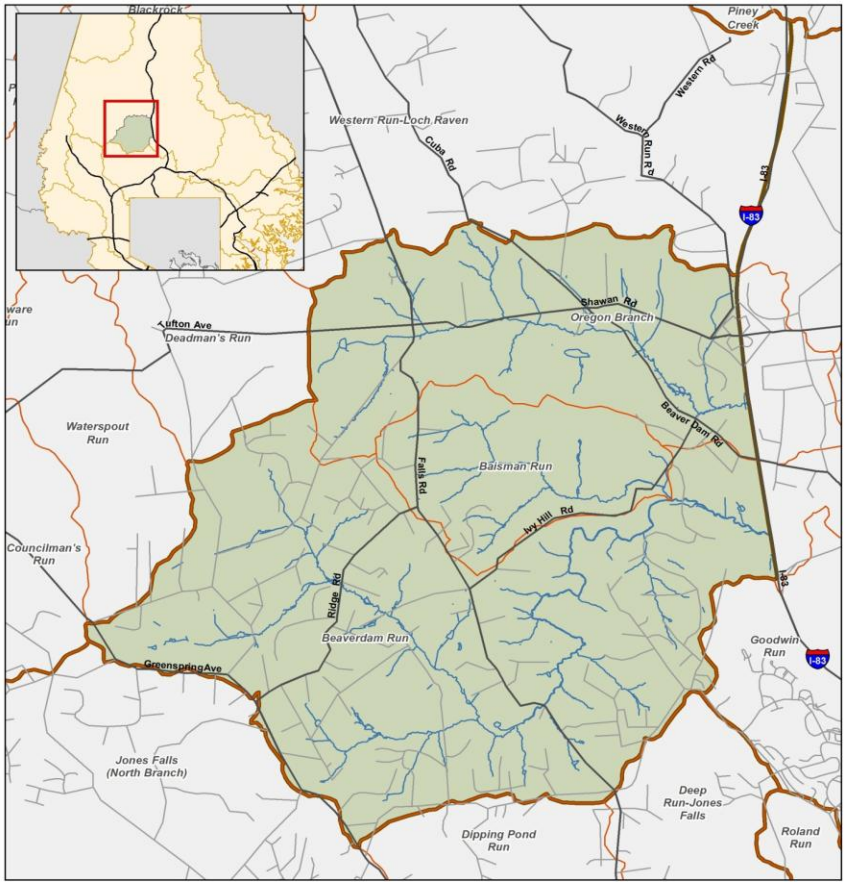
Beaverdam Run, Baisman Run, and Oregon Branch Watershed Characterization Report



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CHAPTER 1.0
Introduction

1.1 Purpose

The Area I Watershed Characterization Report has two primary objectives. First is to summarize the geomorphic, hydrological and biological natural resources in the watershed and to describe the current condition of these resources. The second objective is to describe the various human factors affecting these resources and identify restoration and preservation strategies which will help achieve the goals of the watershed. The information provided here will help to develop a Small Watershed Action Plan (SWAP) for the watershed.

1.2 Watershed Location and Scale

Planning Area I lies in the Piedmont region of Maryland and is located in central Baltimore County. It is bounded on the east by I-83 and on the southwest by Greenspring Avenue as shown on Figure 1-1. It encompasses 8,350 acres (13 square miles). This planning area was divided into three smaller drainage areas known as subwatersheds listed in Table 1-1 and shown on Figure 1-2: Baisman Run, Beaverdam Run and Oregon Branch. Baisman Run is completely contained within Planning Area I. Portions of Beaverdam Run and Oregon Branch extends to the east of I-83 into areas with more urban land use and will be included in the characterization and SWAP for Planning Area O.

Analysis can be conducted at both the watershed (Area I) and subwatershed (Baisman Run, Beaverdam Run and Oregon Branch) level. The analysis at the subwatershed level generally provides the detail required to make decisions about prioritizing restoration and preservation efforts. Monitoring of restoration efforts is also more easily monitored at the subwatershed scale. This characterization report provides information at both levels, with analyses at the subwatershed level referring only to those portions of the subwatersheds within Area I.

Table 1-1: Subwatershed Acreages

Subwatershed	Acres	Square Miles
Baisman Run	1,056.0	1.65
Beaverdam Run	4,984.6	7.79
Oregon Branch	2,309.4	3.61
Total	**8,350.0**	**13.05**

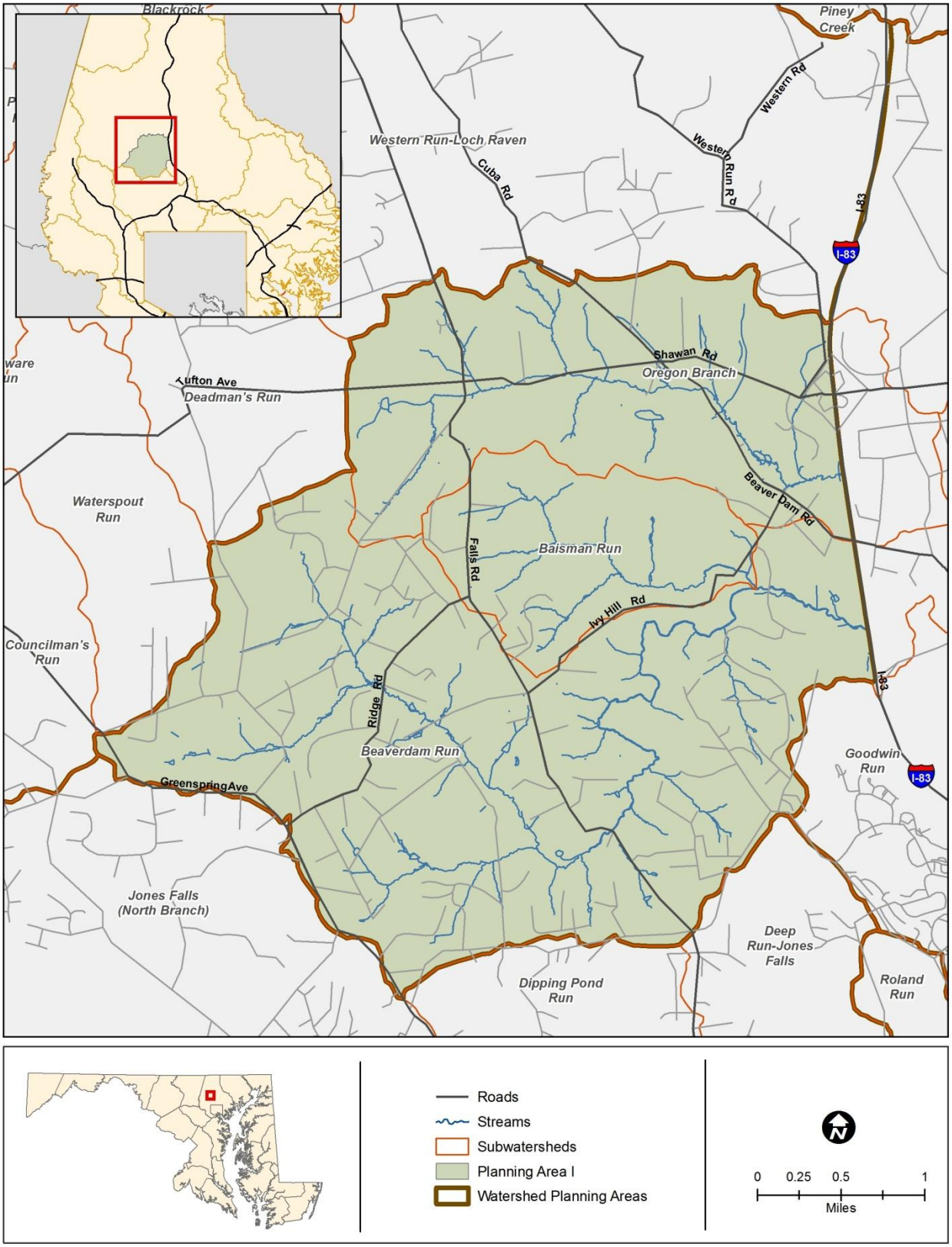


Figure 1-1: Area I Location

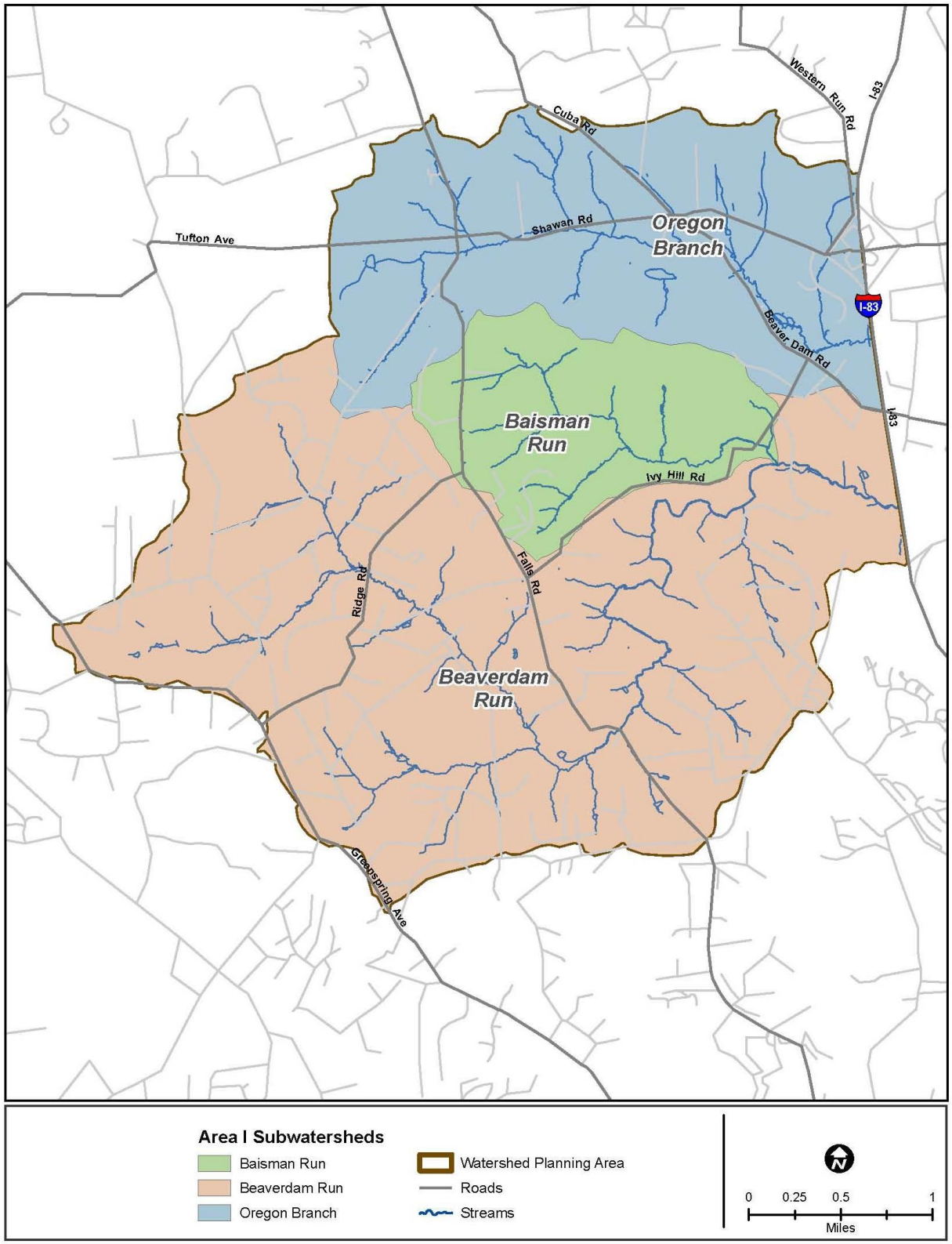


Figure 1-2: Area I Subwatersheds

1.3 Report Organization

This report is organized into five chapters:

Chapter 1 explains the location of the study area and the purpose and scope of the characterization.

Chapter 2 summarizes watershed and subwatershed characteristics that may have an effect on water quality of streams, downstream receiving waters, groundwater, and other natural resources. This chapter includes information on climate, soils, geology, forest cover and streams within the watershed. It also includes information on human factors influencing these natural resources such as current land use, population, impervious cover, wastewater and storm water infrastructure.

Chapter 3 discusses water quality and quantity conditions based on available monitoring and stream assessment data.

Chapter 4 includes the upland assessment conducted to identify sources of pollution and potential restoration opportunities for neighborhoods, institutional land uses, and hotspots.

Chapter 5 summarizes potential preservation and restoration strategies appropriate for accomplishing watershed goals developed by the watershed stakeholders and Area I Steering Committee.

CHAPTER 2.0
Landscape and Land Use

2.1 Introduction

This chapter describes both the existing natural landscape (land cover) and how humans are impacting that landscape through various uses of the land. It covers climate as well as natural physical land characteristics such as topography, geology, soil characteristics, forests, wetlands and streams. Discussion will also include how human activities are impacting these natural physical characteristics and will cover information on current land use, population, impervious surfaces, drinking water, wastewater, stormwater, NPDES facilities and zoning. This information will provide the background for later chapters on water quality, living resources, restoration and management.

This chapter will be presented in two parts: the first will document the background state of the natural resources of the watershed, and the second will describe the present condition of the landscape.

2.2 The Natural Landscape

The natural landscape includes characteristics relevant to watershed processes which are discussed in the following sections. These include climate, topography, geology, soils, forest cover, wetlands and the stream system within the watershed.

2.2.1 Climate

Climate influences soil formation and erosion processes, stream flow patterns and a significant part of the geomorphology of a watershed. Rainfall not only provides water to streams and plants, but the intensity, frequency and amount of rainfall can greatly influence watershed characteristics.

The climate of the region encompassing Area I is best described as humid continental with four well-defined seasons (USDA, 1976). The proximity of the Appalachian Mountains to the west and the Chesapeake Bay to the east provides a temperate climate with precipitation spread evenly throughout the year. Based on data from the National Oceanic and Atmospheric Administration (NWS, 2011), the average monthly rainfall from 1871 to 2010 is 3.52 inches in Baltimore with annual rainfall of 42.28 inches per year. Snowfall generally occurs between January and March, with the heaviest precipitation occurring in January and February. The long-term average from 1883 to 2010 is 22.0 inches per year.

Climate is somewhat wetter and cooler in Area I than at Baltimore and BWI airport. The normal annual precipitation from 1971-2000 is reported as 41.94 inches at BWI and 46.77 in Parkton, MD. Mean temperatures for the same period were 54.6 and 52.0 degrees Fahrenheit, respectively. Towson, MD was reported to be both wetter and warmer than BWI, with annual precipitation of 51.53 inches and average temperature of 55.7 degrees (NOAA, 2002).

Climate change will have an effect on watershed management in the future and may be included in future revisions of the SWAP.

2.2.2 Watershed Delineation

In order to implement a watershed approach to evaluate aquatic resources and water quality conditions it is necessary to delineate a boundary for the watershed, or drainage area. This is accomplished by selecting a specific water body or point along a stream and drawing a boundary that would encompass all land that would contribute runoff to the selected point. Drainage areas vary greatly in size depending on the location of the point of interest. Additionally, they are nested within other drainage areas and can vary from a few acres for a headwater stream to several thousand square miles for large rivers and basins, such as the Chesapeake Bay.

Maryland divides its watersheds into 138 state-defined watersheds (also called 8-digit watersheds) averaging 75 square miles in size. The Loch Raven Reservoir is the 8-digit watershed that includes Area I. Baltimore County has further divided the 8-digit watersheds into 191 subwatersheds. Planning Area I includes the Baisman Run, and the headwater portions of Oregon Branch and Beaverdam Run. The SWAP boundary was selected for consistency of land use in the planning areas. The downstream portions of Oregon Branch and Beaverdam Run cross the Urban Rural Demarcation Line (URDL) into areas with more urban land uses. (This is explained more fully in section 2.3.8.) It is at this smallest subwatershed level that all data will be presented.

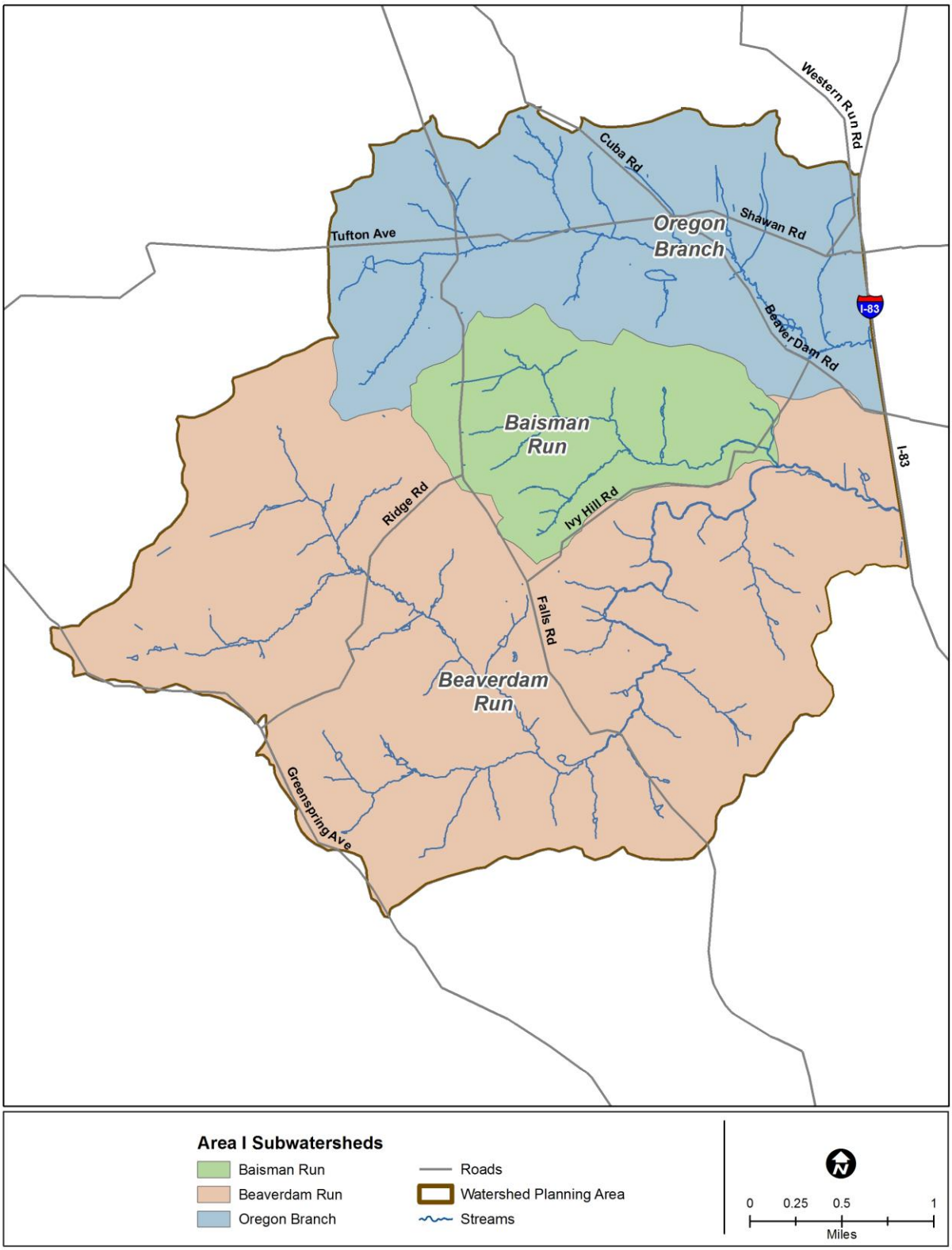


Figure 2-1: SWAP Planning Area

2.2.3 Slope

The SSURGO soils data for Baltimore County was used for the soils data analysis (USDA, 2010). Slopes for this study were determined from GIS soil data layers and were divided into the following five categories:

- Nearly Level (0 – 3% slopes)
- Gently Sloping (>3 – 8% slopes)
- Strongly Sloping (>8 – 15% slopes)
- Moderately Steep (>15 – 25% slopes)
- Steep (>25% slopes)

Table 2-1 summarizes the percentage of area in each subwatershed for each slope category. Figure 2-2 provides a visual display of the slope categories within the watershed.

Table 2-1: Subwatershed Slope Characterization

Subwatershed	Slope Category (%)				
	Nearly Level	Gently Sloping	Strongly Sloping	Moderately Steep	Steep
Baisman Run	8.1	28.4	28.5	16.7	18.3
Beaverdam Run	20.8	39.4	21.5	8.7	9.7
Oregon Branch	21.5	36.2	20.6	13.6	8.1
Total	**19.4**	**37.1**	**22.1**	**11.1**	**10.3**

As shown on Table 2-1 and Figure 2-2, strongly sloping to steep slopes consists of 43.5% of the watershed. The majority of the watershed is gently sloping (37.1 percent). Strongly sloping (22.1 percent) and nearly level (19.4 percent) are the next most prevalent slope categories. Slopes follow those generally seen in the Piedmont Physiographic Province, with rolling uplands and steep stream valleys. Steep and strongly sloping areas are generally associated with higher rates of erosion, with soil type and land use/land cover also playing a role. For Area I, the steepest slopes are associated with stream valleys.

Baisman Run in the central portion of the watershed has the highest percentage of steep, moderately steep, and strongly sloping land (18.3, 16.7, and 28.5 percent, respectively). Beaverdam Run and Oregon Branch have approximately the same percentage of nearly level, gently sloping, and strongly sloping land. The highest percent of gently sloping land is in Beaverdam Run (39.4 percent) and the highest percent of nearly level land is in Oregon Branch (21.5 percent).

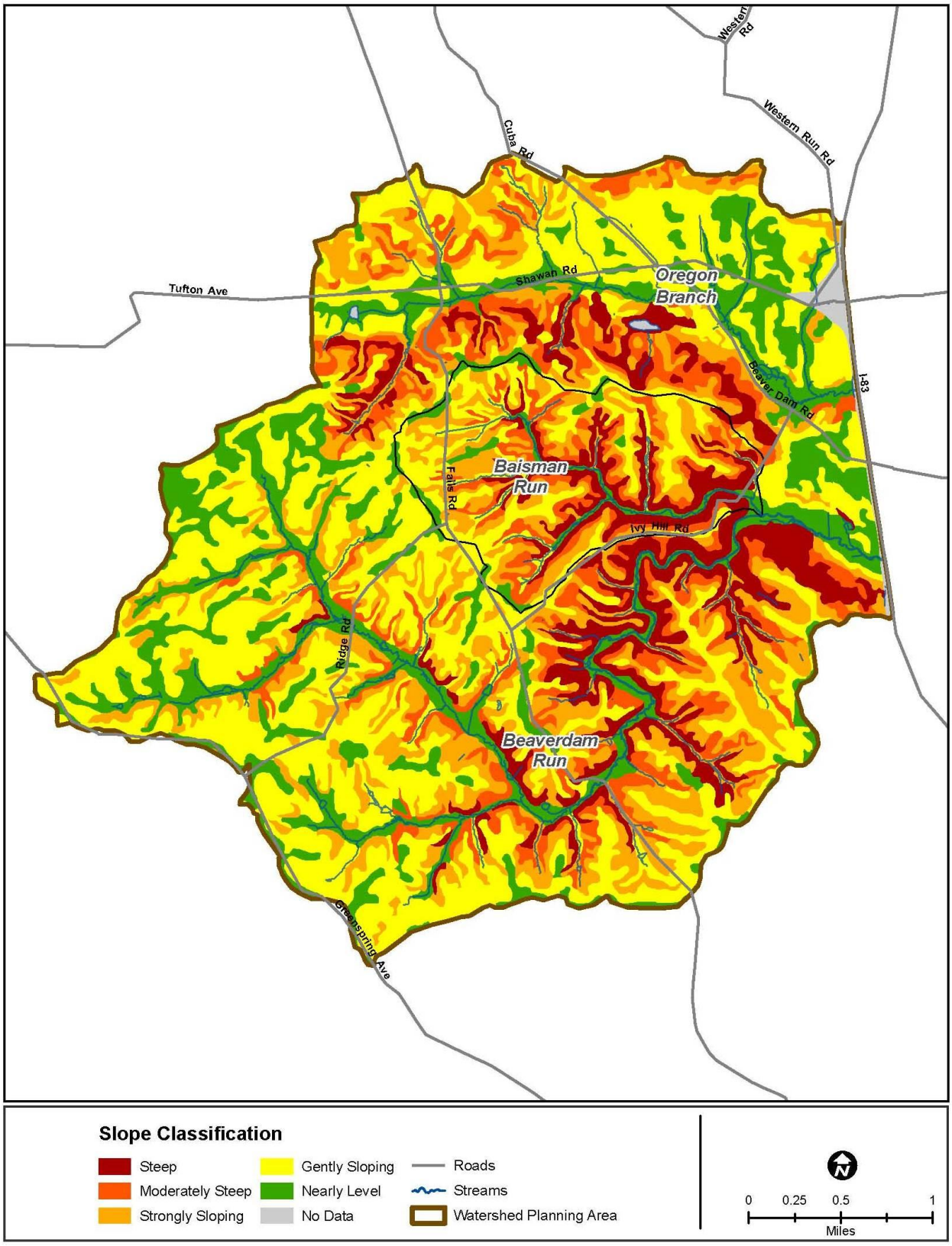


Figure 2-2: Area I Slope Classification

2.2.4 Geology

The geologic formations underlying a watershed have a significant effect on the water resources. Geology is a major determinant of the type of topography and surface features, discussed earlier. The chemical composition and minerals of the parent rock or unconsolidated sediments determines in large part the soil characteristics, including erodibility and infiltration rates. The underlying geology is a major factor in groundwater availability, which will be discussed in further detail in Section 2.3.4.

Area I lies within the Piedmont Plateau Province, which is primarily underlain by metamorphic rock. Three geologic formations are found in Area I, all of them of metamorphic origin. The oldest formation is Baltimore gneiss, which is among the oldest rock in the eastern United States. Overlying this is the Cockeysville marble. This formation is covered by another series of metamorphic rock formations, which in this location is identified as Loch Raven schist (USDA, 1976). The Loch Raven schist comprises the greatest majority of the area and underlies almost the entirety of the Baisman Run subwatershed.

Table 2-2 shows the geologic composition in the three subwatersheds. This information is also displayed on Figure 2-3.

Table 2-2: Area I Geologic Composition by Subwatershed

Subwatershed	Geology (%)		
	Baltimore Gneiss	Cockeysville Marble	Loch Raven Schist
Baisman Run	0.0	0.4	99.6
Beaverdam Run	0.0	4.6	95.4
Oregon Branch	19.4	50.2	30.3
Total	**5.4**	**16.7**	**77.9**

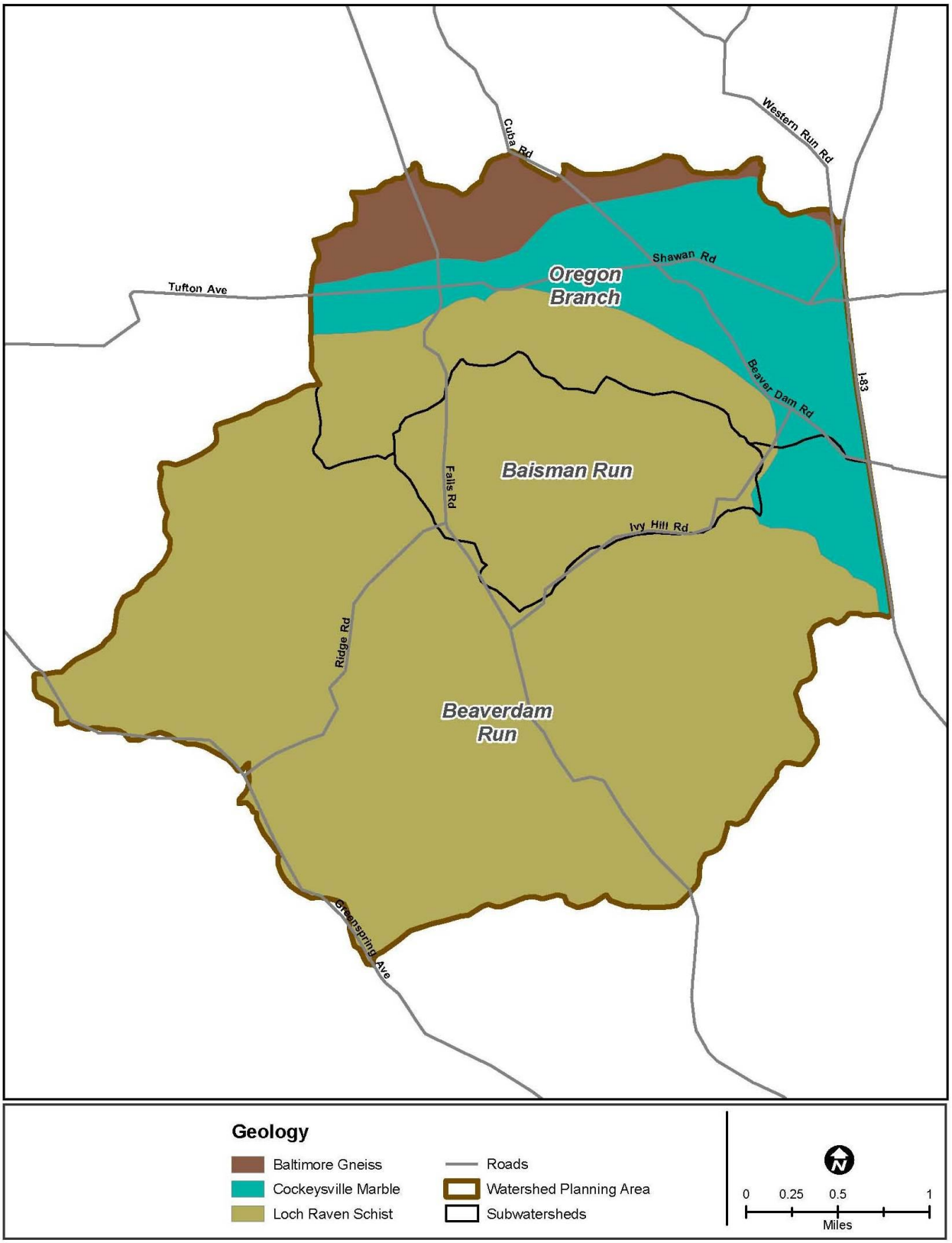


Figure 2-3: Area I Watershed Geology

2.2.5 Soils

Soil conditions are an important factor when evaluating water quantity and quality in streams and rivers. Soil type and moisture conditions greatly impact the amount and quality of runoff. Soils also affect how land may be used and its potential for vegetation and habitat. Soils are an important consideration in targeting projects aimed at improving water quality or habitat. The SSURGO soils data for Baltimore County was used for the soils data analysis (USDA, 2010).

All of the soils in Area I are derived from the parent metamorphic rock. Piedmont soils in upland areas are typically very erodible, with moderate infiltration rates. Piedmont alluvial soils in stream valleys washed down from the upland areas tend to be silts and clays and are far less permeable.

2.2.5.1 Hydrologic Soil Groups

The Natural Resources Conservation Service (NRCS) classifies soils into four hydrologic soil groups (HSG) based on the soil's runoff potential. Runoff potential is the opposite of infiltration capacity, which is the ability of the soil to absorb precipitation. Soils with high infiltration capacity will have low runoff potential, and vice versa. Infiltration rates are highly variable among soil types and are also influenced by disturbances to the soil such as cuts and fills associated with land development that can reduce infiltration and increase runoff potential. The four hydrologic soil groups are A, B, C, and D where Group A soils generally have the lowest runoff potential (highest infiltration) and Group D soils have the greatest runoff potential (lowest infiltration).

Each hydrologic soil group is described below. Additional information on hydrologic soil groups can be found in the Natural Resource Conservation Service's publication, *Urban Hydrology for Small Watersheds*, often referred to as Technical Release 55, or TR-55 (USDA, 1986):

- **Group A** soils are sand, loamy sand, or sandy loam soil types. These soils have high infiltration rates and low runoff potential even when thoroughly wetted. They consist mainly of deep, well-to excessively-drained sands or gravels with a high rate of water transmission.

- **Group B** soils are silt loam or loam soil types. These soils have moderate infiltration rates when thoroughly wet. They consist mainly of somewhat deep to deep, moderately-well to well-drained soils with moderately fine texture to moderately coarse texture with a moderate rate of water transmission.

- **Group C** soils are sandy clay loam soil types. These soils have a low infiltration rate when thoroughly wet. They typically have a layer that hinders downward movement of water and the soils have a moderately fine to fine texture. These soils have a low rate of water transmission.

- **Group D** soils include clay loam, silty clay loam, sandy clay, silty clay, or clay soil types. These soils have a very low infiltration rate and high runoff potential when thoroughly wet. They consist mainly of clays with high swell potential, soils with a permanent high water table, and soils with a claypan or clay layer at or near the surface and shallow soils over nearly impervious material. These soils have a very low rate of water transmission.

As shown on Table 2-3 and Figure 2-4, the majority of soils in Area I are classified as Group B (61 percent) and C soils (32.8 percent), with moderate to low infiltration rates and moderate transmission of water through the soil to the stream system. Area I contains no Group A soils. The small fraction of Group D soils in Area I, with high runoff potential, are associated with stream valleys.

Table 2-3: Area I Hydrologic Soil Categorization

Subwatershed	Hydrologic Soil Group (%)				
	A	B	C	D	Water / Impermeable
Baisman Run	0.0	76.0	21.8	2.2	0.0
Beaverdam Run	0.0	63.9	28.2	7.7	0.3
Oregon Branch	0.0	48.0	47.9	0.4	3.6
Total	**0.0**	**61.0**	**32.8**	**5.0**	**1.2**

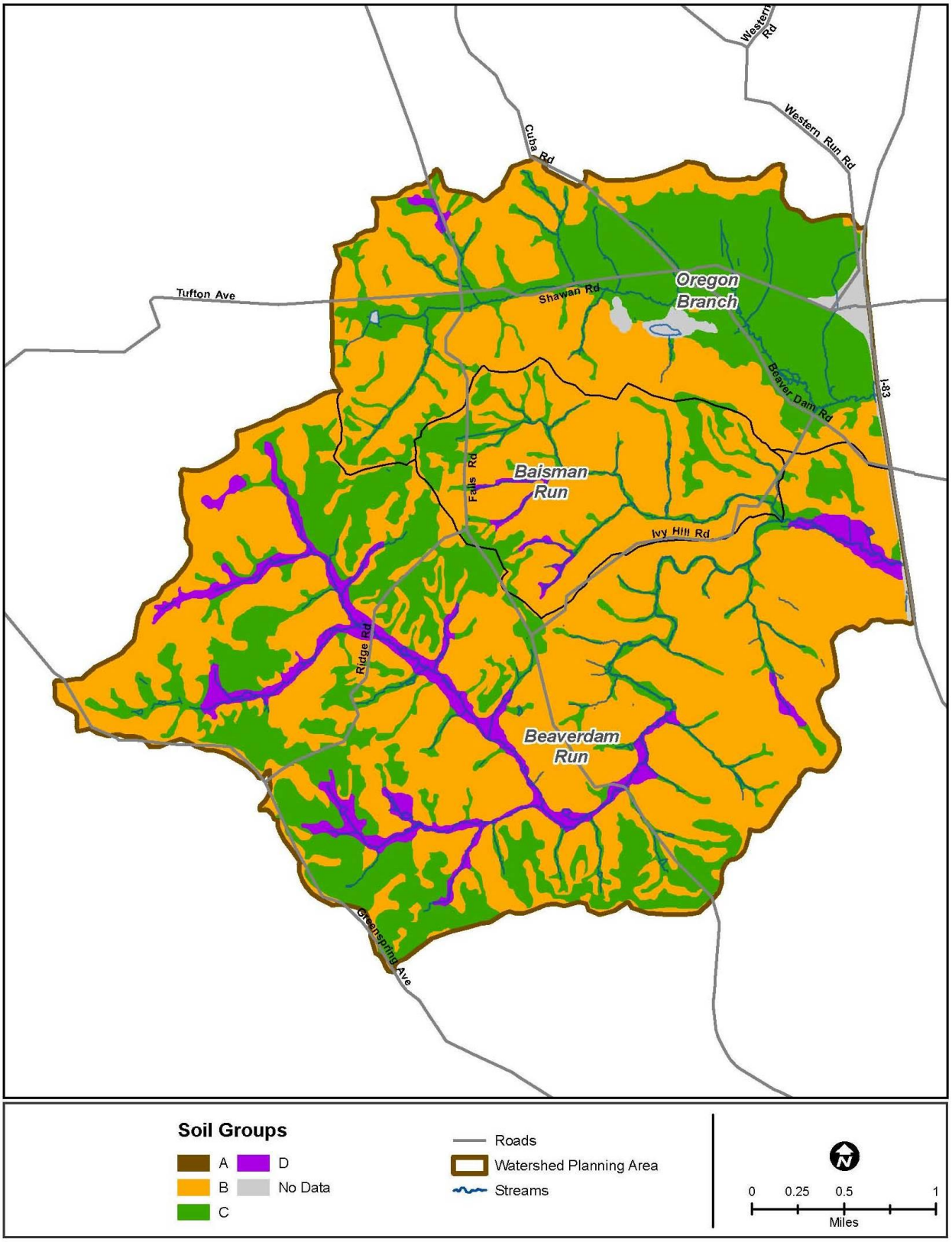


Figure 2-4: Area I Hydrologic Soil Groups

2.2.5.2 Soil Erodibility

Soil erodibility is a measure of the soil's susceptibility to erosion. The Universal Soil Loss Equation (USLE) developed by the United States Department of Agriculture (USDA) Agricultural Research Service is a model used to describe soil erosion processes. In the USLE, erodibility is described quantitatively using the K factor, which represents both the susceptibility of soil to erosion and its contribution to the rate of runoff. For example, clay soils have low K values because they are resistant to detachment. Coarse soils such as sand can also have low K values because even though they are easily detached, they are less susceptible to runoff. Silts have the highest K values because they detach easily and produce high rates of runoff (Institute of Water Research, 2002).

Subwatersheds with the largest percentage of highly erodible soils offer the greatest potential for addressing soil conservation with best management practices (BMPs) aimed at maintaining topsoil, such as riparian buffer forestation. Combining this indicator with other information, such as cropland, slope steepness and distance to streams would help to determine where to retire highly erodible land from farming, a type of BMP. Additionally, a high K value helps to identify areas where urban development near streams, such as road construction or utility placement may have particularly adverse watershed impacts.

Soil erodibility was divided into four categories, three categories match the classes used to classify sensitive areas in the Baltimore County Buffer Protection and Management Ordinance (Baltimore County, 2003).

- Low Erodibility (K factor < 0.24)
- Medium Erodibility (K factor 0.24 – 0.32)
- High Erodibility (K factor > 0.32)

Table 2-4 presents the soil erodibility categories based on K factor for subwatersheds in Area I.

Table 2-4: Area I Subwatershed Soil Erodibility Categories

Subwatershed	Soil Erodibility Category (%)			
	No Data	Low	Medium	High
Baisman Run	0.0	0.0	86.3	13.7
Beaverdam Run	0.3	0.0	81.0	18.8
Oregon Branch	3.6	0.0	83.1	13.3
Total	**1.2**	**0.0**	**82.2**	**16.6**

As shown on Table 2-4 and Figure 2-5, medium erodibility soils make up 82.2 percent of the total watershed, with an additional 16.6 percent of highly erodible soils and no low erodible soils. The three subwatersheds have similar amounts of medium and highly erodible soils. Beaverdam Run has the highest percentage of highly erodible soils, with approximately 19 percent. Erosion in Baisman Run would at first appear to be problematic, with 100 percent of the soils in the medium (86.3 percent) to high erodibility (13.7 percent) categories and a high proportion of steep slopes. However, soil is largely protected in Baisman Run by forest cover in Oregon Ridge Park.

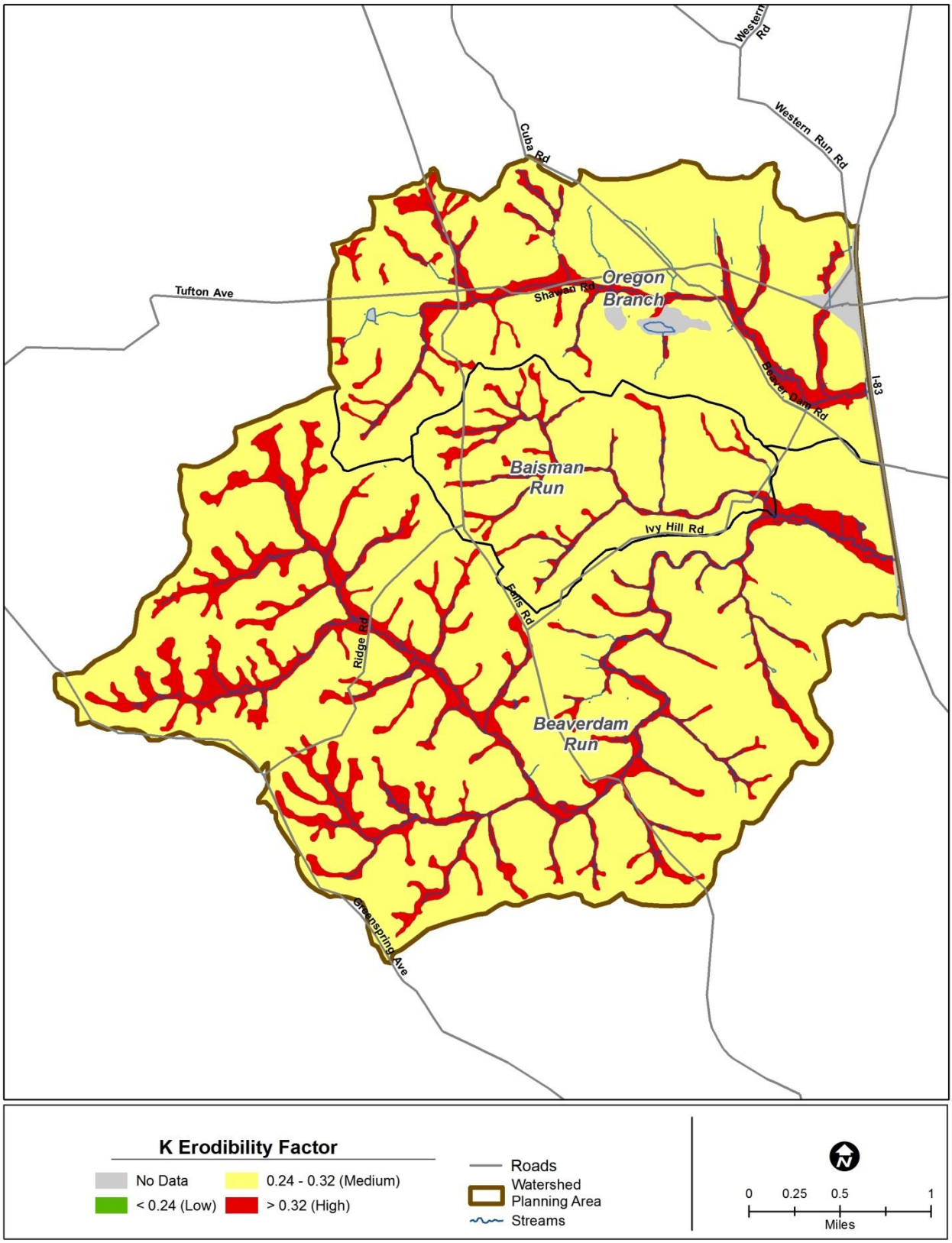


Figure 2-5: Area I Soil Erodibility based on the K factor

2.2.6 Forest Cover

Among land cover types, forest cover provides the greatest protection for soil and water quality. The entire Chesapeake watershed at the time of European settlement consisted primarily of old growth forest. In this type of pristine system, forest and soils co-evolve and shape the entire hydrologic cycle; these systems operate within a natural range of variability, assuring healthy habitat and water quality. In human-impacted systems, forest cover can still provide these same benefits and can help to protect water quality if judiciously planned.

Table 2-5 shows the percentage of forested acres for each subwatershed in Area I. Figure 2-6 shows the distribution of forest cover. This figure is based on Baltimore County's wooded GIS layer and differs from the Maryland Department of Planning's (MDP) 2007 land use/land cover data (which also contains forest data) presented in Section 2.3.1 Land Use and Land Cover. This layer was chosen because it is more accurate for forest cover.

Table 2-5: Area I Subwatershed Forest Cover

Subwatershed	Total Acres	Forested Acres	Forested (%)
Baisman Run	1,056.0	717.0	67.9
Beaverdam Run	4,984.6	1,862.2	37.4
Oregon Branch	2,309.4	783.6	33.9
Total	**8,350.0**	**3,362.8**	**40.3**

Since European settlement, forest cover in Area I has been greatly reduced through development for human uses. However, it remains relatively high when compared to many surrounding urban and suburban watersheds. Over 3,000 acres of forest remain in Area I, just over 40 percent of the total area. Because of Oregon Ridge Park, which covers over 1,000 acres, 68 percent of Baisman Run remains forested. Beaverdam Run and Oregon Branch also have relatively higher percentages of forest cover with 37.4 and 33.9 percent, respectively. These numbers are higher than the percentages shown in Section 2.3.1 using the MDP 2007 land use/land cover classification, which estimates 22.5 percent of forested cover in Area I. Variations are due to different scales and photo sources used to determine forest cover.

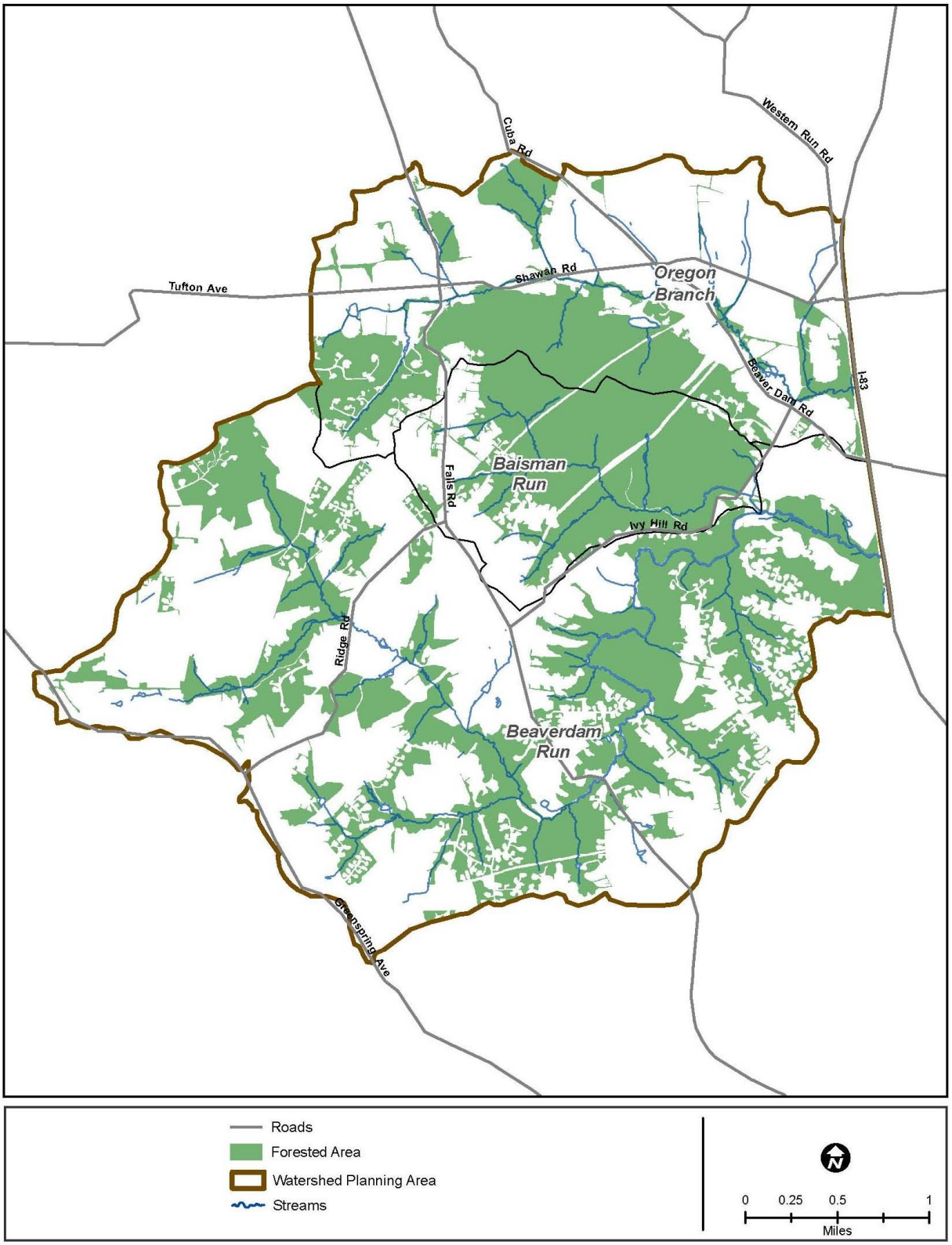


Figure 2-6: Area I Subwatershed Forest Cover

2.2.7 Stream Systems

Streams are a watershed's natural drainage system, and a visible part of the hydrologic cycle. Streams are the flowing surface waters and are distinct from both groundwater and standing surface water (such as lakes), but are closely connected to both. The stream system is an intrinsic part of the landscape and closely reflects conditions on the land. Streams are a fundamental natural resource with numerous benefits for plants, animals and humans. Maintaining a healthy stream system is a priority for many individuals and organizations, and requires insuring that stream flows and water quality closely mimic the conditions found in un-impacted watersheds.

2.2.7.1 Stream Characteristics

As mentioned previously, Area I is part of the 8-digit Loch Raven Reservoir watershed and part of the Chesapeake Bay basin. There are approximately 66 miles of stream in Area I that drain to the Loch Raven Reservoir and eventually the Chesapeake Bay. A summary of stream mileage and density in the Area I subwatersheds is shown in Table 2-6. Figure 2-7 shows the streams and the three subwatersheds comprising Area I. Stream lines were photogrammetrically derived from 1:2400 scale aerial photography captured in 2008.

Table 2-6: Area I Stream Mileage and Density

Subwatershed	Area (mi^2)	Stream Miles	Stream Density (mi/mi^2)
Baisman Run	1.7	11.4	6.7
Beaverdam Run	7.8	33.6	4.3
Oregon Branch	3.6	21.2	5.9
Total	**13.1**	**66.2**	**5.1**

The greatest stream lengths are located in Beaverdam Run (33.6 mi) followed by Oregon Branch (21.2 mi), then Baisman Run (11.4 mi). Stream density is highest in Baisman Run with 6.7 miles per square mile of subwatershed (mi/mi^2).

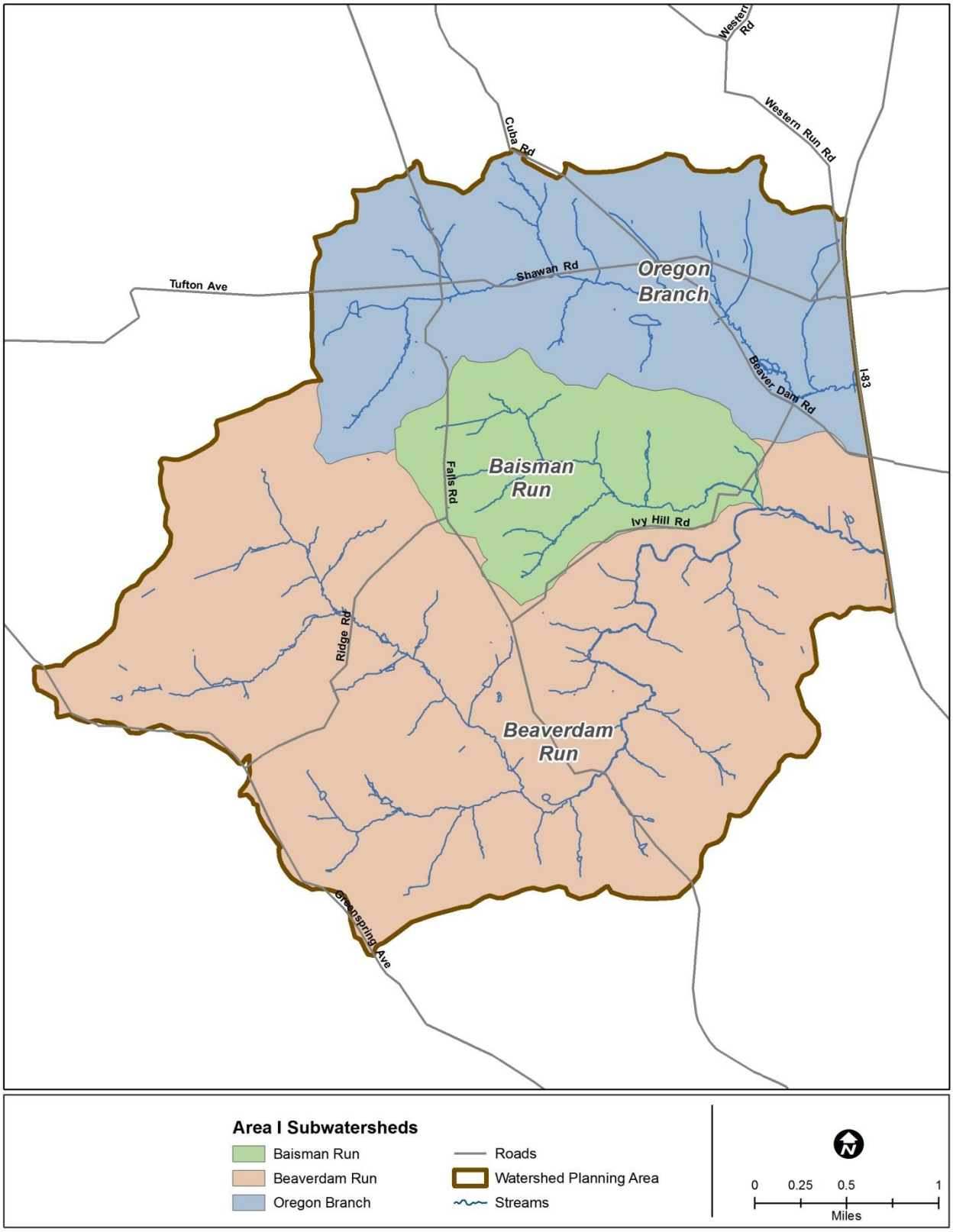


Figure 2-7: Area I Stream System and Subwatersheds

2.2.7.2 Stream Riparian Buffers

Riparian buffers are the vegetated areas adjacent to streams that serve the role of protecting water bodies from pollutant loads and providing bank stabilization and habitat for all types of stream life, including fish. Forested buffers along streams play a crucial role in improving water quality. Leaf litter from trees provide a needed energy source for soil microbes to decompose the organic matter where nutrients are consumed, taken up by plants and released back to the atmosphere, thus reducing the amount of nitrates available for runoff. Buffers mitigate flooding by reducing surface runoff, stabilize stream banks, and trap sediment. For example, tree roots capture and remove pollutants, including excess nutrients such as nitrogen from shallow flowing water. The tree root structure also slows soil erosion and water flow thus reducing sediment load and flooding. Tree canopy shades streams, providing cooler water temperatures required for stream life, particularly cold-water species such as trout.

In smaller streams, such as those found at the subwatershed level, terrestrial plant material falling into the stream is the primary source of food for stream life. Seasonally, trees provide food in the form of leaves and plant parts for stream life at the base of the food chain (such as insects). Fallen tree branches and trunks provide a more consistent, slow-release food source throughout the year. Tree roots and snags also provide important habitat for fish, insects and other aquatic life. Maintaining healthy streams and forest buffers are important for reducing the nutrient and sediment loads to the Chesapeake Bay. When stream riparian buffers are converted from forest to agriculture or other development, many of these benefits are lost and stream health declines. Riparian buffer zones can be replanted or preserved as a type of BMP to reduce impacts of developed land use.

The vegetative condition of the riparian buffer in Area I was analyzed based on a 100-foot buffer on either side of the stream system. Three land cover categories were used to classify stream buffer conditions: forested, open pervious and impervious. GIS was used to overlay the 100-foot stream buffer with impervious areas (roads and buildings). Forested areas were determined in a similar manner (using Baltimore County's forest GIS layer). Remaining areas were classified as open pervious. Table 2-7 shows the percentages and acreages for stream buffer conditions. Figure 2-8 shows the 100-foot stream buffer classification distribution.

Table 2-7: Area I Land Cover in the 100-foot Stream Buffer

Subwatershed	Forested		Open Pervious		Impervious		Total	
	Acres	%	Acres	%	Acres	%	Acres	%
Baisman Run	144.8	85.1	23.8	14.0	1.6	0.9	170.2	14.9
Beaverdam Run	398.7	70.6	159.5	28.2	6.8	1.2	565.0	49.8
Oregon Branch	176.8	44.2	206.1	51.6	16.8	4.2	399.7	35.2
Total	**720.3**	**63.5**	**389.4**	**34.3**	**25.2**	**2.2**	**1,134.9**	**100.0**

Overall, stream buffers in Area I are in good condition with over 63 percent forested. Only two percent of the 100-foot stream buffer is impervious cover. Open pervious area makes up the remaining 34 percent. It should be noted that much of the open pervious area consists of the stream system itself because the stream is classified as open pervious area. An example is shown in Beaverdam Run (Figure 2-8), where the stream is wide and the yellow line in the center of the stream buffer is the stream itself. Other areas of open pervious area are candidates for buffer forestation.

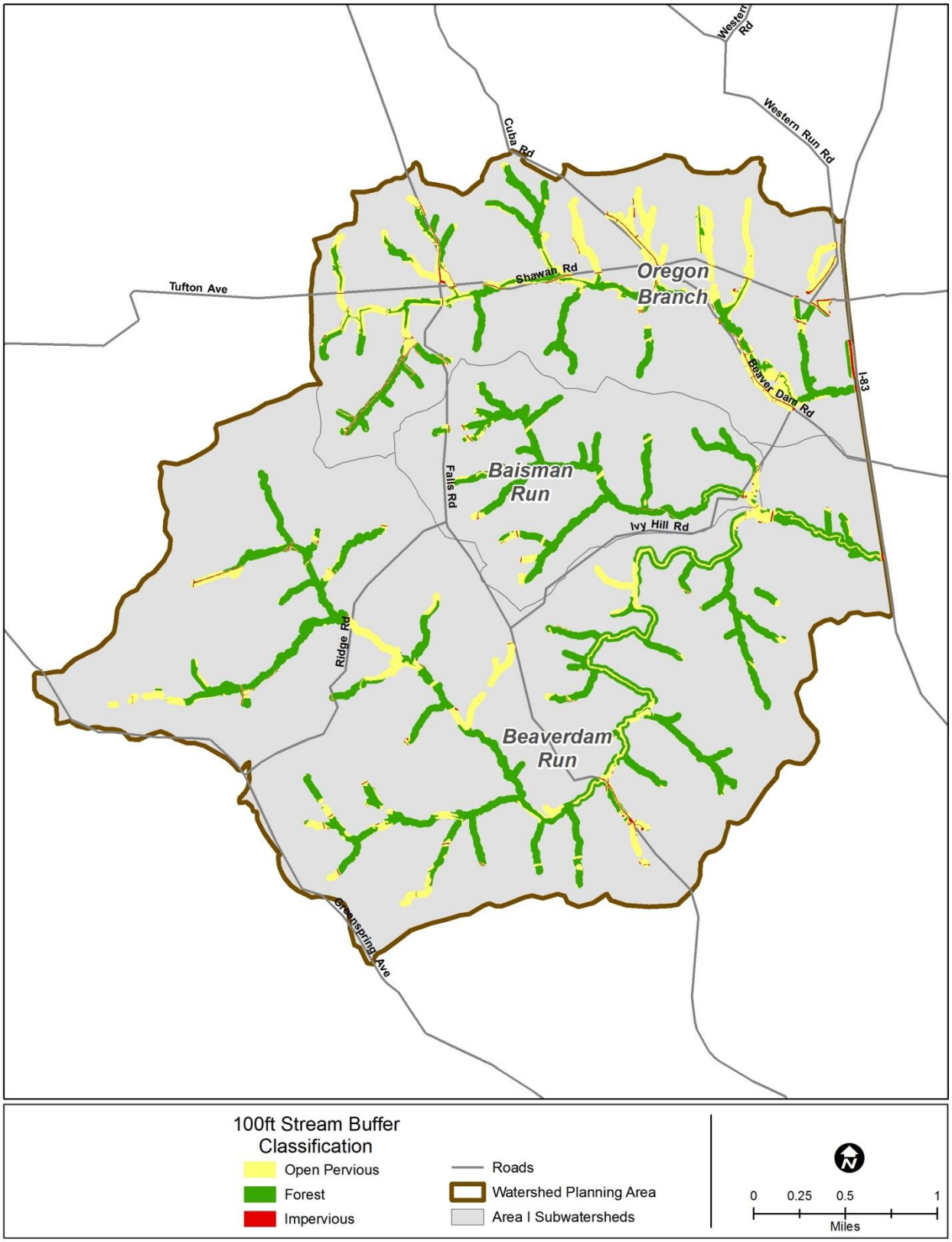


Figure 2-8: Area I 100-foot Stream Buffer Land Cover

2.3 The Human Modified Landscape

The natural landscape has been modified for human use over time. The intensity of development activities has increased, starting with the colonization of Maryland in the 1600s. This modification has resulted in environmental impacts to both terrestrial and aquatic ecosystems. This section will provide a characterization of the human modified landscape and how that modification is associated with impacts to the natural ecosystem. This includes a general description of land use and land cover followed by more specific issues including population, impervious cover, drinking water and wastewater, storm water systems, discharge permits and zoning.

2.3.1 Land Use and Land Cover

Land use has pronounced impacts on water quality and habitat with land uses that generate different types and amounts of pollutants. As discussed previously, a forested watershed has the capacity to absorb pollutants and slow the flow of water into streams. Conversely, impervious surfaces such as roads, parking lots and roofs in developed areas block the natural seepage of runoff. These impervious surfaces tend to concentrate stormwater runoff, accelerate flow rates, and direct stormwater to the nearest stream. In addition, increased impervious cover transmits nutrients, pollutants, and increases temperatures in the stream. This can cause bank erosion and destruction of in-stream and riparian habitat. Watersheds with small amounts of impervious surface tend to have better water quality in local streams than watersheds with greater amounts of impervious surface (Schueler et al., 2009). Additionally, agricultural land, if not properly managed, can cause substantial increases in sediment, nutrients and pathogens in streams.

The Maryland Department of Planning develops land use/land cover data for the entire state of Maryland every five years. This data is created from aerial photography and satellite imagery. The most recent update available and the source of the data presented in this section is draft data from 2007, using 2005 aerial imagery. New land use/land cover categories were introduced for this update that include very low density residential/agriculture and very low density residential/forest (both large lot subdivisions - 5 to 20 acres) and transportation (major highways and other transportation features not classified elsewhere). MDP does not anticipate major changes to the 2007 land use/land cover layer used in this report.

Area I contains 8,350 acres (13 square miles) of land consisting primarily of low and very low density residential uses (46.5 percent and 10.7 percent, respectively). As mentioned previously, 22.5 percent of the watershed is forested, with the highest percentage in Baisman Run. Various agricultural practices (cropland, orchards, and pasture) make up another 14.7 percent of the total area, primarily in the Oregon Branch subwatershed. Data was not available on the exact number of farms but there are several horse farms in Area I. Open urban areas, such as Hayfields Golf Course, and Oregon Ridge Park, located in Oregon Branch subwatershed, make up four percent of the total. Commercial, institutional and industrial areas combined make

up only 1.1 percent of the total area. All other land uses each comprise less than one percent of the total area.

Land use/land cover distribution within each subwatershed is varied. Beaverdam Run consists of primarily low and very low density residential (63.7 and 12 percent, respectively) with forest and agricultural uses (14.4 and 6.8 percent, respectively) making up the next largest percentages of area. Oregon Ridge Park contributes to Baisman Run having the highest percentage of forest cover of the three subwatersheds (55.6 percent). The greatest percentage of land in Oregon Branch is in agriculture uses (38 percent), followed by forest (24.8 percent) and residential (23.6 percent). A summary of the land use/land cover percentages by subwatershed is presented in Table 2-8, and shown in Figure 2-9.

Table 2-8: Area I Land Use/Land Cover Classification

Land Use Type	Baisman Run (%)	Beaverdam Run (%)	Oregon Branch (%)	Total (%)
Very Low Density Residential (Agricultural)	0.9	1.9	3.0	**2.0**
Very Low Density Residential (Forested)	6.7	10.1	6.7	**8.7**
Low-Density Residential	36.0	63.7	13.9	**46.5**
Commercial	0.0	1.2	0.5	**0.9**
Industrial	0.0	0.1	0.0	**0.1**
Institutional	0.5	0.0	0.2	**0.1**
Open Urban Land	0.0	1.3	11.5	**4.0**
Cropland	0.0	4.9	34.0	**12.4**
Pasture	0.4	1.3	4.0	**2.0**
Orchards	0.0	0.6	0.0	**0.3**
Deciduous Forest	55.6	13.7	24.8	**22.1**
Evergreen Forest	0.0	0.2	0.0	**0.1**
Mixed Forest	0.0	0.5	0.0	**0.3**
Transportation	0.0	0.3	1.4	**0.5**

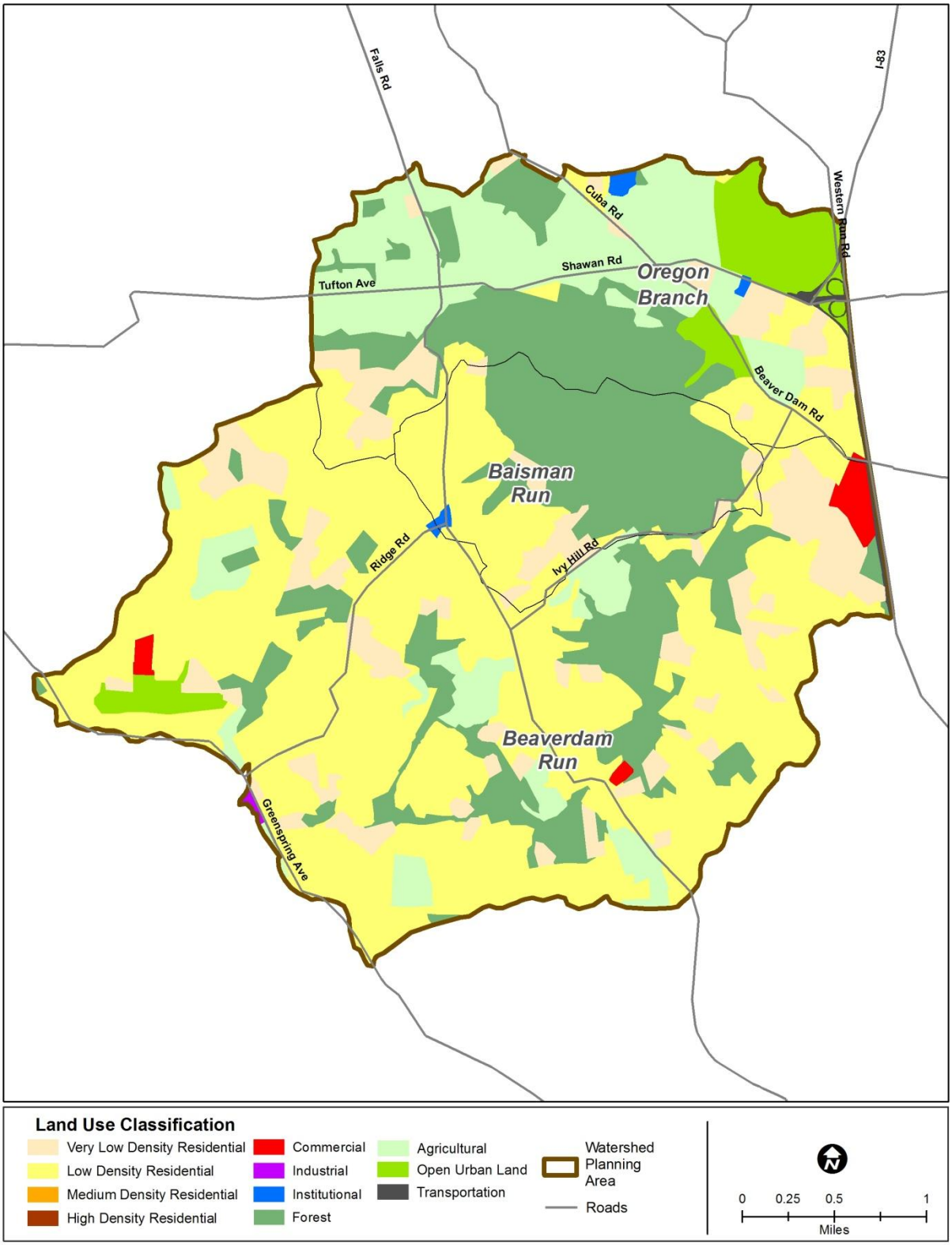


Figure 2-9 : Area I Land Use/Land Cover

2.3.2 Population

Population data provides another way to evaluate the intensity of land use. For example, a higher population density (i.e. persons per acre) represents a more intense use of the land and increases the potential for environmental degradation. Much of the degradation from intensive land uses is related to the extent of impervious cover needed to support higher population densities, which results in the loss of land uses such as forest that protect water resources.

Smart growth principles are aimed at directing future growth to areas of existing services and to where development has already occurred. This will result in less land conversion to residential and supporting commercial areas, resulting in conservation of land uses with lower environmental impact such as forest and agriculture.

Population density in Area I was estimated based on 2000 US Census data (U.S. Census Bureau, 2000). Table 2-9 summarizes the population data by subwatershed. Total population is provided as well as the population density per acre and per impervious acre. Population density distribution is shown on Figure 2-10.

Table 2-9: Area I Population Data

Subwatershed	Total Population (2000 Census)	Total Area (acres)	Population Density (per acre)	Impervious Area (acres)	Population Density (per impervious acre)
Baisman Run	432	1,056.0	0.4	42.8	10.1
Beaverdam Run	4,405	4,984.6	0.9	383.8	11.5
Oregon Branch	712	2,309.4	0.3	112.2	6.3
Total	**5,549**	**8,350.0**	**0.7**	**538.8**	**10.3**

Population density across the watershed and within each subwatershed is low, with an average of 0.7 people per acre across almost the entire watershed. The highest population density is clustered near the eastern boundary of Beaverdam Run. The highest population density per impervious acre is in Beaverdam Run followed by Baisman Run and Oregon Branch.

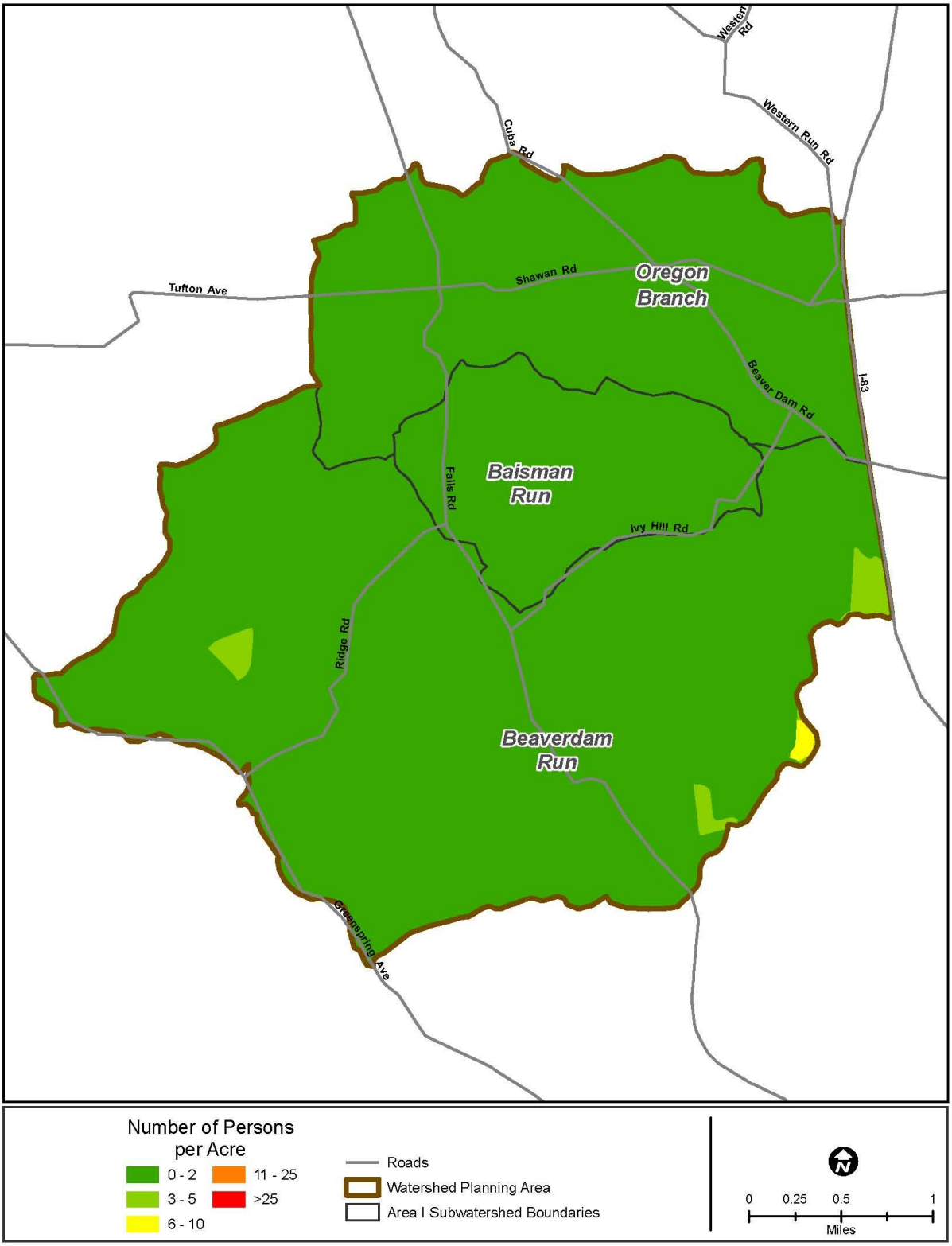


Figure 2-10: Area I Population Distribution

2.3.3 Impervious Surfaces

Impervious surfaces are materials that impede or prevent infiltration of water into the soil. While there are some naturally occurring impervious surfaces such as rock outcroppings, most impervious surfaces are man-made, and include roofs, buildings, streets, and parking areas.

Unlike many natural surfaces, impervious surfaces typically concentrate stormwater runoff, accelerating flow rates and directing stormwater to the nearest stream. This accelerated, concentrated runoff can cause stream erosion and habitat destruction. Runoff from impervious surfaces picks up and washes off pollutants and is usually more polluted than runoff generated from pervious areas. In general, undeveloped watersheds with small amounts of impervious cover are more likely to have better water quality in local streams than urbanized watersheds with greater amounts of impervious cover. Impervious cover is a primary factor when determining pollutant characteristics and loadings in stormwater runoff. Research has been conducted to link the degree of urbanization (as measured by the amount of impervious cover) with various watershed-based indicators of water quality such as the diversity and abundance of aquatic and terrestrial life (Schueler et al., 2009).

The Center for Watershed Protection (CWP) compiled stream research conducted in various parts of the country and developed a simple impervious surface model that relates stream quality to percentage of impervious surfaces in a watershed. This model has been updated and is shown in Figure 2-11. This relationship is represented as a white ‘cone’ that is widest at low levels of impervious cover and decreases as impervious cover increases. This indicates that at low levels of impervious cover, other watershed metrics besides impervious cover such as forest cover, road density, riparian buffer and cropping practices influence stream health. As impervious cover increases, the relationship is stronger and the ‘cone’ is narrower. Studies used to develop the impervious cover model measured stream quality based on a variety of indicators such as the number of aquatic insect species, stream temperature, channel stability, aquatic habitat, wetland plant density, and fish communities.

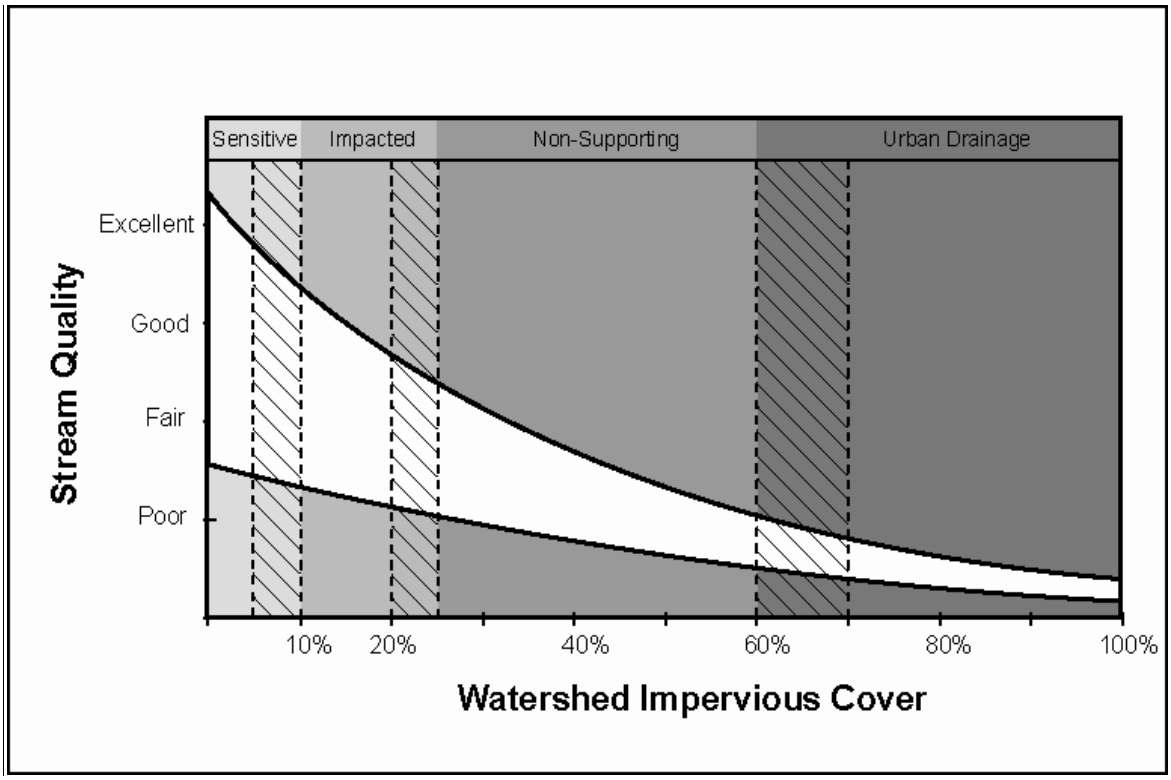


Figure 2-11: Impervious Cover Model (Schueler et al. 2009)

Based on the research compiled, CWP determined the following general categories to classify and predict stream quality in terms of impervious cover represented by bands in Figure 2-11. These 'bands' are colored in a gradation from least (light gray) to most (darker gray) amount of impervious cover.

- Sensitive – watersheds with less than 10 percent impervious cover are referred to as sensitive and typically have high quality streams with stable channels, good habitat conditions, and good to high water quality. Sensitive watersheds are susceptible to environmental degradation with urbanization and increases in impervious cover.

- Impacted – watersheds with between 10 and 25 percent impervious cover show clear signs of degradation such as erosion, channel widening and decline in stream habitat. Stream restoration to a somewhat natural functioning system is still possible in these watersheds.

- Non-supporting – watersheds with between 25 and 60 percent of impervious cover are characterized by fair to poor water quality, unstable channels, severe erosion, and the inability to support aquatic life and provide habitat. Many streams in this category are typically piped or channelized.

- Urban drainage – in watersheds where impervious cover exceeds 60 percent, a watershed is classified as severely damaged which means that most of the natural stream system is gone, most often buried to flow in storm drains.

Management of damaged and severely damaged streams may focus on decreasing pollutant loads to downstream receiving waters but the ability to restore natural functions is unlikely. Restoration efforts may also focus on making the remaining stream systems stable, aesthetically pleasing and an amenity to the community.

The roads and buildings GIS data layers from Baltimore County were used to determine the total impervious area within subwatersheds of Area I. Table 2-10 presents the results of this analysis and Figure 2-12 shows the distribution of impervious area in the study area.

Table 2-10: Area I Estimated Impervious Surfaces

Subwatershed	Total Area (acres)	Roads (acres)	Buildings (acres)	Total Impervious Area (acres)	Total Impervious Area (%)
Baisman Run	1,056.0	28.2	14.6	42.8	4.05
Beaverdam Run	4,984.6	247.6	136.2	383.8	7.70
Oregon Branch	2,309.4	92.8	19.4	112.2	4.86
Total	**8,350.0**	**368.6**	**170.1**	**538.8**	**6.5**

Impervious surfaces represent 6.5 percent of the total area in Area I, with all three subwatersheds below the ten percent of impervious area threshold to qualify as sensitive watersheds according to CWP's impervious cover model (see Figure 2-13). This is a low level of impervious area, especially when compared to more developed subwatersheds in Baltimore County. It should be noted that this analysis was conducted at the subwatershed scale. Based on Figure 2-12, if the analysis was on a smaller scale, such as 10-20 acre catchments, several catchments might be categorized as impacted.

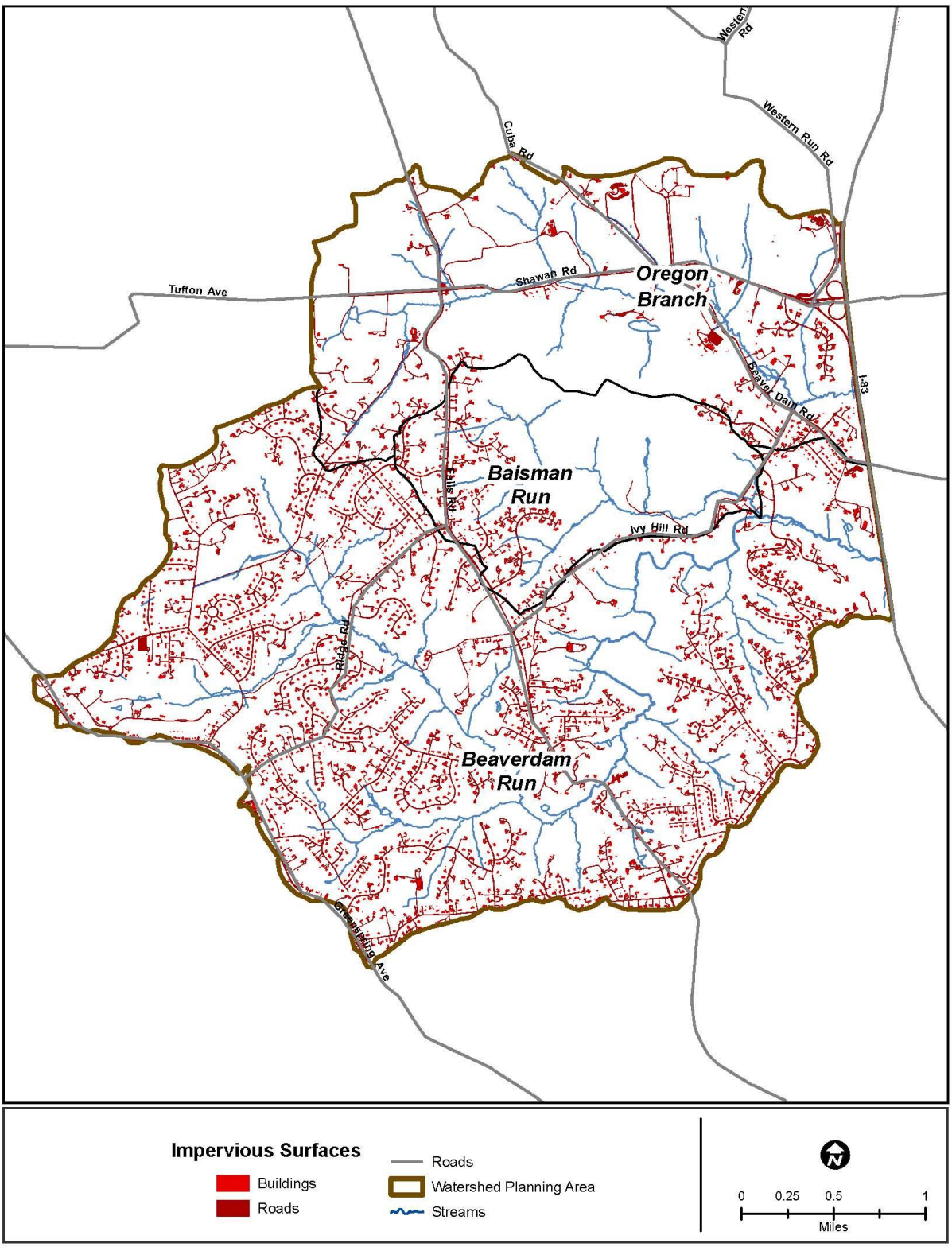


Figure 2-12: Area I Impervious Surfaces

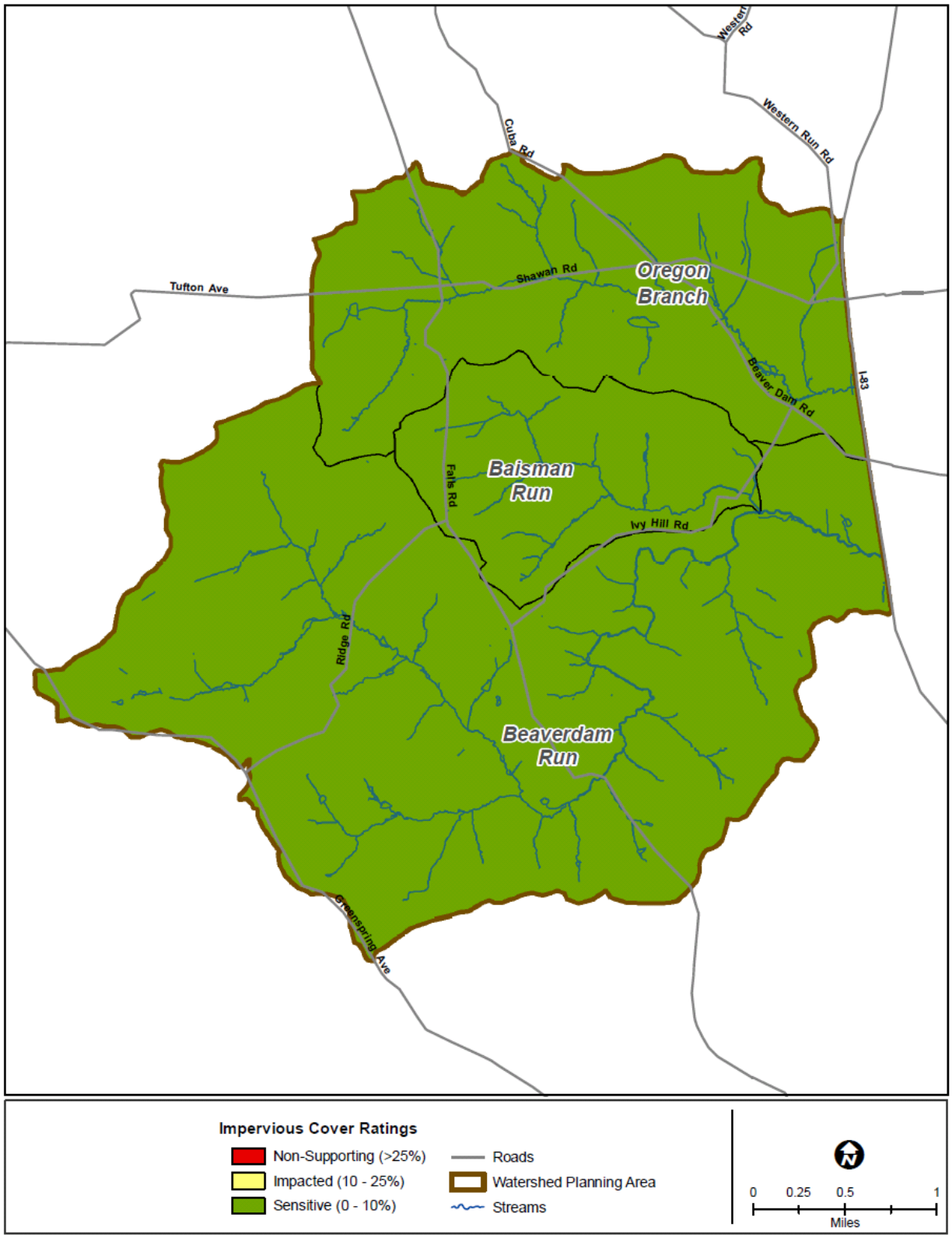


Figure 2-13: Area I Impervious Cover Ratings

2.3.4 Drinking Water

Drinking water is a fundamental need for human development. It can be supplied either by public distribution systems or by wells associated with individual properties. Having an adequate supply of drinking water is essential to maintaining the human population in a region. Area I streams flow into the Loch Raven Reservoir, a major source of public drinking water for the region.

2.3.4.1 Public Water Supply

Environmental impacts associated with public supply of water include the potential for increased residential development, associated impervious cover effects and the potential for leaks from the system. Area I lies outside of the area served by the Baltimore Metropolitan water supply, so the potential for leaks from the system are not an issue in this watershed. However, the effects associated with impervious cover and development in Area I do have an impact on water quality and habitat in local streams and in the Loch Raven Reservoir.

2.3.4.2 Groundwater

Water supply in Area I is provided by groundwater wells. The underlying geology can cause well yield and water quality to be highly variable even in this small area. Wells in the Cockeysville marble have some of the highest yields in Baltimore County due to fractures and cavities that have high capacities to hold and conduct water. Wells in areas underlain by Loch Raven schist have been identified by the county as critical yield areas due to a lower degree of fracturing in the rock. This means that wells located in the Loch Raven schist may yield less flow than wells in other geology.

Groundwater quality is also affected by geologic formations. For example, naturally occurring radionuclides have been detected in groundwater at levels above the US EPA Drinking Water Standards in areas underlain by the Baltimore gneiss. Hardness may be a problem in areas underlain by marble due to higher concentrations of calcium and magnesium. In addition, groundwater may be more acidic when obtained from aquifers in gneiss and schist while in marble formations, ground water is usually alkaline (Baltimore County DEPRM, 2006a).

2.3.5 Wastewater

Wastewater created through human use must be treated and disposed. This is accomplished either through public conveyance to a wastewater treatment facility (not applicable in Area I) or through individual wastewater treatment systems (i.e., septic systems). Residential wastewater consists of all water typically used by residents including wash water, bathing water, human waste disposal water, and any other rinse water (e.g., paint brush, floor washing, etc.). Industrial and commercial operations must also dispose of any water used as part of their operation. Depending on the operation the water could contain any number of contaminants, including metals, organic compounds, detergents, or synthetic compounds. All of these wastes have the potential to harm the natural environment.

2.3.5.1 Septic Systems

Properly functioning septic systems provide treatment for pathogens and phosphorus present in wastewater, but can discharge nitrogen in the form of nitrates. Depending on the location of the system the nitrates may either be reduced or eliminated through denitrification as the water passes through riparian buffers, particularly forested riparian buffers. Failing systems can release nitrogen, phosphorus, and other chemicals, contaminating the aquatic environment. They can also result in increased bacterial contamination of nearby streams and are therefore a human health concern.

There is no public sewer in use in Area I and therefore septic systems are numerous. According to Baltimore County Bay Restoration Fund tracking there are approximately 2,138 septic systems in Area I. Table 2-11 shows the distribution of these septic systems among the three subwatersheds.

Table 2-11: Approximate Number of Septic Systems in Area I

Subwatershed	Number of Septic Systems (estimated)
Baisman Run	186
Beaverdam Run	1,763
Oregon Branch	189
Total	**2,138**

2.3.5.2 Public Sewer

A public sewer system conveys wastewater from individual residences or businesses to a facility that treats the wastewater prior to discharge. Area I lies outside of the area served by the Baltimore County public sewer system, and therefore issues such as leakage or overflows are not applicable in this watershed.

2.3.6 Stormwater

Stormwater is surface water or snowmelt resulting from precipitation. Stormwater that does not infiltrate into the ground or evapotranspire through plants becomes the runoff that flows directly to storm drainage systems or to streams. Stormwater runoff is affected by the amount and intensity of rainfall, soil characteristics, surface slope and land use/land cover. Runoff is higher in areas with greater impervious surfaces and on agricultural land than on undeveloped land. Certain types of agricultural uses such as row crops can dramatically increase runoff especially compared to low density development. This can lead to flooding and stream erosion,

resulting in the destruction of habitat and a reduction of a stream's natural ability to remove pollutants.

Stormwater runoff can also carry various contaminants. Pollutants deposited on impervious surfaces and other developed lands from daily human activities are often washed off into stream systems by stormwater. Runoff from agricultural operations and residential areas can carry pollutants such as nutrients, pathogens, and chemicals to receiving water bodies.

2.3.6.1 Storm Drainage System

The storm drainage system commonly consists of curb and gutter with associated inlets (road drains), and a piping system. Drainage swales (e.g., roadside ditches) may or may not be connected to storm drain pipes. The purpose of these systems is to remove water quickly from roadways to prevent flooding and potentially hazardous situations. However, the environmental impacts from the two systems are different. The curb and gutter system quickly and efficiently removes water from impervious surfaces and routes that water to low spots in the topography, usually directly to the stream. This type of system delivers not only increased volumes of water, but pollutants associated with impervious surfaces are carried untreated directly to the stream system or other receiving water body (bypassing any existing buffer).

Drainage swales do not move the water as quickly as curb and gutter systems but may allow the water to slow somewhat prior to entering the stream system, or in some cases storm drain pipes. Drainage swales also allow some infiltration into the soil thus reducing the amount of water eventually delivered to the receiving water body. The infiltration and slower movement of water also provide some filtering of pollutants. Table 2-12 shows the components of the storm drain system by subwatershed in Area I. The information is divided between major (> 3 feet in diameter) and minor (< 3 feet in diameter) storm drain outfalls and corresponding pipe lengths. The length of pipe for which cross-sectional size is unknown is also shown. Table 2-13 shows the percentage of area served by the storm drain system.

Table 2-12: Area I Storm Drain System Components

Subwatershed	Major (> 3ft)				Minor (<3 ft)			
	Outfalls (#)	Inlets (#)	Pipe Length (ft)	Drainage Area (acres)	Outfalls (#)	Inlets (#)	Pipe Length (ft)	Drainage Area (acres)
Baisman Run	1	6	550	34	3	11	1,885	18.6
Beaverdam Run	2	10	740	35	44	125	18,350	382.8
Oregon Branch	0	0	0	0	8	31	4,275	46.7
Total	**3**	**16**	**1,290**	**69**	**55**	**167**	**24,510**	**448.1**

Subwatershed	All Outfalls						
	Total Outfalls (#)	Total Inlets (#)	Total Pipe Length (ft)	Total Pipe Density (ft/acre)	Total Culverts (#)	Total Culvert Density (#/stream mi)	Total Drainage Area (acres)
Baisman Run	4	17	2,435	2.3	7	0.6	52.6
Beaverdam Run	46	135	19,090	3.8	62	1.8	417.8
Oregon Branch	8	31	4,275	1.8	49	2.3	46.7
Total	**58**	**183**	**25,800**		**118**		**517.1**

Table 2-13: Area I Stormwater System Coverage

Subwatershed	Stormwater System Drainage Area (acres)	Area Covered by Stormwater System (%)	Number of Inlets (#)	Inlet Density (# / mi^2)
Baisman Run	52.6	4.9	11	6.6
Beaverdam Run	417.8	8.3	125	16.0
Oregon Branch	46.7	2.0	31	8.5
Total	**517.1**	**6.1**	**167**	**31.1**

2.3.6.2 Stormwater Management Facilities

Starting in the mid-1980s the Maryland Department of Environment (MDE) began requiring new development to implement stormwater management to control the quantity of stormwater runoff. This continues to be a significant consideration for development across the state. Stormwater management systems can reduce erosion, sedimentation, pollution, and flooding. Increased importance of water quality and water resource protection led to the development of the Maryland Stormwater Design Manual (MDE, 2000) which provided BMP design standards that endeavored to mimic natural hydrologic processes to preserve pre-development conditions. The subsequent Maryland Stormwater Management Act of 2007 expanded on the 2000 manual regulations by requiring that environmental site design (ESD) techniques be implemented in new development via nonstructural BMPs and/or other better site design techniques. Full implementation of onsite ESD can in some cases eliminate the need for downstream stormwater management (SWM) facilities. There are many types of BMPs available

for managing stormwater runoff and providing stormwater quality treatment, all with differing pollutant removal capabilities. Several considerations are taken into account when selecting appropriate stormwater treatment measures such as space, maintenance, cost, and community acceptance.

Table 2-14 and Figure 2-14 summarize and display the location of the 73 public and private stormwater management facilities in Area I. In addition, the total drainage area (including both urban and nonurban areas) treated by these facilities is provided. Facilities are numerous in Beaverdam Run and widely distributed. Baisman Run has only two facilities, while Oregon Branch has 18. Filtration practices and extended detention facilities are the most numerous across the entire watershed. Beaverdam Run contains the majority of BMPs (59), treating 879.4 acres. These stormwater management facilities provide water quality treatment with the exception of the dry pond that is an older stormwater management designed for flood control.

Table 2-14: Area I Stormwater Management Facilities

SWM Facility Type	Baisman Run	Beaverdam Run	Oregon Branch	Total
Dry Pond (#)	0	7	3	10
Drainage Area (ac)	0	262.2	10.4	272.6
Extended Detention (#)	1	18	1	20
Drainage Area (ac)	10.6	287.7	25.4	323.7
Filtration (#)	1	21	4	26
Drainage Area (ac)	5.1	219.7	17.8	242.5
Infiltration (#)	0	9	2	11
Drainage Area (ac)	0	10.7	3.5	14.2
Proprietary BMP (#)	0	0	1	1
Drainage Area (ac)	0	0	0.6	0.6
Wet Ponds / Wetlands (#)	0	4	1	5
Drainage Area (ac)	0	99.2	28.0	127.2
Total (#)	**2**	**59**	**12**	**73**
Total Drainage Area (Acres)	**15.7**	**879.4**	**85.7**	**980.7**

Table 2-15 shows the percentage of urban land use area treated by stormwater management whereas Table 2-14 provides a summary of both urban and non-urban land use areas treated by stormwater management. Table 2-15 was calculated by locating SWM facilities in the following MDP land uses: low and medium density residential, commercial, industrial, institutional, open urban and transportation and calculating the area treated by each of these SWM facilities. Table 2-15 shows that 18.2 percent of the urban land uses in Area I are treated by SWM, with Beaverdam Run receiving the highest area of urban land treated at 22.8 percent and Oregon Branch, the least at 2.8 percent. Locations of urban land use where there is no current stormwater management are good candidates for implementing BMPs. Locations for implementing BMPs will be further discussed in Chapters 3 and 4.

Table 2-15: Area I Urban Land Uses Treated by Stormwater Management

Subwatershed	Total Area (acres)	Urban Land Use (acres)	Urban Land Use Treated by SWM (acres)	Urban Land Use Treated by SWM (%)
Baisman Run	1,056.0	385.7	15.7	4.1
Beaverdam Run	4,984.6	3,325.5	757.5	22.8
Oregon Branch	2,309.4	635.3	17.9	2.8
Total	**8,350.0**	**4,346.5**	**791.1**	**18.2**

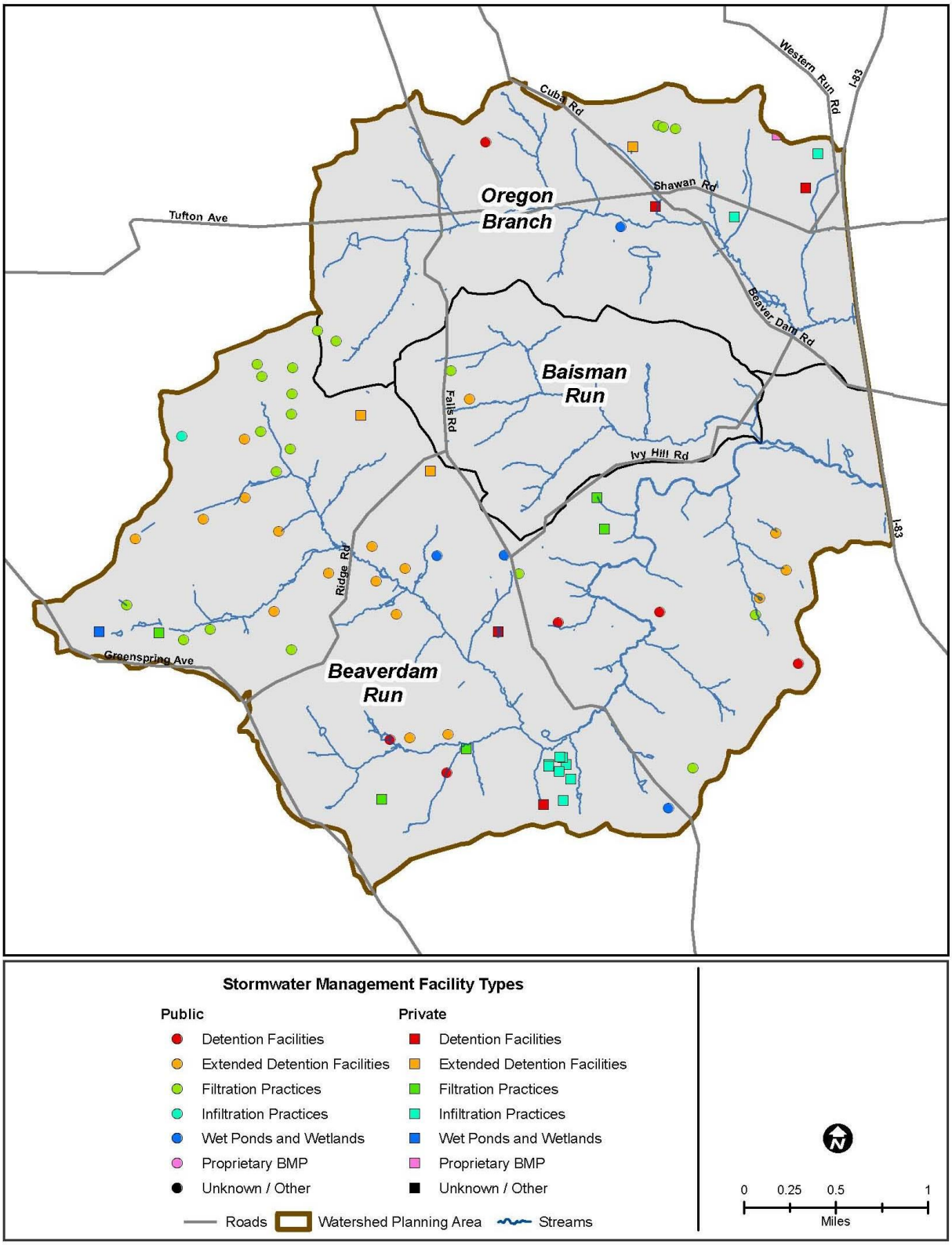


Figure 2-14: Stormwater Management Facility Types

2.3.7 NPDES Permits

Facilities that discharge municipal or industrial wastewater or conduct activities that can contribute pollutants to a waterway are required to obtain a National Pollutant Discharge Elimination System (NPDES) permit. The number and type of NPDES-permitted facilities within Area I is summarized in Table 2-16.

There is only one permitted facility within Area I, a commercial swimming pool discharge located in Beaverdam Run that is no longer in operation.

Table 2-16: NPDES Permits in Area I

Subwatershed	# Industrial	# General	# Pools	# of Permits
Baisman Run	-	-	-	-
Beaverdam Run	-	-	1	1
Oregon Branch	-	-	-	-
Total	**-**	**-**	**1**	**1**

2.3.8 Zoning

The Baltimore County Office of Planning (2009) defines zoning as “a system of land use regulation that controls the physical development of land. It is a legal mechanism by which local government is able to regulate an owner’s right to use privately owned land for the sake of protecting the public health, safety, and/or general welfare.” Zoning controls development patterns throughout the county over time.

The Comprehensive Zoning Map Process (CXMP) takes place every four years as specified in the County Code. There will be a rezoning cycle in 2012 that will start in the fall of 2011.

In 1967, Baltimore County established the Urban Rural Demarcation Line (URDL) as part of its smart growth management policy. This line identified areas of Baltimore County that had or would receive public water and sewer infrastructure, thus allowing for commercial and residential development. Limits on infrastructure growth effectively ensured limited development in areas outside of the URDL, including all of Area I.

The current zoning for Area I is summarized in Table 2-17 and shown on Figure 2-15. There are many zoning categories in Baltimore County. Only those most applicable to Area I are

shown on the legend. Areas so small that they comprise zero percent of the watershed (that is, they are a remnant of a GIS intersect and are approximately one acre or less) are not displayed on the map, but are included in the table for accounting purposes. These are all located at the very eastern edge of Area I, near I-83. Outside of these very minor exceptions, all zoning categories within the watershed are resource conservation ('RC') categories. There are also several properties that are in agricultural or conservation easements. These are discussed later in section 2.3.8.1 Conservation Easements.

The greatest percentage of land in Area I is zoned 'RC 5' or rural residential (41.4 percent), followed by areas zoned 'RC 4', or watershed protection (32.4 percent) that are associated with streams and their riparian areas. Agricultural zoning ('RC 2') in northern Oregon Branch (14.9 percent) and resource preservation (in the vicinity of Oregon Ridge Park) (11.1 percent) comprise the other significant zoning areas in Area I. There are no areas zoned for commercial use in Area I.

Table 2-17: Area I Zoning (Baltimore County Office of Planning, 2006b)

Zoning Code	Zoning Description	Total (Acres)	% of Watershed Area
DR 3.5	Density Residential (3.5 units/acre) – Foster a greater variety of housing types within residential developments	1.1	0.0
DR 5.5	Density Residential (5.5 units/acre) – Foster a greater variety of housing types within residential developments	0.1	0.0
ML	Manufacturing Light – Industrial uses requiring assembly, production, processing, packaging, or treatment of various elements; laboratories, office/medical clinics; excavations not using explosives; equipment/material storage yards; heliports.	0.3	0.0
MLR	Manufacturing Light Restricted – Uses permitted in MR zone (except heliport type II), car wash and fuel service stations in planned industrial parks with IM district.	0.1	0.0
O-3	Office Park – Provide solely for office buildings with no residential development allowed	0.5	0.0
RC 2	Agricultural Protection – Foster and protect agriculture	1,246.3	14.9
RC 4	Watershed Protection – Protect the watersheds of the three regional reservoirs	2,703.9	32.4
RC 5	Rural Residential – Provide for residential development in appropriate rural areas	3,458.1	41.4
RC 6	Rural Conservation and Residential – Provide greater protection for resource areas	6.7	0.1
RC 7	Resource Preservation – Protect cultural, historical, recreational and environmental resources	923.6	11.1

Zoning Code	Zoning Description	Total (Acres)	% of Watershed Area
RC 8	Environmental Enhancement – Protect forests, reservoir watersheds and extensive natural areas	7.1	0.1
RCC	Resource Conservation Commercial – Provide small areas of commercial development for rural needs	2.3	0.0
Total		**8,350.0**	**100.0**

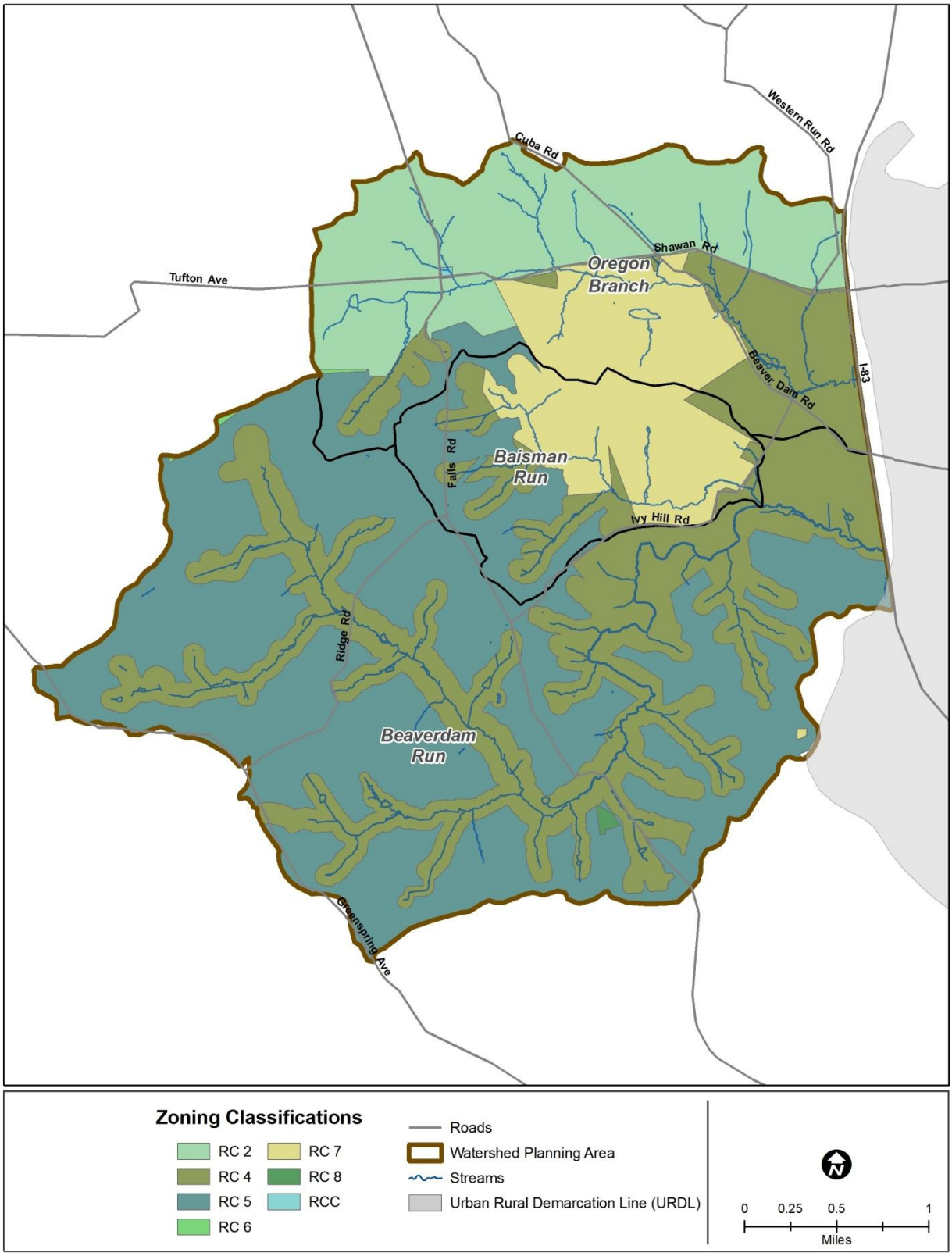


Figure 2-15: Area I Zoning

2.3.8.1 Conservation Easements

A conservation easement ensures the protection of significant natural resources on a property. Placing a property under easement may allow the landowner to receive income, or estate and property tax benefits while still maintaining ownership of the property.

Area I contains several conservation easements held under various preservation programs. For Area I these include properties held under local land trusts, Maryland Agricultural Land Preservation Foundation or Maryland Environmental Trust and open space on properties that are situated in areas zoned by Baltimore County as watershed protection (RC-4). These categories are discussed in more detail below. Table 2-18 summarizes the area within each subwatershed held in easement and Figure 2-16 shows the location of these properties.

Table 2-18: Conservation Easements

Subwatershed	Local Land Trust Properties (Acres)	Maryland Environmental Trust (MET) Properties (Acres)	Maryland Agricultural Land Preservation Foundation Properties (Acres)	Watershed Protection Zoning (RC-4) (Acres)	Total (Acres)
Baisman Run	6.3	0.0	0.0	0.0	6.3
Beaverdam Run	14.9	86.7	0.0	155.8	257.3
Oregon Branch	0.0	81.6	234.6	0.0	316.2
Total	**21.2**	**168.3**	**234.6**	**155.8**	**579.8**

There are 189.5 acres either in Maryland Environmental Trust (MET) or local land trusts, primarily in Beaverdam Run. The MET and local land trusts are preservation programs created in 1967 by the Maryland General Assembly to protect Maryland's natural environment. The MET seeks donated easements on farms and forestlands, wildlife habitats, waterfront acreages, natural areas, historic sites, and other valuable and scenic features. Larger properties (greater than 50 acres) are preferred for preservation under these programs, but local land trusts are often willing to work with smaller properties (EPS, 2011).

The Maryland Agricultural Land Preservation Foundation (MALPF) properties make up the largest portion of easement properties, with 234.6 acres all located on one property within the Oregon Branch subwatershed. The MALPF was a program created in 1979 and jointly funded by Baltimore County and the State of Maryland. This program is dedicated to preserving farmland and promoting commercial agriculture. To qualify for this program, a farm must be a minimum of 50 acres or located adjacent to a preserved property. Landowners receive cash payments for participating in this easement program (EPS, 2011).

There is also open space on several properties that is held under easement in areas zoned by Baltimore County as Watershed Protection Areas (RC-4 zoning designation). In Area I, there are 155.8 acres all located in Beaverdam Run. Residential development in the Watershed Protection Area (RC-4) requires the allocation of an open space (unbuildable area) of 70% of the total tract acreage. The 70% includes forest stands, farm fields, steep slopes, and/or wetlands (EPS, 2011). Watershed Protection Areas are established to provide for the protection of the water supplies of metropolitan Baltimore. These areas prevent contamination of the water supply by limiting unsuitable types or levels of development in the watershed.

In addition to the formal easements described above, there are some parcels in the watershed protected from development by unique circumstances. In the case of the Catholic Community of St. Francis Xavier on Cuba Road, in conjunction with approval of a special exception to the RC-2 zoning which allowed for construction of the church, the bulk of the church property cannot be further developed within the foreseeable future. This restriction applies to the area outside of a specified “development envelope” where the church building and related improvements are located. It will remain as open space or in agricultural use for over 40 years in the future as long as conditions specified in documents recorded in the County land records are met. Without in depth research, it is not known how many properties in Area I have similar restrictions.

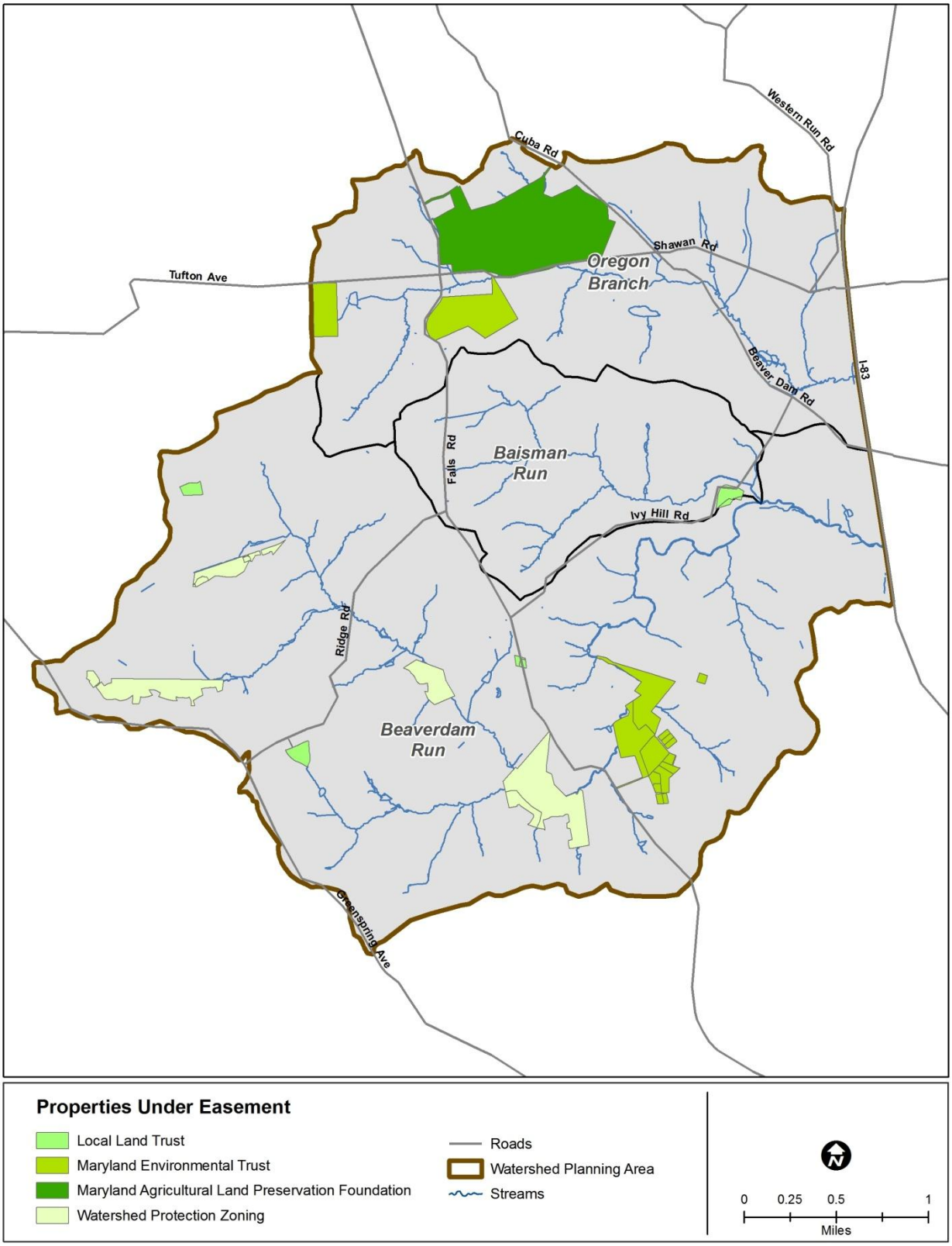


Figure 2-16: Area I Properties Under Easement

2.3.9 Historical Development

Historical development within Area I began before 1900 with the majority of the watershed built from the 1970s to 1990s. Table 2-19 provides a summary of the number of units within each subwatershed and the decade built. Figure 2-17 shows the decade parcels were built using the GIS shapefile "HistoricalDevo2005" provided by Baltimore County. As discussed in section 2.3.6.2, in the mid-1980s the Maryland Department of Environment (MDE) began requiring new development to implement stormwater management to control the quantity of stormwater runoff. In 2007, the Maryland Stormwater Management Act of 2007 expanded on the 2000 manual regulations by requiring that environmental site design (ESD) techniques be implemented in new development via nonstructural BMPs and/or other better site design techniques.

Table 2-19: Decade Built and Number of Units

Decade Built	Number of Units			
	Baisman Run	Beaverdam Run	Oregon Branch	Total
Before 1900	32	275	41	**348**
1900-1919	0	19	4	**23**
1920s	0	4	2	**6**
1930s	0	8	6	**14**
1940s	4	35	6	**45**
1950s	6	125	12	**143**
1960s	5	106	6	**117**
1970s	36	231	23	**290**
1980s	72	351	56	**479**
1990s	37	467	27	**531**
2000s	0	192	14	**206**
Total	**192**	**1,813**	**197**	**2,202**

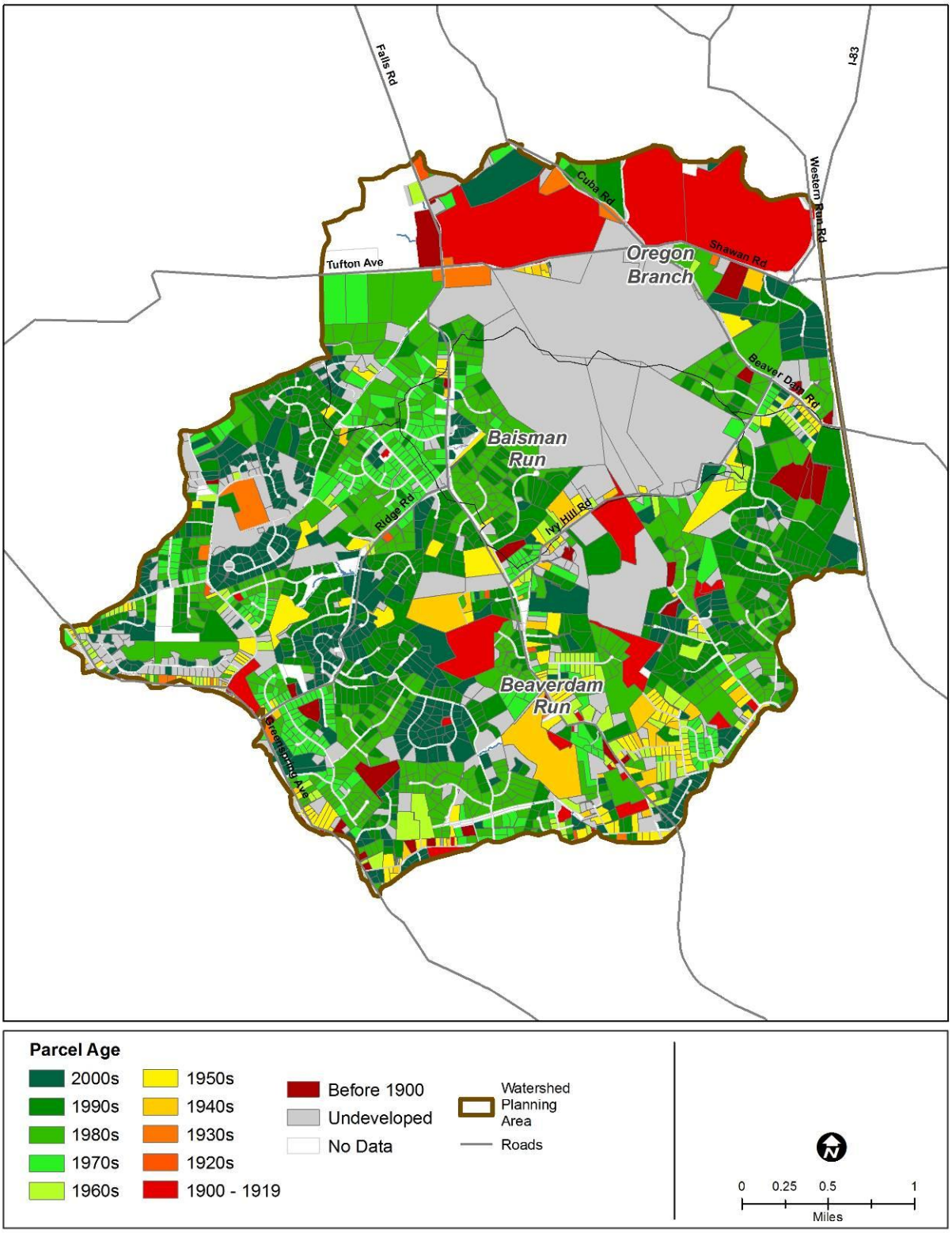


Figure 2-17: Decade Built

CHAPTER 3.0

Water Quality and Living Resources

3.1 Introduction

Area I is located in the Loch Raven Reservoir watershed and includes Oregon Branch, Baisman Run and Beaverdam Run. Area I is in the southern part of the watershed, west of Interstate 83. The combined subwatersheds of Area I account for approximately 6% of the Loch Raven Reservoir watershed drainage area (Table 3-1).

Chapter 3 describes the water quality, living resources, and habitat for Area I based on existing watershed conditions. In addition to water quality maintenance and improvement strategies, the SWAP aims to provide a plan for the support of plants, animals, and their habitat. Species living in natural communities require many habitat characteristics for survival including land, water, and biological conditions that provide for their needs of food, water, shelter and reproduction.

Water is an integral part of the habitat of all species. Animals and plants require water to survive; their populations are intimately connected to water's availability and its quality. They respond to changes in water quality and habitat conditions in ways that reflect the health of water bodies, the local geomorphology and activities occurring in the watershed. In some cases, water quality is measured in terms of its ability to support living resources such as trout or shellfish. Information on living resources is presented in this chapter as an indicator of water quality health and of overall habitat conditions in the watershed. A baseline assessment such as this can help to determine if current and future watershed management practices are adequately providing for the needs of natural communities.

Existing water quality data was reviewed for the SWAP and was generally representative of the entire Loch Raven Reservoir watershed. The data review included: impairments from Maryland's 303(d) listing, pollutant loadings analysis for total nitrogen and total phosphorus, water quality monitoring data available to date, forest health, stream corridor assessments, and stormwater management facility assessments.

Table 3-1: Percent of Area I Watershed within the Loch Raven Watershed

	Total Area (Acres)	% of Loch Raven Watershed
Baisman Run	1,056	0.76
Beaverdam Run	4,985	3.57
Oregon Branch	2,309	1.65
Loch Raven Reservoir Watershed	139,554	100
Area I Total	**8,350**	**5.98**

3.2 Designated Water Uses, the 303(d) Listings and Total Maximum Daily Loads (TMDLs)

Area I contributes 6% of the drainage area to the Loch Raven Reservoir watershed which is managed by a 2005 Reservoir Watershed Management Agreement and Action Strategy. This section provides a summary of water quality impairments for the Loch Raven Reservoir watershed as reported by the Maryland Department of the Environment (MDE). MDE has designated the Gunpowder River above Loch Raven Reservoir as Use III-P, defined as Nontidal Cold Water and Public Water Supply. The designated uses include: water contact sports, leisure activities involving direct contact with surface water, fishing, growth and propagation of trout and other fish, aquatic life and wildlife, agricultural water supply, industrial water supply, and public water supply.

Section 303(d) of the 1972 Clean Water Act requires states to develop, and periodically update, a list of impaired waters that fail to meet applicable state water quality standards which are defined by their designated uses. States must also establish priority rankings and develop Total Maximum Daily Loads (TMDLs) for waters on the 303(d) list. According to USEPA, a TMDL is a calculation of the maximum amount of a pollutant that a water body can receive and still safely meet state water quality standards. TMDLs can be developed for a single pollutant or group of pollutants of concern, e.g. sediment, metals, bacteria, nutrients, and pesticides.

The Loch Raven Reservoir watershed (8-digit watershed) is listed as impaired in the Maryland 303(d) list of impaired waters for various pollutants of concern including: fecal coliform, methylmercury, sedimentation and siltation, total phosphorous and impacts to benthic/fish communities (MDE, 2008). The Loch Raven Reservoir impoundment is impaired for sedimentation and siltation, methylmercury, and total phosphorus. The Loch Raven Reservoir watershed streams are impaired for impacts to benthic and fish communities (1st through 4th order streams) and fecal coliform (mainstem river). Table 3-2 provides a summary of the

impairment listings and status. Impairment listings reflect the inability to meet water quality standards for the designated uses discussed above.

Four TMDLs have been completed and approved for the Loch Raven Reservoir watershed (Table 3-2). In the Area I subwatersheds, the impairment that is most relevant is the impact on benthic/fish communities in first through fourth order streams. According to MDE the stream biological community impairment listing has a low priority and a TMDL will be developed at some point in the future (MDE, 2008). While the impairment documented in Area I subwatersheds is a lower priority, it may also be contributing to the downstream impairments in the river mainstem and the reservoir impoundment. In addition, it is important that measures are taken in Area I to help meet the TMDL's for phosphorous, sediment and fecal coliform which are a problem in the reservoir and mainstem river.

Table 3-2: Water Quality Impairment Listing and Status

Impairment (Year Listed)	Water Type	TMDL Status	Applicable Designated Use
Sedimentation/siltation (1996)	Reservoir	TMDL Approved (2007) [1]	Drinking Water Supply
Total Phosphorus (1996)	Reservoir	TMDL Approved (2007) [1]	Aquatic Life and Wildlife
Impacts to Benthic and Fish Communities (based on completed bioassessments (2002))	Streams (1st – 4th order streams)	TMDL Required	Aquatic Life and Wildlife
Methylmercury-fish tissue (2002)	Reservoir	TMDL Approved (2004)	Fishing
Fecal Coliform (2008)	Streams (Mainstem River)	TMDL Approved (2009)	Water Contact Sports

[1] TMDLs for both total phosphorus and sediment were set simultaneously and are dependent on each other.

With the completion of a number of TMDL analyses for impaired waters, target load reductions for phosphorous, sediment and fecal coliform have been determined. Load reductions for methylmercury focus on targeting air deposition. Table 3-3 summarizes the reductions required for the Loch Raven Reservoir watershed for each waterborne pollutant of concern. Even though the yet to be determined TMDL for impacts to benthic/fish communities is most relevant for area I, measures must be taken in area I to help meet the TMDLs for phosphorous, sediment and fecal coliform, which are a problem in the reservoir and mainstem river.

Table 3-3: TMDL Reduction Requirements for Urban Stormwater (EPS, 2010a)

Watershed	Total Phosphorus	Sediment	Fecal Coliform
Loch Raven Reservoir	50%	25%	80.2%

3.2.1 Sediment and Nutrients

A single TMDL was developed for total phosphorus and sedimentation/siltation that was approved by MDE in 2007 and is included as Appendix F. Sources of total phosphorus include surface runoff from urban and agricultural land uses in addition to discharge from small industrial sources and the Hampstead Municipal Waste Water Treatment Plant (WWTP). Excess total phosphorus in the aquatic environment leads to algal blooms. When the algae die, they consume oxygen from the reservoir that decreases the available oxygen to support aquatic life. In order to meet the water quality standards, a 50% target reduction of total phosphorus was established.

Sources of sediment in the Loch Raven Reservoir include urban, agricultural, and stream erosion. Sediment accumulation within the reservoir limits the storage capacity and therefore impacts its ability to function as a water supply reservoir. Excessive sedimentation can also negatively impact the fish population and recreational uses. Some of the total phosphorus control measures will also control sediment as phosphorus often enters the reservoir attached to sediment particles. In order to meet the water quality standards, a target reduction of sediment was established as a 25% reduction.

In the Loch Raven Reservoir and other Baltimore City water supply reservoirs (i.e. Prettyboy Reservoir and Liberty Reservoir) historical trends from an extensive water quality monitoring effort show that total phosphorus concentrations in monitored streams and from wastewater treatment plants have been declining. Likewise, algal levels in all three reservoirs have gradually improved during the past 15-18 years. Steadily increasing nitrate levels over this period appear to be stabilizing. All three reservoirs are still in various states of eutrophication and need further improvement and continued protection. Sedimentation is monitored periodically to assess the practical storage capacity of these impoundments. Each reservoir was reported as losing storage capacity: Loch Raven Reservoir has lost about 11 percent of its original volume, Prettyboy Reservoir has lost 7.5 percent, and Liberty Reservoir has lost 3.3 percent (BMC, 2004).

The Chesapeake Bay Program's draft Watershed Model Phase 5.3 was made available in late 2010. The Chesapeake Bay TMDL for nutrients and sediment will be based on this model, as well as the Airshed Model and the Estuarine Model. The Chesapeake Bay TMDL was finalized on December 29, 2010. Subsequent to the completion of the Chesapeake Bay TMDL, the State of Maryland will allocate load reductions to each source sector and to each local jurisdiction. When those load reduction targets become available, they will supersede the current targets listed

in the Tributary Strategies. All of the Baltimore water supply reservoirs are “treated” as nutrient traps by the Chesapeake Bay model and a reduction credit will be applied.

3.2.2 Fecal Coliform

The Maryland Department of the Environment (MDE) has identified the tributaries of Loch Raven Reservoir as impaired for fecal coliform bacteria (MDE, 2008). Fecal bacteria are microscopic single-celled organisms (primarily fecal coliform and fecal streptococci) found in the wastes of warm-blooded animals. Excessive amounts of fecal bacteria in surface water used for recreation are known to indicate an increased risk of pathogen-induced illness to humans.

Based on data collected by MDE and others, the mainstem tributaries to the reservoir were listed as impaired for fecal coliform bacteria. Sources of bacteria are from domestic (pets and human associated animals), human (human waste), livestock (agriculture-related animals), and wildlife (mammals and waterfowl) source categories. In order to meet the water quality standards for the Loch Raven Reservoir, a load reduction of 77% in Maryland and 13% in Pennsylvania are required (MDE, 2009). The bacteria monitoring station downstream of Area I requires a 80.2% reduction in bacteria. The source distribution is: human (38%), pet (8%), livestock (12%), and wildlife (42%). A TMDL developed for fecal coliform was developed in 2009 and is included as Appendix G.

3.2.3 Mercury

Based on early mercury data in fish tissue from a subset of lakes across the state, MDE announced a statewide fish consumption advisory for lakes. This advisory was established statewide as a precautionary measure because the primary source of mercury is understood to be atmospheric deposition, which is widely dispersed. Based on additional fish tissue data, Maryland has verified that Loch Raven Reservoir is impaired due to mercury in fish tissue. A TMDL for methylmercury in fish tissue was approved in 2004. Methylmercury is formed from inorganic mercury by the action of anaerobic organisms that live in aquatic systems including lakes, rivers, wetlands, sediments, soils and the open ocean. This methylation process converts inorganic mercury to methylmercury in the natural environment. Limited options exist to address a methylmercury TMDL through stormwater discharge regulations or practices because the pollution is transported through the air from Maryland and other states. In Maryland, the major sources of mercury air emissions are as follows: 43% attributed to power plants, 31% municipal waste combustors, 19% medical waste incinerators, 6% Portland cement plants, and 1% other (e.g., landfills, oil-fired power plants, other industries) (MDE, 2002). A TMDL developed for fecal coliform was developed in 2004 and is included as Appendix H.

3.2.4 Water Quality Analyses (WQA) with EPA Concurrence of MDE's Findings

In addition to mercury, the Loch Raven Reservoir watershed was initially identified on the 1996 303(d) list as impaired by other heavy metals. The heavy metal impairments were listed for the non-tidal streams. The original listing for heavy metals was questionable because: 1) no

specific pollutants were defined; 2) the original listing was based on total recoverable metals and current standard is for dissolved metals; 3) inappropriate sampling techniques were applied (e.g., lack of filtration); 4) supporting data needed to interpret criteria was not available (e.g., hardness); and 5) a default hardness of 100 mg/l was used to convert and relate the total recoverable metals to the dissolved metals criteria, which superseded the total recoverable metals criteria. A water quality analysis (WQA) of heavy metals for the Loch Raven Reservoir impoundment was performed using recent water column and sediment toxicity data. The conclusions of the WQA indicate no impairment for heavy metals currently exists (MDE, 2003).

3.3 Pollutant Loading Analysis - Total Nitrogen and Total Phosphorous

As part of the Water Resources Element (HB 1411), a pollutant loading analysis for each of the 8-digit watersheds located entirely or in part within Baltimore County was developed. The analyses assess the impacts of current and future development on water quality. To support these analyses, Baltimore County derived watershed-specific pollutant loading rates for total nitrogen and total phosphorus based on two sources: technical guidance provided by the Maryland Department of the Environment's (MDE) User's Guide for Nutrient Load Analysis Spreadsheet in Support of the Water Resources Element (WRE) and by the Chesapeake Bay Program's (CBP) Watershed Model Phase 4.3 and Phase 5.2 (CBP, 1998). Urban pervious and impervious nutrient loading rates are from CBP Model 5.2. Table 3-4 provides a summary of pollutant loading rates used for Area I. Additional information regarding pollutant loading rates and analysis methods are provided in Baltimore County's WRE Technical Memo – B, Pollutant Loading Analysis (Baltimore County EPS, 2010b). This pollution loading analysis was based exclusively on existing development.

Table 3-4: Annual Pollutant Loading Rates for Area I (lbs/acre/year)

WRE Land Use	Total Nitrogen Per Acre	Total Phosphorus Per Acre
Impervious Urban	14.1	2.26
Pervious Urban	7.25	0.429
Cropland	16.55	0.72
Pasture/Orchards/Agricultural Buildings	7.35	0.73
Livestock	24.87	1.18
Forest	1.41	0.02
Water	10.05	0.57
Wetlands	1.41	0.02

Total nitrogen loads from septic systems were calculated for each subwatershed using the equation below. Table 3-5 provides a summary of the number of people and septic systems in each subwatershed. The nitrogen load from septic discharge passes through the soil and reaches the stream through groundwater. A portion of the nitrogen load will be attenuated by the soil. The pass-though rate is defined as the percent of the septic nitrogen load that reaches the stream through groundwater (i.e., is not attenuated). Results are provided in Table 3-7.

Table 3-5: Number of People and Septic Systems in each Subwatershed

	Baisman Run	Beaverdam Run	Oregon Branch	Total
# People	432	4,405	712	5,544
# Septic Systems	186	1,763	186	2,138
# People/Septic System	2.32	2.50	3.83	2.60

Pounds of total nitrogen from septic systems=

(Number of people) x (Pounds of nitrogen/person/year) x (Pass-Through Rate)

Where:

# of people = provided in Table 2-9

Pounds of nitrogen/person/year = 8.92 (from CBP)

Pass-through rate = 0.4 (60% of the septic nitrogen load is attenuated by the soil)

As discussed in Chapter 2.3.1, land use information for Area I was obtained from MDP's 2007 land use/land cover GIS layer. For the pollutant loading analysis, the MDP land use/land cover categories were aligned to the WRE land cover categories (Table 3-6). Land use codes 191 and 192 have percentage breakdowns as shown in Table 3-7 that were taken from the *Analysis of Land Use Cover components of MDP LU_CODEs 191 and 192, Large lot subdivision (agriculture) and Large lot subdivisions (forest)* (Hirsch, 2011). The urban land cover categories were split into pervious urban and impervious urban acreage. The urban pervious category was calculated by subtracting the impervious acreage provided in Section 2.3.3. from the urban land use acreage.

Table 3-6: Relationship between MDP land use/land cover categories to WRE land cover categories for Area I

MDP Land Use/Land Cover Categories	WRE Land Cover Categories
191 Large Lot Subdivision (Agriculture)	See Table 3-6
192 Large Lot Subdivision (Forest)	See Table 3-6
11 Low Density Residential	Urban
12 Medium Density Residential	Urban
13 High Density Residential	Urban
14 Commercial	Urban
15 Industrial	Urban
16 Institutional	Urban
17 Extractive	Urban
18 Open Urban	Urban
21 Cropland	Cropland
22 Pasture	Pasture/Orchards/Ag. Building
23 Orchards	Pasture/Orchards/Ag. Building
24 Feeding Operations	Livestock
25 Row and Garden Crops	Cropland
41 Deciduous Forest	Forest
42 Evergreen Forest	Forest
43 Mixed Forest	Forest
44 Brush	Forest
50 Water	Water
60 Wetlands	Wetlands
72 Bare Rock	Urban
80 Transportation	Urban
242 Ag. Buildings	Pasture/Orchards/Ag. Building

Table 3-7: Recommended Load Group Composition for Large Lot Subdivision Type (Hirsch, 2011)

MDP Land Use/Land Cover Categories	Proportion of Area by Loading Rate Groups			
	Cropland	Urban	Forest	Pasture
191 Large Lot Subdivision (Agriculture)	14.2%	16.1%	27.6%	42.1%
192 Large Lot Subdivision (Forest)	5.4%	9.6%	78.4%	6.6%

The total acreage for each WRE land cover category was calculated. These were multiplied by the corresponding pollutant loading rates in Table 3-4. Resulting annual pollutant loads for total nitrogen and total phosphorus for Area I are summarized in Table 3-8.

Table 3-8: Total Annual Nutrient Loads from Area I

WRE Land Cover	Area (Acres)	Nitrogen		Phosphorus	
		Rate (lbs/acre/yr)	Load (lbs/yr)	Rate (lbs/acre/yr)	Load (lbs/yr)
Impervious Urban	539	14.1	7,600	2.26	1,218
Pervious Urban	3,905	7.25	28,311	0.429	1,675
Cropland	1,095	16.55	18,122	0.72	789
Pasture/Orchards/Agricultural Buildings	312	7.35	2,293	0.73	228
Livestock	0	24.87	0	1.18	0
Forest	2,499	1.41	3,524	0.02	50
Water	0	10.05	0	0.57	0
Wetlands	0	1.41	0	0.02	0
Septic Systems	--	8.92	19,798	--	--
Total	**8,350**		**79,648**		**3,960**

As discussed in Section 3.2, the TMDL goal for total phosphorus in the Loch Raven Watershed is a reduction of 50%. In Area I, the total phosphorus urban load is 2,893 pounds and 1,017 pounds for the agriculture load. To achieve the total phosphorus TMDL target, a total of 1,980 pounds must be reduced.

Nutrient loads were also calculated on a subwatershed basis using the same loading rates and land cover designations. These estimates provide baseline nutrient loads before implementation of restoration projects and provide a better assessment of both progress made to date and further progress needed to meet TMDL goals for urban nonpoint source reduction. Table 3-9 provides a summary of WRE land cover categories for each subwatershed.

Table 3-9: Area I WRE Land Cover Categories

WRE Land Cover	Baisman Run (Acres)	Beaverdam Run (Acres)	Oregon Branch (Acres)	Totals (Acres)
Impervious Urban	43	384	112	539
Pervious Urban	351	3,005	549	3,905
Cropland	5	287	803	1,095
Pasture/Orchards/Agricultural Buildings	12	167	132	312
Livestock	0	0	0	0
Forest	645	1,141	713	2,499
Water	0	0	0	0
Wetlands	0	0	0	0
Totals	**1,056**	**4,985**	**2,310**	**8,350**

The resulting nutrient loads for the three subwatersheds in Area I are summarized for total phosphorus in Table 3-10 and total nitrogen in Table 3-11. These tables include total nitrogen and total phosphorus loading rates for each subwatershed. The largest subwatershed, Beaverdam Run contributes the largest total nitrogen and total phosphorus load of 50,508 lbs/yr and 2,508 lbs/yr, respectively. The greatest nutrient loading on a per acre basis is from the Oregon Branch subwatershed that contributes 0.51 lbs/acre/yr of total phosphorus and 10.1 lbs/acre/yr of total nitrogen. The land covers with the greatest total nitrogen loads for the watershed are pervious urban (28,312 lbs/yr) and cropland (18,128 lbs/yr) followed by impervious urban land **c**over (7,598 lbs/yr). Similarly, the land covers with the greatest total phosphorus loads for the watershed are pervious urban (1,675 lbs/yr), followed by impervious urban (1,218 lbs/yr) and cropland (789 lbs/yr). The total Area I planning level pollutant load

estimate will be used to determine necessary reductions to meet local TMDLs, the Chesapeake Bay TMDL, and Baltimore County's Watershed Implementation Plan.

Table 3-10: Annual Total Nitrogen Loads by Subwatershed

Subwatershed		Baisman Run	Beaverdam Run	Oregon Branch	Totals
Total Area (Acres)		1,056	4,985	2,310	***8,350***
Annual Total Nitrogen Loads by WRE Land Cover (lbs/yr)	**Impervious Urban**	604	5,412	1,582	***7,598***
	Pervious Urban	2,545	21,787	3,980	***28,312***
	Cropland	84	4,752	13,292	***18,128***
	Pasture/Orchards/Ag. Buildings	90	1,231	971	***2,291***
	Forest	909	1,609	1,005	***3,523***
Septic Systems		1,541	15,717	2,540	***19,798***
Total Nitrogen Load (lbs/yr)		5,773	50,508	23,370	***79,651***
Total Nitrogen Loading Rate (lbs/acre/yr)		5.5	10.1	10.1	***9.5****

*Watershed loading rate

Table 3-11: Annual Total Phosphorus Loads by Subwatershed

Subwatershed		Baisman Run	Beaverdam Run	Oregon Branch	*Totals*
Total Area (Acres)		1,056	4,985	2,310	***8,350***
Annual Total Phosphorus Loads by WRE Land Cover (lbs/yr)	**Impervious Urban**	97	867	254	***1,218***
	Pervious Urban	151	1,289	236	***1,675***
	Cropland	4	207	578	***789***
	Pasture/Orchards/Ag. Buildings	9	122	96	***228***
	Forest	13	23	14	***50***
Total Phosphorus Load (lbs/yr)		273	2,508	1,178	***3,960***
Total Phosphorus Loading Rate (lbs/acre/yr)		0.26	0.50	0.51	***0.5****

*Watershed loading rate

3.4 Water Quality Monitoring Data

Baltimore County conducts chemical, biological, and illicit discharge and elimination monitoring within Area I. Section 3.4.1 summarizes the chemical data available for Area I in addition to the Baltimore Ecosystem Study data. Section 3.4.2 summarizes the biological monitoring program. Section 3.4.3 discusses the illicit discharge detection and elimination program. In addition, Baltimore County conducted a synoptic sampling survey that is included in Appendix I.

3.4.1 Chemical Data

Baltimore County Baseflow Data

A baseflow monitoring program was initiated by Baltimore County in 2003. Baseflow is groundwater seepage into the stream channel and baseflow conditions exist when groundwater provides the entire flow of a stream. Typically after three days of no rain the flow in the channel is provided by groundwater. The County's baseflow monitoring program monitors sites in the Patapsco/Back River Basin in odd-numbered years, while the Gunpowder Basin/Deer Creek are monitored in the even-numbered years. Area I is located in the Gunpowder Basin and is therefore monitored in even numbered years. The sampling sites were chosen to maximize the number of subwatersheds monitored. In 2007, the sampling sites were divided into two tiers: Tier 1 sites are regular sampling sites, while Tier 2 sites are only to be sampled if a Small Watershed Action

Plan (SWAP) or other project begins in the area. Fifty three Tier 1 and 22 Tier 2 sites are in the Gunpowder Basin/Deer Creek watershed (Baltimore County EPS, 2011).

There is one monitoring point for each of the three subwatersheds in Area I. The site on Baisman Run corresponds to a USGS gaging station (01583580 Baisman Run). Figure 3-1 shows the locations of the baseflow monitoring sites.

The target number of baseflow samples is eight samples per year at each site. The actual number of samples taken varies depending on weather conditions, staffing and other duties. The standard set of monitored pollutants includes total suspended solids (TSS), total solids (TS), total Kjeldahl nitrogen (TKN), nitrate/nitrite, total phosphorus, ortho-phosphorus, cadmium, copper, lead, zinc, biochemical oxygen demand (BOD), chemical oxygen demand (COD), chlorides, sodium, hardness, magnesium and calcium as well as temperature and pH determined *in situ*. In addition, discharge measurements are taken at each site. A minimum of three days of dry weather is required prior to monitoring any baseflow site.

Figure 3-1: Area I Baseflow Monitoring Site Locations

Beaverdam Run and Baisman Run are Tier 1 sites that were sampled in 2004, 2006, and 2008. Oregon Branch is a Tier 2 site that was sampled in 2004 and 2006. Table 3-12 shows the sampling results for each site. In addition, metals (i.e. copper, cadmium, lead, and zinc) were analyzed and found not to exceed the chronic and acute aquatic life, or the drinking water standards for either total or dissolved metals.

Table 3-12: Summary of Baseflow Monitoring Data for Area I

Parameter (mg/l)		Site		
		Baisman Run	Beaverdam Run	Oregon Branch
Chloride	No. Samples	9	9	6
	Min.	20.2	33.9	31.1
	Max.	91.2	125.2	62.0
	Mean	**35.4**	**60.4**	**40.9**
	St. Dev.	21.7	26.8	11.1
	Median	28.8	51.5	38.8
Nitrate/ Nitrite	No. Samples	9	9	6
	Min.	0.70	1.33	1.57
	Max.	1.78	3.00	2.75
	Mean	**1.23**	**2.39**	**1.99**
	St. Dev.	0.30	0.51	0.25
	Median	1.20	2.53	1.73
Total Kjeldahl Nitrogen	No. Samples	11	11	7
	Min.	0.10	0.10	0.10
	Max.	0.67	0.40	0.32
	Mean	**0.17**	**0.17**	**0.16**
	St. Dev.	0.18	0.10	.10
	Median	0.10	0.10	0.10
Total Nitrogen	No. Samples	8	8	6

Parameter (mg/l)		Site		
		Baisman Run	Beaverdam Run	Oregon Branch
	Min.	0.80	1.43	1.83
	Max.	2.19	3.10	2.85
	Mean	**1.42**	**2.49**	**2.16**
	St. Dev.	0.43	0.56	0.44
	Median	1.34	2.52	1.94
Total Phosphorus	No. Samples	11	11	7
	Min.	0.010	0.010	0.010
	Max.	0.120	0.070	0.030
	Mean	**0.022**	**0.020**	**0.017**
	St. Dev.	0.033	0.018	0.008
	Median	0.010	0.010	0.020
Temperature (°C)	No. Samples	10	11	7
	Min.	1.6	1.0	1.8
	Max.	23.0	20.7	21.5
	Mean	**14.9**	**14.9**	**12.6**
	St. Dev.	7.9	6.7	6.9
	Median	18.3	17.9	11.6

Chloride is important because it is linked to chronic toxicity in urban streams and the Loch Raven Reservoir watershed is 303(d) listed for biological impairment. The USEPA National Recommended Water Quality Criteria (USEPA, 2009) lists the chronic aquatic life criterion for chloride as 230 mg/l and the acute toxicity limit is 860 mg/l (USEPA, 1988). None of the samples exceeded the chronic aquatic life criterion for chloride or the acute criteria. However, the mean and the median for Beaverdam Run exceeded the 50mg/L chloride level determined by the Maryland Biological Stressor Identification Process (MDE, 2009) to be detrimental to aquatic life. Baltimore City data has shown an increasing trend in chlorides and sodium in raw and treated potable water over the past three decades. While levels are below EPA "action levels", the 2005 Reservoir Watershed Action Strategy recommends the establishment of

sodium and chloride reduction goals for all three reservoirs. (http://www.baltometro.org/RWP/RWPActionStrategy2005.pdf)

Nutrient data (i.e. nitrate/nitrite, TKN, TN and TP) were rated based on the rating system detailed in Table 3-13. Total nitrogen concentration data ratings are adapted from the Maryland Department of Natural Resources (2005a) using loading coefficients reported by Frink (1991). Total phosphorus ratings were developed by evaluating non-tidal phosphorus data from the Chesapeake Bay Program (USGS, 1999). Table 3-14 provides a summary of the nutrient ratings for each subwatershed.

Table 3-13: Ratings by Mean Nutrient Concentrations

Rating	Total Nitrogen (mg/l)	Nitrate/Nitrite (mg/l)	Total Phosphorus (mg/l)
Low	<1.0	<0.65	<0.01
Moderately elevated	1.0 – <2.0	0.65 – <1.0	0.01 – <0.02
Elevated	2.0 – <3.0	1.0 – <2.0	0.02 – <0.03
High	3.0 – <4.0	2.0 – <4.0	0.03 – <0.04
Very High	>4.0	>4.0	>0.04

Table 3-14: Subwatershed Nutrient Ratings

Rating	Total Nitrogen (mg/l)	Nitrate/Nitrite (mg/l)	Total Phosphorus (mg/l)
Beaverdam Run	Elevated	High	Elevated
Baisman Run	Moderately Elevated	Elevated	Elevated
Oregon Branch	Elevated	Elevated	Moderately Elevated

There are no water quality standards for nutrients in Maryland but for purposes of this analysis, the nutrient ratings used are provided in Table 3-13. Total nitrogen is moderately elevated for Baisman Run and elevated for Beaverdam Run and Oregon Branch. Only during one sampling event, March 8, 2006, is one of the sites (Beaverdam) in the “high” category for total nitrogen. Baisman Run and Oregon Branch are elevated for nitrate/nitrite, but Beaverdam Run is ranked high. TKN was elevated only once on July 31, 2008 for Baisman Run. The total phosphorus mean is moderately elevated for Oregon Branch and elevated for Baisman Run and Beaverdam Run. The highest total phosphorus level found during sampling was 0.12 mg/L and it

coincides with the elevated TKN event on Baisman Run. Only one sampling event was ranked high and that coincides with the high total nitrogen sample from Beaverdam Run.

Baltimore Ecosystem Study Data

The Baltimore Ecosystem Study (BES) is a National Science Foundation Long Term Ecological Research site where flow and water quality data have been collected at a set of longitudinal sampling stations in the Gwynns Falls watershed, in addition to a forested reference site, Pond Branch that is located in the Beaverdam Run subwatershed. Baisman Run is also part of the long-term monitoring effort with low density residential as it major land use. Water quality samples have been taken since 1998 on a weekly basis, although there are some gaps in some of parameters analyzed. The day of the week water was sampled varied to provide a random component to the sampling scheme and no attempt was made to avoid wet weather (Groffman et al. 2004).

The long-term average concentrations for Baisman Run and Pond Branch are summarized in Table 3-15.Tables 3-16 and 3-17 provide a summary of annual water quality statistics based on the weekly sample collection from the BES. The years where annual statistics are not provided is due to a limited number of samples collected (e.g. one month) or no data provided. The impact from development on water quality is apparent in Baisman Run as all of the parameters are elevated compared to Pond Branch, with the exception of phosphate. Chloride and nitrogen concentrations are an order of magnitude greater in Baisman Run. The data suggest that different nitrogen species may dominate Pond Branch compared to Baisman Run by comparing the nitrate-N to the total nitrogen concentrations. Nitrate-N comprises the majority of the nitrogen in Baisman Run compared to 20% of the total nitrogen concentration in Pond Branch. Organic nitrogen is likely a more dominant species in this watershed and spikes in the annual concentrations with greatest concentrations occurring in 2003 and 2009 in Baisman Run. Pond Branch has relatively stable concentration of chloride. However, total phosphorus concentrations appear to have a generally increasing trend for the period between 1998 and 2010 in Pond Branch, although quite variable.

Table 3-15: Long-Term Average Mean Concentrations (mg/l) for Pond Branch and Baisman Run, 1998-2010

BES Monitoring Site	Chloride (mg/l)	Nitrate-N (mg/l)	Total Nitrogen (mg/l)	Total Phosphorus (mg/l)	Phosphate (mg/l)	Sulfate (mg/l)
Pond Branch	2.67	0.04	0.19	9.44	3.45	1.68
Baisman Run	29.44	1.52	1.61	6.61	3.49	3.25

Table 3-16: Summary of Weekly Water Quality Samples from Baltimore Ecosystem Study Monitoring Site at Pond Branch, 1998-2010

Parameter (mg/L)		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Chloride	Mean	2.39	2.48	2.44	2.65	2.51	2.70	2.78	2.60	2.62	2.88	2.86	3.03	2.81
	St. Dev	0.21	0.28	0.29	0.35	0.50	0.72	0.22	0.24	0.18	0.31	0.22	0.22	0.13
	Min.	2.00	2.00	1.26	1.97	1.68	2.17	2.24	2.28	2.30	2.40	2.47	2.75	2.62
	Max.	2.90	3.29	3.00	3.45	4.21	6.30	3.34	3.69	3.20	4.48	3.57	3.79	3.04
	No. Samples	12	52	52	53	55	48	51	49	52	51	51	47	19
Nitrate-N	Mean	0.01	0.05	0.04	0.05	0.07	0.02	0.05	0.05	0.05	0.04	0.04	0.03	0.02
	St. Dev	0.00	0.06	0.04	0.05	0.07	0.01	0.05	0.04	0.05	0.04	0.05	0.04	0.01
	Min.	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.01
	Max.	0.01	0.22	0.17	0.19	0.25	0.06	0.29	0.15	0.19	0.15	0.18	0.12	0.05
	No. Samples	12	52	52	53	55	48	52	50	52	51	51	47	19
Total Nitrogen	Mean	No Data	0.06	0.30	0.18	0.27	0.27	0.20	0.24	0.16	0.13	0.14	0.22	0.29
	St. Dev		0.07	0.76	0.12	0.33	0.47	0.29	0.48	0.30	0.11	0.20	0.28	0.47
	Min.		0.01	0.01	0.01	0.05	0.01	0.04	0.01	0.01	0.01	0.01	0.01	0.01
	Max.		0.29	4.24	0.81	1.53	1.93	1.70	3.42	2.10	0.37	1.01	1.17	1.74
	No. Samples		23	50	54	48	49	52	49	52	52	50	47	19
Total Phosphorus	Mean	No Data	2.60	6.84	8.56	7.35	5.78	11.73	11.60	13.72	9.39	10.89	9.60	15.17
	St. Dev		0.81	9.95	10.11	11.48	3.68	11.37	8.85	28.52	5.64	13.89	8.10	17.80
	Min.		1.50	1.50	1.50	1.50	1.50	1.50	1.50	2.33	1.50	1.90	1.89	2.54
	Max.		3.35	47.06	71.69	61.89	18.21	74.60	36.60	206.00	24.00	70.00	45.90	73.70
	No. Samples		7	52	54	48	50	47	50	52	52	51	47	19
Phosphate	Mean	7.48	2.80	2.24	2.02	2.19	2.76	4.96	3.68	2.90	3.62	3.29		
	St. Dev	2.22	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	2.09	1.50		
	Min.	29.78	7.72	5.00	4.52	4.06	7.17	20.30	5.74	6.67	7.97	4.54		

Parameter (mg/L)		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
	Max.	97.28	145.75	116.43	108.99	120.46	137.96	257.70	183.87	133.56	177.21	131.67	No Data	No Data
	No. Samples	13	52	52	54	55	50	52	50	46	49	40		
Sulfate	Mean	0.96	1.83	1.58	1.35	2.32	2.43	1.63	1.57	1.51	1.39	1.50	1.64	2.11
	St. Dev	0.82	0.74	0.74	0.72	0.92	0.76	0.29	0.80	0.82	0.67	0.64	0.69	1.08
	Min.	1.35	4.59	4.32	2.78	7.44	4.77	3.29	3.32	3.06	3.10	3.77	3.95	2.98
	Max.	11.52	95.17	82.21	71.81	127.59	119.30	84.98	78.30	78.57	72.46	76.35	77.20	40.05
	No. Samples	12	52	52	53	55	49	52	50	52	52	51	47	19

Table 3-17: Summary of Weekly Water Quality Samples from the Baltimore Ecosystem Study for Baisman Run, 1998-2010

Parameter (mg/L)		1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Chloride	Mean	27.83	21.67	25.43	27.96	31.17	24.83	26.87	27.74	29.13	35.90	43.62	31.15
	St. Dev	17.13	6.83	4.02	11.07	11.55	4.74	8.89	5.47	10.38	5.83	35.55	3.49
	Min.	16.93	8.49	20.61	19.70	18.20	16.70	19.00	17.50	22.60	22.40	21.20	26.60
	Maximum	115.50	50.70	38.57	88.43	81.00	48.60	69.20	61.20	78.50	65.90	232.00	38.30
	No. Samples	51	52	55	57	51	51	52	53	52	52	48	20
Nitrate-N	Mean	1.63	1.55	1.62	1.18	1.63	1.51	1.46	1.55	1.42	1.49	1.65	1.54
	St. Dev	0.34	0.35	0.30	0.49	0.31	0.23	0.19	0.30	0.35	0.26	0.35	0.20
	Min.	0.89	0.54	0.66	0.29	1.06	1.03	0.84	0.65	0.78	0.75	0.67	1.25
	Maximum	2.61	2.18	2.17	2.04	2.50	2.10	1.90	2.02	2.46	2.02	2.23	1.96
	No. Samples	51	51	55	57	51	51	52	53	52	52	48	20
Total Nitrogen	Mean	No Data	1.75	1.69	1.49	1.79	1.53	1.52	1.63	1.42	1.50	1.67	1.71
	St. Dev		0.47	0.30	0.60	0.42	0.23	0.18	0.26	0.35	0.26	0.34	0.22
	Min.		0.96	0.66	0.35	1.24	1.04	1.03	0.83	0.78	0.80	0.75	1.38
	Maximum		3.83	2.18	2.61	3.22	2.13	2.02	2.07	2.46	2.10	2.23	2.25

Parameter (mg/L)		1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
	No. Samples		52	54	49	49	51	51	53	52	51	46	20
Total Phosphorus	Mean	No Data	4.36	4.01	3.66	13.69	11.81	6.46	6.62	4.42	5.42	4.73	7.54
	St. Dev		6.14	3.01	5.02	41.28	15.62	4.67	11.06	4.27	7.28	3.52	7.35
	Min.		1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.18	1.76	2.02
	Maximum		25.94	15.62	24.12	279.00	72.89	26.20	75.30	21.80	51.30	19.20	35.70
	No. Samples		49	53	49	50	47	52	52	52	52	48	20
Phosphate	Mean	6.65	2.11	2.06	1.75	3.00	5.65	4.10	2.86	3.47	3.27	No Data	No Data
	St. Dev	23.35	1.19	1.35	0.47	2.47	6.45	1.16	0.90	0.67	0.70		
	Min.	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	2.09	1.98		
	Maximum	163.76	8.00	9.15	3.84	10.11	27.70	6.99	4.80	5.06	4.44		
	No. Samples	50	52	55	57	47	52	52	48	50	41		
Sulfate	Mean	3.25	2.82	2.58	2.93	4.89	3.23	3.08	3.21	2.79	2.91	3.35	3.90
	St. Dev	0.94	0.84	0.82	1.24	1.10	0.78	0.83	0.70	0.95	0.80	0.87	0.64
	Min.	1.93	1.16	1.51	1.67	2.89	2.11	1.86	2.23	1.69	1.99	2.22	2.62
	Maximum	5.73	4.74	4.80	6.56	7.02	5.14	5.38	5.11	5.00	5.85	5.50	5.07
	No. Samples	50	52	55	57	50	52	51	53	52	52	48	20

3.4.2 Biological Data

This section combines biological monitoring data from four different surveys. The collection methods for fish and macroinvertebrate sampling are fairly similar at each site but the station selection, sampling period and replication vary between sources. Baltimore County Department of Environmental Protection and Sustainability (EPS) employ a Random Point Monitoring Program to evaluate the benthic macroinvertebrate community. Maryland Department of Natural Resources (MD DNR) Fisheries and EPS used a targeted fish sampling strategy to evaluate the fish community in Area I during 2010. The Maryland Biological Stream Survey (MBSS) uses a statewide stratified random sampling strategy for both fish and benthic macroinvertebrate data. MBSS has also established a series of "sentinel sites" to track long term ecological trends at minimally disturbed stream sites around the state. LOCH-120-S-xxxx is a sentinel site in the Baisman Run subwatershed.

In order to provide a succinct overview of conditions within Area I, the results of all these studies have been combined and listed chronologically by subwatershed and year in the following tables and figures. All the raw data and methods are available in the source documents (MD DNR 2005b, MD DNR 1999).

Baltimore County Biological Monitoring Programs

In December 2010, the Baltimore County EPS published a Biological Assessment of Beaverdam Run Watershed. This report was written in support of the Small Watershed Action Plan (SWAP) for Area I. The report describes both the benthic macroinvertebrate and fish communities. The full report is found in Appendix J. The watershed boundaries for the assessment are slightly larger than the boundaries of Area I. The report includes the larger Beaverdam Run watershed which extends east of I-83, downstream to the confluence with the Loch Raven Reservoir. There are two benthic macroinvertebrate monitoring sites and five fish monitoring sites outside of Area I.

Fish Community Data

The fish community data was collected during August and September 2010 using a targeted fish sampling strategy, by biologists from EPS and the MD DNR Fisheries Service using the MBSS protocols. A primary goal of the fish sampling was to assess the status of naturally reproducing trout populations, especially native brook trout. Native brook trout are extremely sensitive to environmental disturbance such as elevated temperatures, and their presence indicates good water quality. Results of the fish data analysis include a Fish Index of Biological Integrity (FIBI) score based on the fish community characteristics at a sampling site. Qualitative ratings of stream biological integrity are based on FIBI scores and range from good (4.0 – 5.0) denoting minimally impacted conditions to very poor (1.0 – 1.9) indicating severe degradation.

Benthic Macroinvertebrate Data

The benthic macroinvertebrate data was compiled from an annual sampling program managed by EPS. EPS employs a Random Point Monitoring Program to evaluate the benthic macroinvertebrate community. Benthic macroinvertebrates are organisms without a backbone that live on the bottom of streams and can be seen with the naked eye. They are an important part of stream ecosystems as they are a source of food for other aquatic life such as fish. The presence, condition, numbers, and types of benthic macroinvertebrates also convey information about a water body's quality. Similar to the fish data, results of the data include a benthic Index of Biological Integrity (IBI) score based on the benthic community characteristics at a sampling site.

Maryland Biological Stream Survey

Biological monitoring data is also available from the Maryland Biological Stream Survey (MBSS). MBSS is a random design stream sampling program intended to provide unbiased estimates of stream conditions with known precision at various spatial scales. Goals of the program are to assess the current condition of ecological resources in Maryland's streams and rivers; identify the impacts of acidic deposition, climate change, and other stressors on ecological resources in Maryland's streams and rivers; provide an inventory of biodiversity in Maryland's streams; assess the efficacy of stream restoration and conservation efforts to stream ecological resources; continue to build a long-term database and document changes over time in Maryland's stream ecological condition and biodiversity status and communicate results to the scientific community, the public, and policy makers. Figure 3-2 and Table 3-18 present the combined MBSS and EPS data for fish data. Figure 3-3 and Table 3-19 present the combined MBSS and EPS data for benthic data.

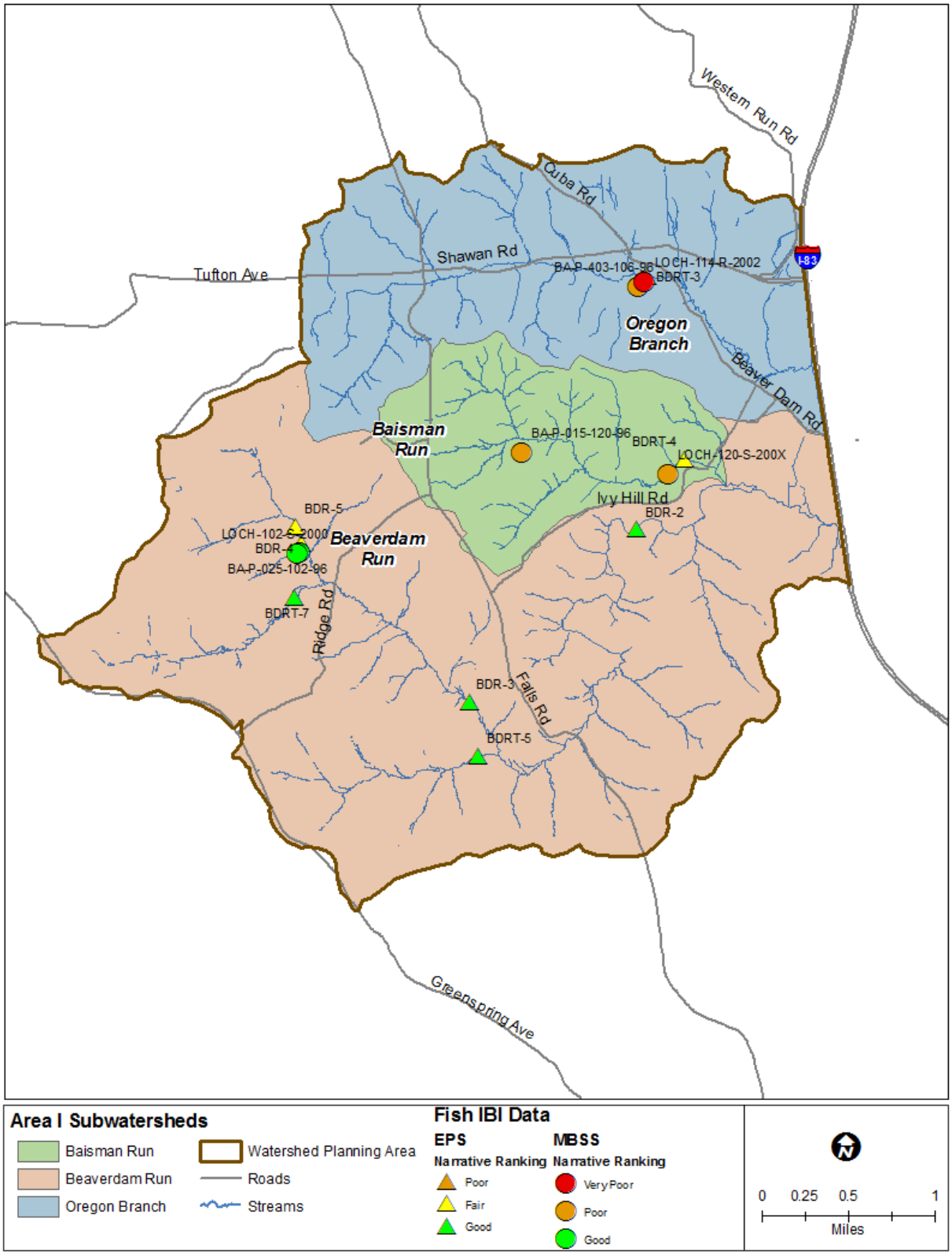


Figure 3-2: Location of Fish Sampling Sites

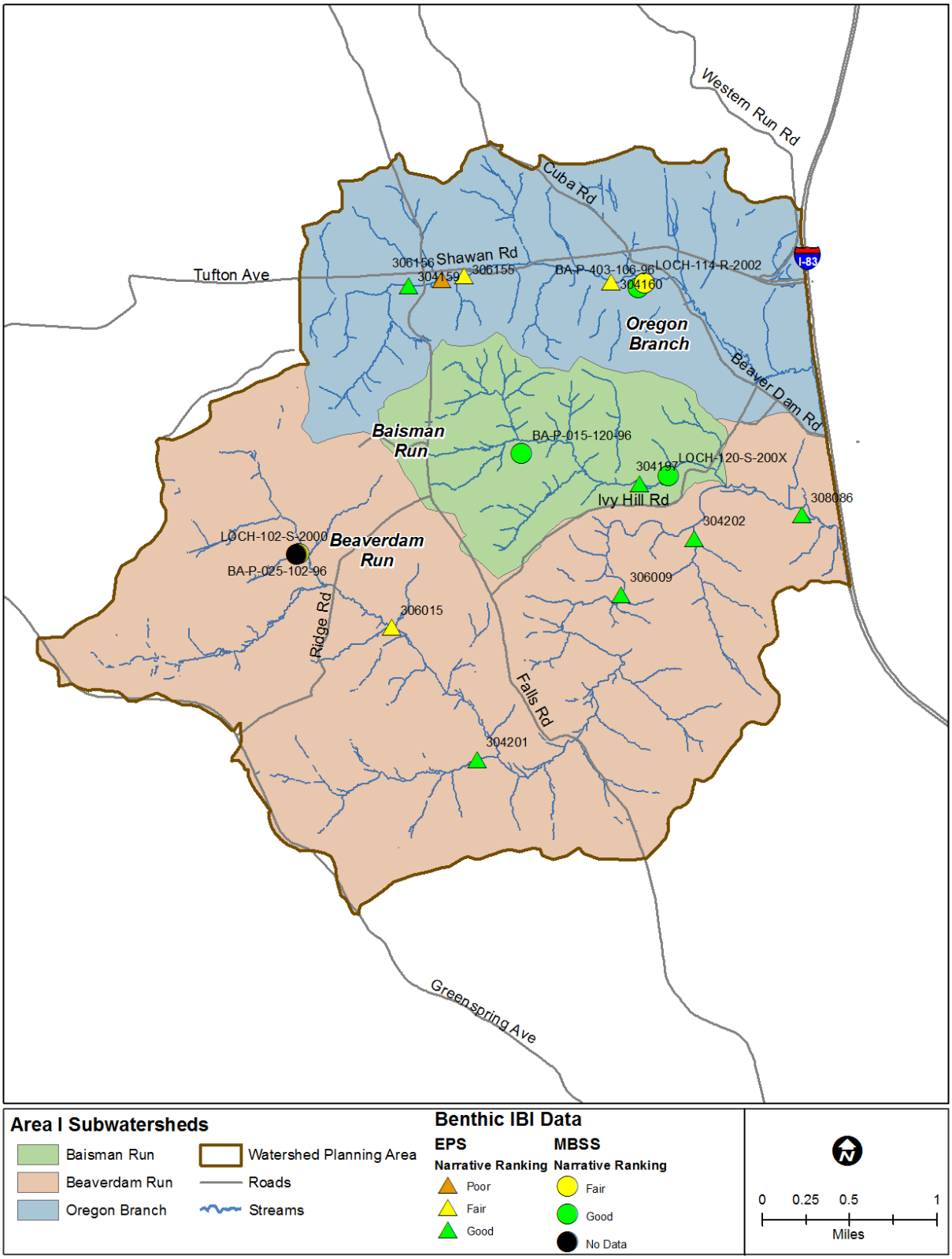


Figure 3-3: Location of Benthic Macroinvertebrate Sampling Sites

Combined Results of EPS and MBSS data

Table 3-18: Fish Index of Biological Integrity

Station ID	Year	Fish IBI Score	Narrative Ranking	Data Source
Baisman Run				
BA-P-015-120-96	1996	2.00	Poor	MBSS
LOCH-120-S-2000[1]	2000	2.67	Poor	MBSS
LOCH-120-S-2001[1]	2001	2.67	Poor	MBSS
LOCH-120-S-2002[1]	2002	2.33	Poor	MBSS
LOCH-120-S-2003[1]	2003	2.33	Poor	MBSS
LOCH-120-S-2004[1]	2004	2.00	Poor	MBSS
LOCH-120-S-2005[1]	2005	1.67	Very Poor	MBSS
LOCH-120-S-2006[1]	2006	2.67	Poor	MBSS
LOCH-120-S-2007[1]	2007	1.67	Very Poor	MBSS
LOCH-120-S-2008[1]	2008	2.00	Poor	MBSS
LOCH-120-S-2009[1]	2009	2.00	Poor	MBSS
BDRT-4	2010	3.00	Fair	EPS
Oregon Branch				
BA-P-403-106-96	1996	2.67	Poor	MBSS
LOCH-114-R-2002	2002	1.67	Very Poor	MBSS
BDRT-3	2010	2.33	Poor	EPS
Beaverdam Run				
BA-P-025-102-96	1996	3.67	Good	MBSS
LOCH-102-S-2000	2000	3.00	Good	MBSS
BDR-2	2010	4.00	Good	EPS
BDR-3	2010	4.33	Good	EPS
BDR-4	2010	3.67	Fair	EPS

Station ID	Year	Fish IBI Score	Narrative Ranking	Data Source
Baisman Run				
BDR-5	2010	3.33	Fair	EPS
BDRT-5	2010	4.33	Good	EPS
BDRT-7	2010	4.33	Good	EPS
[1]Single sentinel site sampled over several years.				

Table 3-19: Benthic Index of Biological Integrity

Station ID	Year	IBI score	Narrative ranking	Data source
Baisman Run				
BA-P-015-120-96	1996	5.00	Good	MBSS
LOCH-120-S-2000[1]	2000	4.33	Good	MBSS
LOCH-120-S-2001[1]	2001	5.00	Good	MBSS
LOCH-120-S-2002[1]	2002	4.33	Good	MBSS
LOCH-120-S-2003[1]	2003	4.00	Good	MBSS
LOCH-120-S-2004[1]	2004	4.33	Good	MBSS
304197[2]	2004	4.30	Good	EPS
LOCH-120-S-2005[1]	2005	4.67	Good	MBSS
LOCH-120-S-2006[1]	2006	4.67	Good	MBSS
304197[2]	2006	4.30	Good	EPS
LOCH-120-S-2007[1]	2007	4.00	Good	MBSS
LOCH-120-S-2008[1]	2008	4.33	Good	MBSS
304197[2]	2008	4.00	Good	EPS
LOCH-120-S-2009[1]	2009	5.00	Good	MBSS
Oregon Branch				
BA-P-403-106-96	1996	4.33	Good	MBSS
LOCH-114-R-2002	2002	3.67	Fair	MBSS

Station ID	Year	IBI score	Narrative ranking	Data source
304159	2004	4.00	Good	EPS
304160	2004	3.70	Fair	EPS
306155	2006	3.30	Fair	EPS
306156	2006	2.70	Poor	EPS
Beaverdam Run				
BA-P-025-102-96	1996	3.67	Fair	MBSS
LOCH-102-S-2000	2000	No Data	No Data	MBSS
304201	2004	4.00	Good	EPS
304202	2004	4.00	Good	EPS
306009	2006	4.00	Good	EPS
306015	2006	3.70	Fair	EPS
LOCH-104-R-2007	2007	No Data	No Data	MBSS
308086	2008	4.00	Good	EPS
[1]Single sentinel site sampled over several years.				
[2]Baltimore County sentinel site.				

The results of the various sampling programs support the general conclusions presented in the December 2010, the Baltimore County EPS Biological Assessment of Beaverdam Run Watershed. The full report is found in Appendix J.

Overall, the benthic and fish data show agreement in the condition of streams in the Beaverdam Run subwatershed. Well-forested, lightly developed stream reaches support healthy biological communities. The data show that a small population of native brook trout remains in Beaverdam Run. Stream reaches with more intensive land use, particularly the commercial/industrial area near Hunt Valley, and the more heavily agricultural area in the upper end of Oregon Branch, showed impairment in both the benthic and fish communities.

The following discussion of the fish community also comes from the December 2010 EPS report.

Brook trout

Native brook trout were found in Baisman Run and in the uppermost reaches of the mainstem of Beaverdam Run. Four adult brook trout (145 mm/31 g, 150 mm/31 g, 165 mm/44 g, and 210 mm/93 g) were captured during qualitative electrofishing in the stream reaches between stations BDR-4 and BDR-5, but only one brook trout was found within the station limits in the mainstem of Beaverdam Run. Three year-classes of brook trout were present in Baisman Run.

Brown trout

Wild brown trout were collected at all stations except the most downstream station on the mainstem of Beaverdam Run (BDR-1). Length-frequency analysis for brown trout suggests the presence of three year-classes of fish in both Beaverdam Run and Oregon Branch (and possibly a fourth year-class in Beaverdam Run), and two year-classes in Baisman Run. Brown trout were not equally abundant within the study reach, as shown by the standing crop estimates. The highest biomass of brown trout was found in station BDR-3, and in station BDRT-5, the nearby un-named tributary at Berans Road. Otherwise, brown trout were present in moderate to small numbers.

Non-trout Fish Community

The Beaverdam Run subwatershed supports a diverse fish community composed of cold, cool, and warm-water fish species.

3.4.3 Illicit Discharge and Elimination Data

An illicit discharge is a discharge into a municipal separate storm sewer, which is not composed entirely of storm water (e.g. discharge of waste water or gray water). Baltimore County is responsible for establishing an illicit discharge detection and elimination (IDDE) program to ensure that any potential illicit discharges are either permitted by MDE or eliminated under its MS4 permit. Baltimore County tracks illicit discharges through a program of routine stormdrain outfall screening of major outfalls (≥36” in diameter) and small outfalls (≤36” in diameter) throughout the county. The outfall screening program consists of three parts:

(1) A quantitative analysis of the effluent that includes measuring the effluent flow rate, temperature and pH, and field-testing for parts per million (ppm) of chlorine, phenols and copper, using a specially configured LaMotte NPDES test kit;

(2) A qualitative assessment of the effluent, the outfall structure and the receiving channel, noting such conditions as water color, odor, vegetative condition, sedimentation, erosion, damage, etc.; and,

(3) A visual inspection of each outfall that notes any structural damage.

Baltimore County has an outfall prioritization system based on data from the outfall screening. The system allows for a more streamlined approach in selecting outfalls to screen and provides a more efficient use of staff. In addition, the system allows for outfalls screened once or not at all *(Priority 0)* to be screened sufficiently (three or more times) and properly prioritized. The list of outfalls to be screened is generated by a Microsoft Access Query based on the prioritization scheme.

The outfall prioritization system works as follows: Outfalls that have not been screened three times are not prioritized. Outfalls screened three or more times are assigned one of three priority ratings.

- *Priority 0 (Not prioritized)*: Outfalls with insufficient data to determine a priority rating. This may be due to inaccessibility or only a single screening.
- *Priority 1 (Critical)*: Outfalls with major problems that require immediate correction and/or close monitoring, or outfalls with recurrent problems. These outfalls are sampled four times each year.
- *Priority 2 (High)*: Outfalls with moderate to minor problems that have the potential to become severe. These outfalls are sampled once a year.
- *Priority 3 (Low)*: Outfalls with minor or no problems that do not require close monitoring. These outfalls are sampled on a ten-year cycle.

A second screening is done if nearly a decade has passed since the last screening. If no pollution problems were indicated, then the outfall is considered a low priority. This allows more focus on outfalls with more potential of an illicit connection.

A second screening is also performed at an outfall when prior screening indicates that one or more of the water quality criteria were exceeded. The second screening helps determine whether the pollutant is a persistent constituent of the effluent or an anomaly. No remedial action is taken if the second screening is within acceptable pollutant levels. However, the outfall is considered to have a potential illicit connection and is automatically queued for re-screening within one year.

If the problem is severe enough to warrant immediate correction, then an investigation begins immediately. Some sites are determined to have problems severe enough to warrant immediate investigation and/or corrective action after only one screening.

In Baltimore County, there are approximately 3,569 total stormdrain outfalls; of these, approximately 2,933 outfalls are less than 36 inches in diameter. The minor outfalls are just starting to be prioritized with 151 already prioritized. The county has 636 outfalls with pipe diameter of 36 inches or greater, of which 587 have a prioritization rating (Baltimore County DEPRM, 2010).

There are three major outfalls and 55 minor outfalls in Area I. Table 3-20 shows the distribution of storm drain outfalls by subwatershed.

Table 3-20: Number of Storm Drain Outfalls by Subwatershed

	Beaverdam Run	Baisman Run	Oregon Run	Total # of Outfalls
Major Outfalls (≥36")	2	1	0	3
Minor Outfalls (≤36")	45	3	7	55
Total	**47**	**4**	**7**	**58**

Table 3-21 provides the outfall prioritization results for Area I. The sampling and prioritization of minor outfalls has only begun recently in areas with a higher degree of urbanization targeted. All of the major outfalls are categorized as priority 2 (moderate to minor pollution problems) and all of the minor outfalls are categorized as "0" since none have been sampled.

Table 3-21: Storm Drain Outfall Prioritization Results

	Beaverdam Run	Baisman Run	Oregon Run	Total
Priority 0	45	3	7	55
Priority 1	0	0	0	0
Priority 2	2	1	0	3
Priority 3	0	0	0	0
Total	**47**	**4**	**7**	**58**

3.5 Forest Health

Baltimore County EPS used the Montreal Process to provide a framework for sustainability of the county's forest resources that resulted in the draft Baltimore County Forest Sustainability Strategy (2005). The strategy summarizes the management challenges and presents action plans for sustaining the county's forest resources while balancing socio-economic needs of the citizens.

As part of this strategy, the County is working on forest plans for all its major parks, the first of which was prepared for Oregon Ridge Park (Len-Mar, 2007). The park contains nearly 900 acres

of contiguous forest that is dominated by oak species. The study found that the forest is comprised of four forest cover types, of which oak species is the dominant type. Almost all of the forest stands are more than 100 years old, with several between 108 and 121 years old, suggesting that the forest was widely harvested in the 1880's and 1890's. Trees were found to be stressed due to overcrowding, deer browsing, and a localized 2006 gypsy moth infestation making them more vulnerable to mortality. In addition, deer browsing has greatly impacted the herbaceous community. Notably, 54% of the study plots showed no regeneration of forest trees, demonstrating the need for forest management. The full Oregon Ridge Park Forest Management Plan is found at http://www.baltimorecountymd.gov/agencies/environment/workgroup/programimplementation.html.

3.6 Stream Corridor Assessments

Stream corridor assessments (SCAs) were conducted for a subset of stream reaches in the Area I watershed. The stream segments surveyed in this study were intended to cover parts of the watershed that had not been assessed during the preparation of Baltimore County's 1997 Water Quality Management Plan for Loch Raven Watershed (Tetra Tech, 1997).

The 1997 Loch Raven watershed stream surveys initially focused on second and third order streams, although significant impairments of first order streams were also observed. A variety of stream survey methods were employed throughout the 1997 project. The stream stability indicators include those described by Pfankuch (1975). Information on a set of riparian indicators was also collected during the field survey including: vegetation type, buffer width and buffer density. The traditional Level I Rosgen approach (1994) was enhanced to include the use of in-field assessments rather than relying on estimates from topographic maps. In addition, a simplified pebble count procedure was used. The analysis concluded that there is potential for recovery as shown from the Rosgen Level II and I classifications..

The current survey focused on mainly fourth and first order stream reaches in Oregon Branch and Beaverdam Run which were not surveyed during the 1997 study, and all the streams in the Baisman Run subwatershed. The stream survey method was based on Maryland DNR's SCA Survey Protocols and an abbreviated version of a stream stability assessment which was specified by Baltimore County. The SCA protocols were developed as a tool for environmental managers to quickly identify environmental problems within a watershed's stream network (Yetman, 2001). It is a rapid field survey rather than a detailed scientific assessment. It is intended to help target the need for more detailed monitoring, management, and conservation efforts on the watershed and subwatershed scale.

The SCA survey is designed to be flexible and can be modified to suit the needs of the individual project. The modifications to the Area I SCA survey included the deletion of the accessibility and correctability ratings as well as the representative site forms. A new Stream

Stability Assessment (SA) form was added to the regular SCA forms. The SA form was derived from the concepts presented in Simon and Hupp (1986) on Channel Evolution Models. One version of the SA form was tested in the field with EPS personnel and then streamlined to make it more amenable to a rapid stream walk survey such as the SCA. The protocols and results of the SCA and SA for the Area I watershed are described in the following sections.

3.6.1 Assessment Protocol

The SCA method is used to quickly assess physical conditions and identify common environmental problems in a stream corridor. Two-person field crews walked the wadeable streams within each of the selected subwatersheds and identified the following environmental problems:

- Channelized or Altered Stream Sections (CA)
- Unusual Conditions – Comments (UC)
- Erosion Sites (ES)
- Fish Migration Barriers (FB)
- Pipe Outfalls/Exposed Pipe (PO)/ (EP)
- Inadequate Stream Buffers (IB)
- Trash Dumping Sites (TD)
- In or Near Stream Construction (IC)

The field survey teams walked along the selected stream corridors noting the location of problems on either field maps or a hand held Global Positioning System (GPS). At least one photograph was taken at each site to document the conditions observed. After returning from the field, all data was entered into a Geographic Information System (GIS). Each site was assigned a unique identification (ID) number including a county map grid identification number. Figure 3-4 shows the stream surveyed in 1997, 2010-2011 SCA, as well as dry, shallow drainage depressions that were assigned a field designation of “Unclassified Channels”.

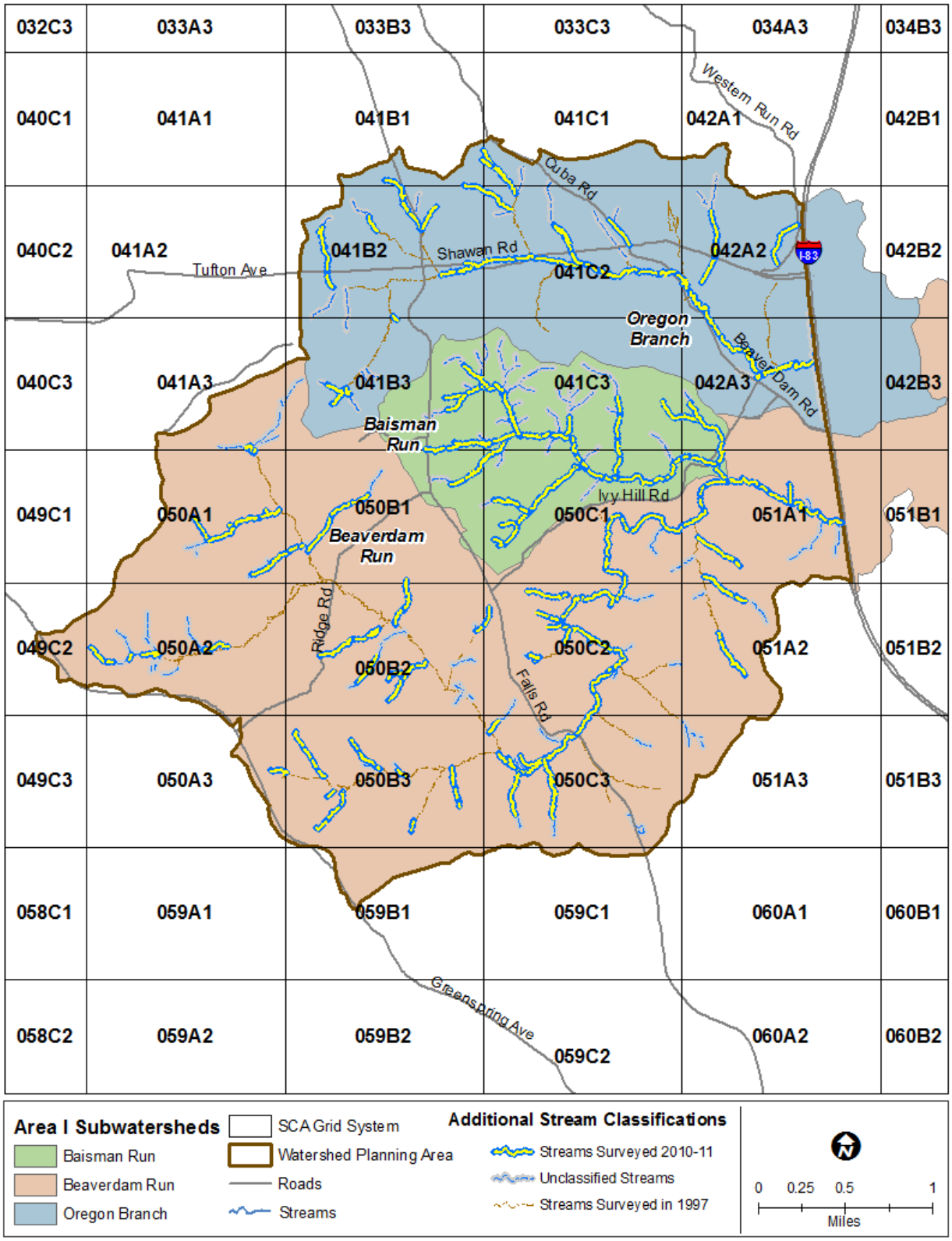
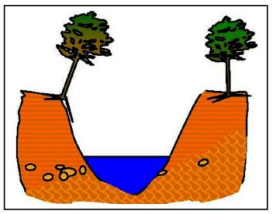
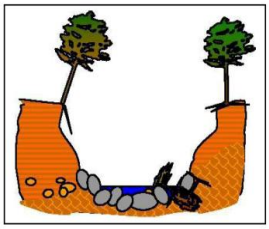


Figure 3-4: SCA Grid Identification System

All problem sites were scored by the field survey team on a scale of one to five for severity. The scores are intended to help prioritize potential restoration opportunities where a score of 5 denotes a minor problem, or one that is easy to fix, and a score of 1 would be the worst observed in a particular problem category. The criterion for scoring problem severity is dependent on the problem type and is described in detail in the SCA manual (Yetman, 2001). The severity rating is a measure of how bad a problem site is compared to other problems in the same category. The most severe problems (rating =1) are those with a direct and wide impact on stream resources.

The new Stream Stability Assessment form (SA) has 3 major descriptive categories: Channel Condition, Bed Condition and Planform. Within each major category there is a subset of conditions to choose from that were all determined using visual assessments with no in-field measurements. Stream reaches were delineated by field teams based on observations of significant changes in the local stream characteristics. For Channel Condition there are four evolution descriptions: Stage I – Incision, Stage II – Widening, Stage III – Deposition, Stage IV Recovery and Reconstruction (Figure 3-5).

Stage I Incision • Downcutting liberates sediment • Loss of perched bankfull floodplains • "U" shaped channel • Woody vegetation high on bank with many "surfer" trees	
Stage II Channel Widening • Widespread bank failures as banks exceed critical height or were undercut by toe scour • Channel adjusts to new flow regime • Significant sediment loads generated; most significant erosion hazard in this phase • Bank armoring generally ineffective	

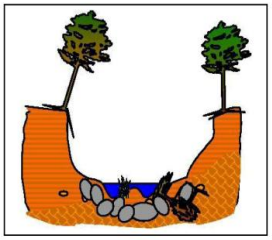
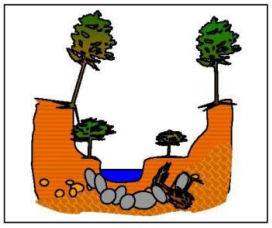
Stage III Deposition • Deposition begins from liberated sediment • Vegetation establishes near water line	
Stage IV Recovery and Reconstruction • Bankfull floodplains may be reconstructed from liberated sediment • Woody vegetation establishes near water line • Stability re-established	

Figure 3-5: Four Stages of Channel Evolution

The numbering sequence for the four categories follows an abbreviated version of Simon and Hupp's (1986) progression of change in channel evolution after some type of physical disturbance. For Stage I – Incision, the channel is downcutting which liberates sediment. Stormwater cannot access the floodplain where it could dissipate erosive energy. The channel cross section becomes "U" shaped and woody vegetation is left high on the unstable banks. For Stage II – Widening, there are widespread bank failures as the banks are undercut by high storm flows which can no longer access the floodplain. The channel tries to adjust to the new confined flow regime. Significant sediment loads are generated; *the* most significant erosion hazard occurs during this phase. Bank armoring is generally ineffective at this stage. For Stage III –Deposition, the enlarged channel dimensions can now accommodate the higher stormwater volumes and begins to develop an entrenched low flow channel from the deposition of liberated sediment. Vegetation begins to appear near the water line. For Stage IV – Recovery and Reconstruction, a new entrenched bankfull floodplain may be established. Woody vegetation and stable stream habitat begin to appear and dynamic stability is re-established.

The second major SA category is Bed Condition and it describes the dominant and secondary particle sizes in the stream reach. The choices are: Bedrock, Boulder, Cobble, Gravel, Sand, or Silt/Clay. The particle size distribution provides some indication of the potential resistance to erosion. Larger particle sizes will only be moved by higher storm flows. The third major category is Planform which describes the horizontal pattern of the stream bed. The Planform categories are: Straight, Meandering or Braided. These patterns are influenced by geology, slope, and vegetation patterns and they can help mediate water velocities and sediment transport rates.

The data from the SA evaluation is used in conjunction with SCA ratings such as erosion, and local geology/land use in order to prioritize unstable stream segments for further investigation and/or restoration. All the SCA survey data are shown as tables in Appendix K.

3.6.2 Summary of Sites Investigated

The SCA targeted mainly fourth and first order stream reaches in Oregon Branch and Beaverdam Run, and all the streams in the Baisman Run subwatershed. As indicated in Table 3-22, the SCA evaluated 41.6 stream miles in the assigned stream segments. Of the total stream mileage evaluated during the SCA there was a total of 14.6 miles of dry, shallow drainage depressions that were assigned a field designation of "Unclassified Channels". These channels accounted for 3.6 miles in Oregon Branch, 4.3 miles in Baisman Run, and 6.7 miles in Beaverdam Run.

The stream lengths and locations evaluated in the SCA survey were provided in the form of a GIS geo-database from Baltimore County. The GIS layer was compiled by Sanborn Mapping Company using stereophotogrammetry from 2008 orthophotography for stream lines (stream orders from 2005). This method of delineating streams creates an over estimate of total stream mileage when compared to field observations. The largest difference appears to occur when shallow drainage depressions are labeled as first order stream reaches that were field designated as "Unclassified Channels". The variability in mapping protocols can also lead to some differences in mileage estimates between report segments.

Table 3-22: Area I Miles of Stream Assessed

Area I Subwatersheds	2010-2011 Survey			Miles Surveyed (1997)	Total survey miles (2010-2011, 1997)	% Total Stream Miles Surveyed
	Stream Miles Surveyed	Miles of Unclassified Channels	Total Miles			
Baisman Run	6.6	4.3	11.2	0.0	11.2	98.2
Beaverdam Run	13.2	6.7	19.8	11.1	31.0	92.3
Oregon Branch	7.0	3.6	10.6	4.9	15.5	73.1
Totals	**26.8**	**14.6**	**41.6**	**16.1**	**57.9**	**87.5**

3.6.3 SCA General Findings

Within the 41.6 miles of streams surveyed in the Area I watershed, 219 potential problems were identified. Table 3-23 summarizes the number of potential problems identified in each category for each stream walked.

Table 3-23: Area I SCA Survey Results – Number of Potential Problems

Subwatershed	Channel Alterations	Erosion Site	Exposed Pipes	Fish Barriers	Inadequate Buffers	In or Near Stream construction	Pipe Outfalls	Trash Dumping	Unusual Conditions	Comment Sheets	Totals
Baisman Run	2	23	2	3	6	0	4	0	4	6	50
Beaverdam Run	8	53	0	0	15	0	42	0	3	17	138
Oregon Branch	1	4	1	3	14	0	4	0	4	0	31
Totals	11	80	3	6	35	0	50	0	11	23	219
% of Total	5	37	1	3	16	0	23	0	5	11	

Erosion sites were the most frequent problem observed followed by pipe outfalls and inadequate buffers. All of the other potential problem types combined amounted to only 14% of the observations. There were no trash dumping or in or near stream construction sites noted. Possibly the most surprising observation was the lack of significant trash dumping in Area I. Comment sheets are provided in Appendix K and were used to document observations made in the field that wasn't identified as a potential problem. A summary of the lengths of channel alterations, erosion and inadequate buffers are summarized in Table 3-24 by subwatershed. A description of each potential problem category is provided in the proceeding sections.

Table 3-24: Area I SCA Survey Results – Lengths of Potential Problems

Subwatershed	Length of Channel Alteration (ft)	Length of Erosion (ft)	Length of Inadequate Buffer (ft)
Baisman Run	261	10,319	2,773
Beaverdam Run	1,673	10,873	9,332
Oregon Branch	131	2,006	13,618
Totals	2,065	23,198	25,723

The field teams also recorded stream stability conditions for all stream segments walked. The results are discussed in Section 3.6.9 Stream Stability Assessment. In terms of length and frequency, Stage IV – Recovery and Reconstruction, was the predominant condition in all three subwatersheds that accounted for 64% (17.1 miles) of the surveyed miles. Stage II – Widening, ranked second in terms of length in all three subwatersheds, and second or third in terms of frequency with 24% (6.4 miles) of the stream length in this condition. Stage I – Incision, made up approximately 10 % (2.7 miles) of the surveyed miles, while Stage III – Deposition, consisted of only 2.4% (0.65 miles) of the surveyed miles.

3.6.3.1 Channel Alterations

Channel Alteration refers to stream sections where the banks or channel have been significantly modified from their naturally occurring structure or condition. This includes channelized stream sections where a stream channel has been dredged, widened, straightened, and/or covered with concrete. Channelized streams are typically intended to convey more water and to prevent flooding but often create adverse environmental impacts such as impairing habitat and increasing water temperature. Table 3-25 summarizes the number and length of channel alteration sites in each subwatershed and their associated severity rating. Locations of channel alteration sites are shown on Figures 3-8, 3-9, and 3-10. Appendix K provides tables of channel alterations site data ranked by severity for each subwatershed.

Table 3-25: Area I SCA Survey Results – Channel Alterations

Subwatershed	Severity Rating Inventory						Length		% of Total Length Surveyed
	Very Severe	Severe	Moderate	Low Severity	Minor	Total	(ft)	(mi)	
Baisman Run	0	0	0	1	1	2	261	0.05	0.7
Beaverdam Run	0	0	0	5	3	8	1,673	0.32	2.4
Oregon Branch	0	0	1	0	0	1	131	0.02	0.4
Totals	**0**	**0**	**1**	**6**	**4**	**11**	**2,065**	**0.39**	1.5

A total of 11 channel alteration sites were documented during the Area I survey for a total length of 2,065 feet or 1.5% of the stream length surveyed. The total length of channel alterations is relatively small considering the historic agricultural land use of the region, particularly in the Oregon Branch subwatershed. This is due to the amount of time that has passed since active ditching for agriculture has occurred. Most of these older, altered stream segments appear to have reached a new hydrologic and sediment transport equilibrium over time. With the exception of one channel section on an Oregon Branch tributary, channel alteration sections in Area I are all relatively short lengths and have low to minor severity ratings that can be expensive and challenging to correct. Figure 3-6 illustrates the one moderate alteration identified on an Oregon Branch tributary and a minor channel alteration in the Beaverdam Run subwatershed. The photo on the left is a 150 foot section of stream that is piped in a road culvert on a tributary in Oregon Branch (CA-OR-1571). The metal pipes have rusted out and the surrounding fill is now being gradually eroded out. The photo on the right is a gabion lined intermittent channel in the Beaverdam Run subwatershed (CA-BV-099).

Figure 3-6: Examples of Moderate and Minor Severity Channel Alteration Sites

3.6.3.2 Unusual Conditions

The unusual conditions form was used to document the location of anything out of the ordinary or to provide additional comments on a specific problem. An unusual condition was ranked as very severe if the potential problem was considered to have a direct and wide-reaching impact on the stream's aquatic resources. A site was rated as minor if it was considered to have no significant impact on the streams aquatic resources. Table 3-26 summarizes the number of unusual conditions sites associated in each subwatershed and their severity rating. Locations of unusual conditions sites are shown on Figures 3-8, 3-9, and 3-10. Appendix K provides tables of unusual conditions site data ranked by severity for each subwatershed.

Table 3-26: Area I SCA Survey Results – Unusual Conditions

Subwatershed	Severity Rating Inventory					
	Very Severe	Severe	Moderate	Low Severity	Minor	Total
Oregon Branch	0	2	1	1	0	4
Baisman Run	0	1	1	2	0	4
Beaverdam Run	0	1	1	1	0	3
Totals	**0**	**4**	**3**	**4**	**0**	**11**

Five of the unusual conditions were observations of excessive algae; three were rated as severe, one as moderate and one as low severity. It should be noted that all these observations of excessive algae were made during a cold period in December and January, when biological activity is usually relatively slow.

Figure 3-7 shows two of the severe rated excessive algae sites. The photo on the left (UC-BA-1745), in Baisman Run, is a pond on a drainage swale and it is located just upstream of a large underground natural gas line. The photo on the right (UC-OR-1804), in Oregon Branch, is in a wooded stream channel on a large equestrian center. However, there was no evidence of livestock grazing or loafing near this site.

Figure 3-7: Examples of Severe Rated Unusual Conditions with Excessive Algae

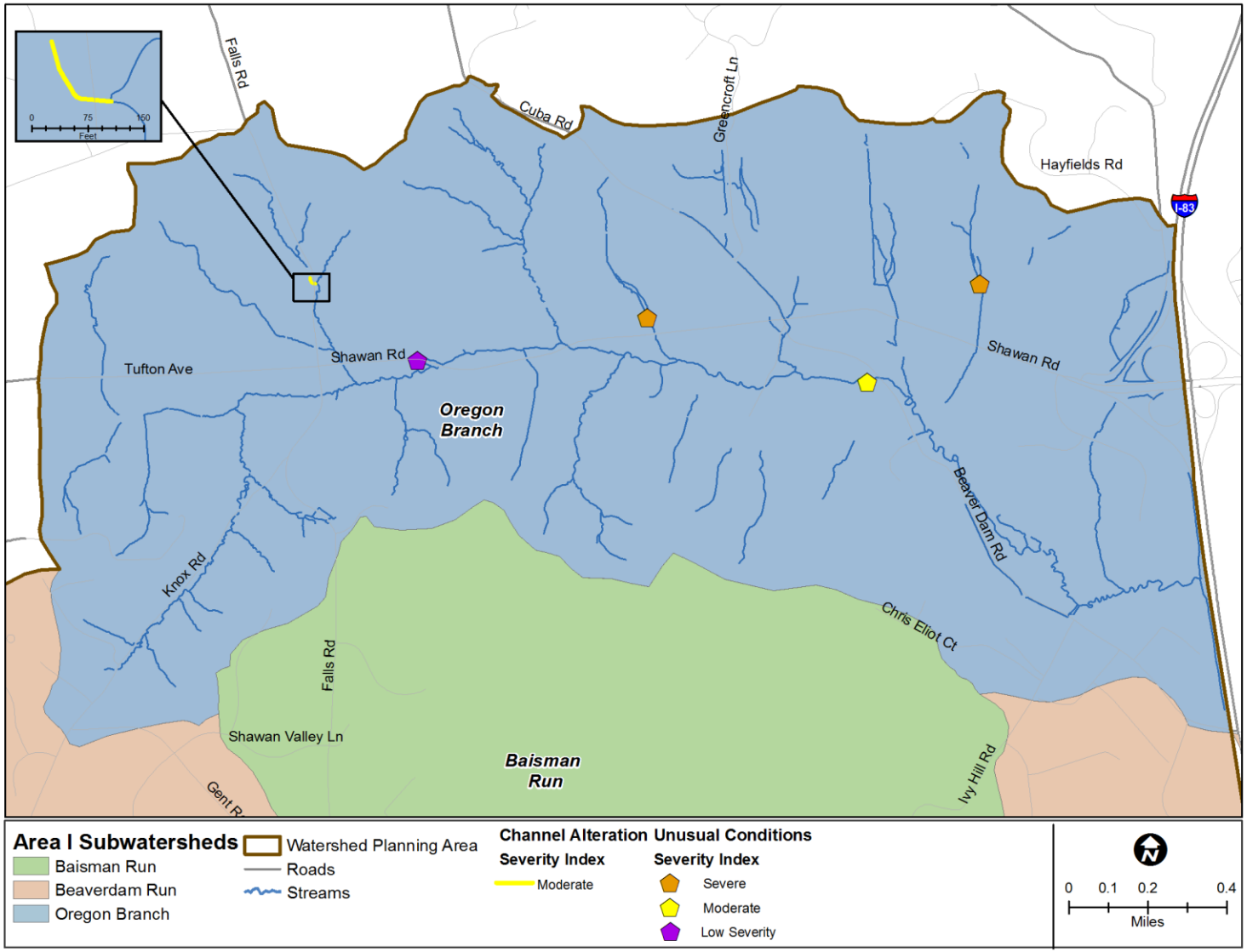


Figure 3-8: Oregon Branch Subwatershed, Channel Alterations and Unusual Conditions

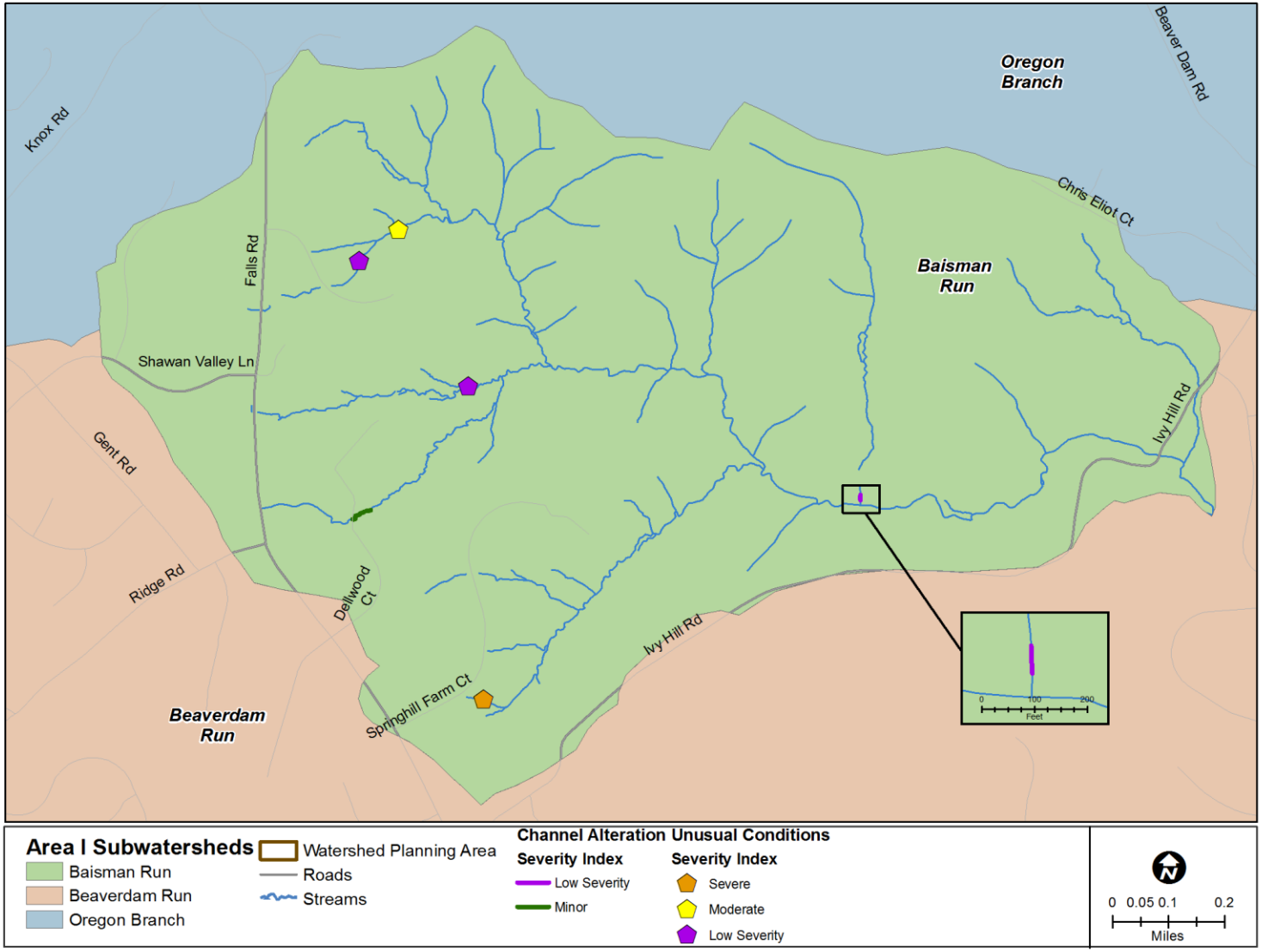


Figure 3-9: Baisman Run Subwatershed, Channel Alterations and Unusual Conditions

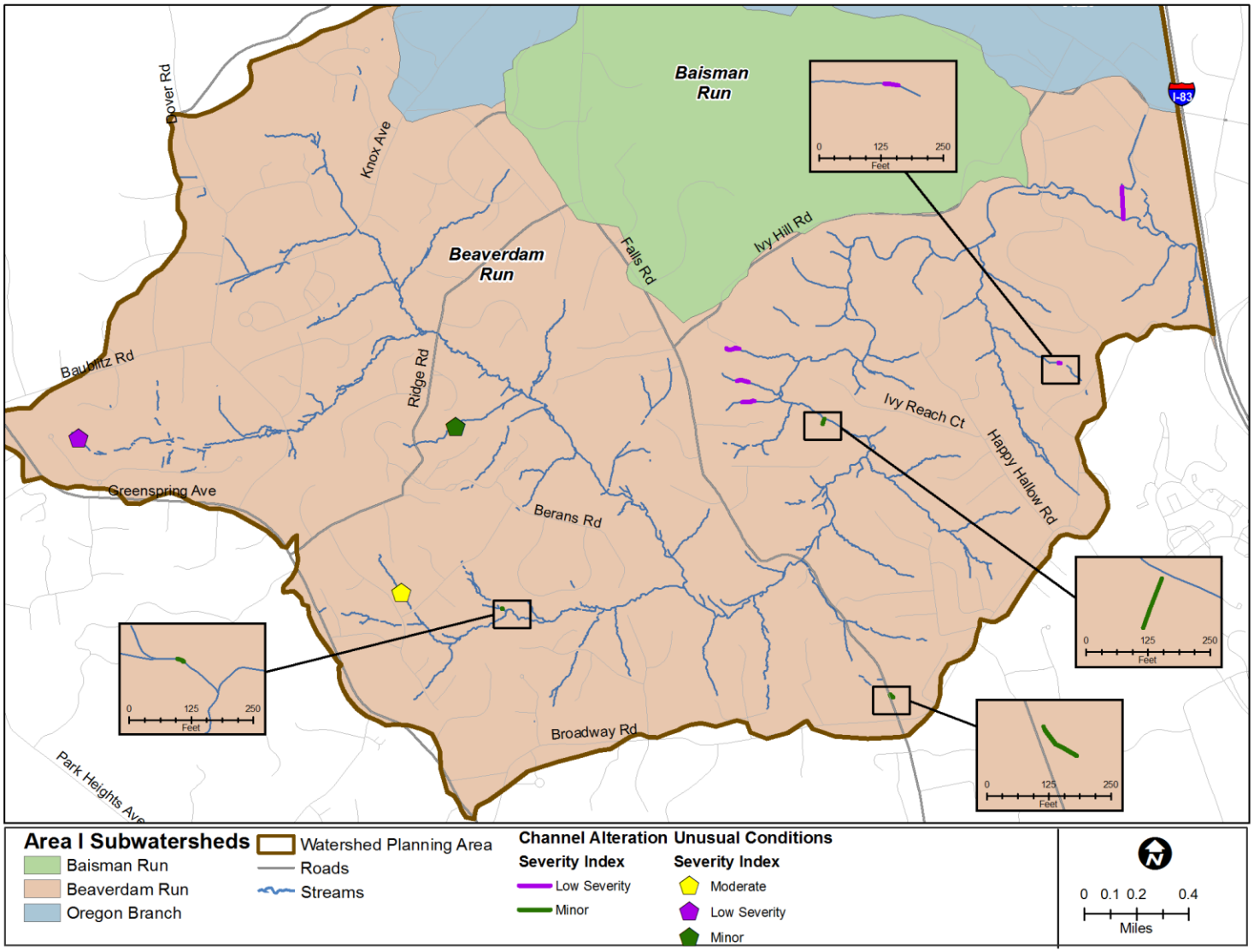


Figure 3-10: Beaverdam Run Subwatershed, Channel Alterations and Unusual Conditions

3.6.3.3 Erosion Sites

Erosion can destabilize stream banks, impact habitat, and cause sediment pollution problems downstream. Significant erosion problems are a result of changes to stream hydrology or sediment supply which is often attributed to land use changes in a watershed (e.g., urbanization, increased impervious cover). Since erosion is also a natural process, it was not the purpose of the SCA survey to identify every occurrence of erosion. Erosion was documented for unstable stream reaches with significant amounts of erosion along the stream's banks such as vertical stream banks and where vegetative roots along a reach were unable to hold soil onto the banks. The type of erosion, possible cause, adjacent land use, and whether there was a threat to infrastructure was noted for each erosion site. Table 3-27 summarizes the number of erosion sites associated with each subwatershed and their severity rating. Locations of erosion sites are shown on Figures 3-13, 3-14, and 3-15. Appendix K provides tables of erosion site data ranked by severity for each subwatershed.

Table 3-27: Area I SCA Survey Results – Erosion Sites

Subwatershed	Severity Rating Inventory						Length		% of Total Length Surveyed
	Very Severe	Severe	Moderate	Low Severity	Minor	Total	(ft)	(mi)	
Baisman Run	0	1	12	10	0	23	10,319	1.95	29.5
Beaverdam Run	1	5	34	13	0	53	10,873	2.06	15.6
Oregon Branch	0	0	1	3	0	4	2,006	0.38	5.4
Totals	**1**	**6**	**46**	**26**	**0**	**80**	**23,199**	**4.39**	16.4

A total of 80 erosion sites were documented and approximately 91 percent were rated in the moderate to low severity categories. Stream widening was the most common type of erosion, usually found at a bend at a steep slope. This type of erosion could be described as a natural process. The erosion prevalent at the low number of severe rating sites was predominantly headcutting or downcutting with five of the sites located below road crossings. The one very severe erosion site was downstream of a large stormwater basin in Beaverdam Run (Figure 3-11, photo on left). It appears that the most highly eroded stream segments are located below man made features that concentrate flow (i.e. road crossings). Most of these segments are in the upper half of Baisman Run or Beaverdam Run. They are all near the headwaters of north facing tributaries where the land use is dominated by residential subdivisions.

Figure 3-11 shows the very severe erosion site on Beaverdam Run (ER-BV-1630) on the left and the photo on the right (ER-BA-1722) shows the most severe erosion site in Baisman Run, which is approximately 2,606 feet long.

Figure 3-11: Examples of Very Severe and Severe Erosion Sites

3.6.3.4 Fish Migration Barriers

A fish migration barrier denotes anything in the stream that significantly interferes with the upstream movement of fish. Unimpeded upstream movement is important for various species that move up and downstream during different parts of their life cycle such as spawning. Fish barriers can reduce the fish population and diversity in stream sections. Fish barriers include manmade structures such as dams or road culverts and natural features such as waterfalls. Three main factors were considered in the field when identifying blockages: 1) the vertical drop was too high for fish to swim over (e.g. vertical drop greater than 6 inches); 2) the water depth was too shallow (e.g., water spread over a large area at channelized sections or road crossings); and 3) the water was moving too fast (e.g., steep culvert pipe discharging high velocity flow). The severity was rated based on the location of the barrier in the stream network and whether the blockage was total, partial, or temporary. A fish migration barrier was considered very severe when a structure completely blocked a large stream or river. A minor rating was assigned to temporary and/or natural fish barriers that blocks little in-stream habitat. Table 3-28 summarizes the number of fish migration barrier sites associated in each subwatershed and their severity rating. Locations of fish migration barrier sites are shown on Figures 3-13, 3-14, and 3-15. Appendix K provides tables of fish migration barrier site data ranked by severity for each subwatershed.

Table 3-28: Area I SCA Survey Results – Fish Migration Barriers

Subwatershed	Severity Rating Inventory					
	Very Severe	Severe	Moderate	Low Severity	Minor	Total
Oregon Branch	0	1	0	1	1	3
Baisman Run	0	1	2	0	0	3
Beaverdam Run	0	0	0	0	0	0
Totals	**0**	**2**	**2**	**1**	**1**	**6**

Fish migration barriers are relatively uncommon in Area I. It should be noted that the criteria for this metric was originally designed to evaluate problems for anadromous fish which are relatively weak swimmers. Anadromous fish spend most of their life in the sea and return to freshwater to spawn. Area I is in the Piedmont physiographic region where most resident fish species live in freshwater their entire life and are adapted to moving around steep, fast moving stream systems. To account for this, the severity rating was adjusted to account for the swimming capacities of local species, particularly trout. There were no barriers documented in the Beaverdam Run subwatershed and three barriers each in Oregon Branch and Baisman Run. All the barriers were at road crossings or stream impoundments structures. See Figure 3-2, fish sampling site LOCH-120_S_200X for potential impact of the Ivy Hill Road barrier on fish populations in Baisman Run.

Figure 3-12 shows the two severe fish migration barriers; on the left is the Shawan Road crossing in Oregon Run (FB-OR- 0028) and the USGS stream-gaging station weir and Ivy Hill Road crossing on Baisman Run is shown on the right (FB-BA-1581).

Figure 3-12: Example of Severe Fish Migration Barriers

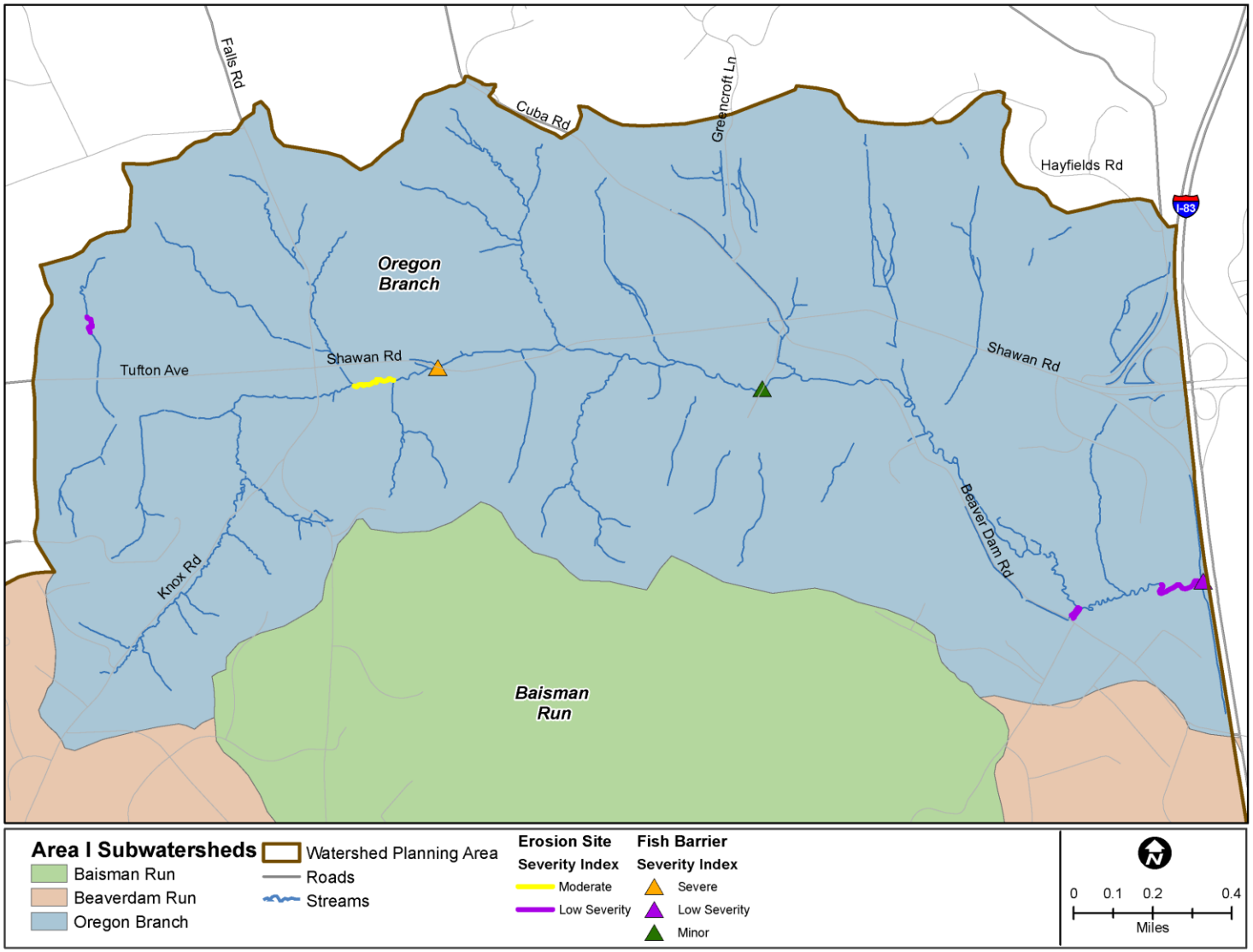


Figure 3-13: Oregon Branch Subwatershed Erosion Sites and Fish Barriers

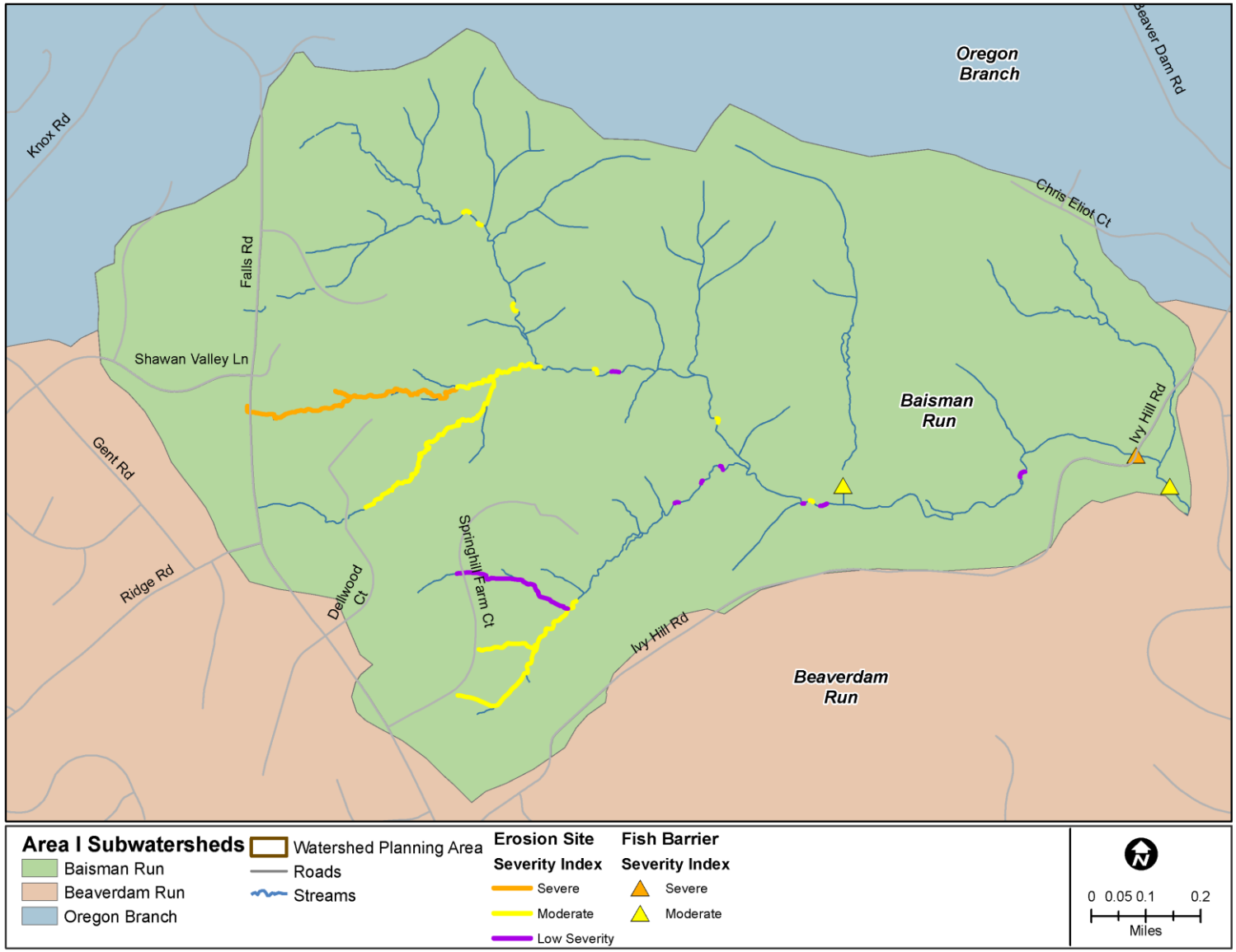


Figure 3-14: Baisman Run Subwatershed Erosion Sites and Fish Barriers

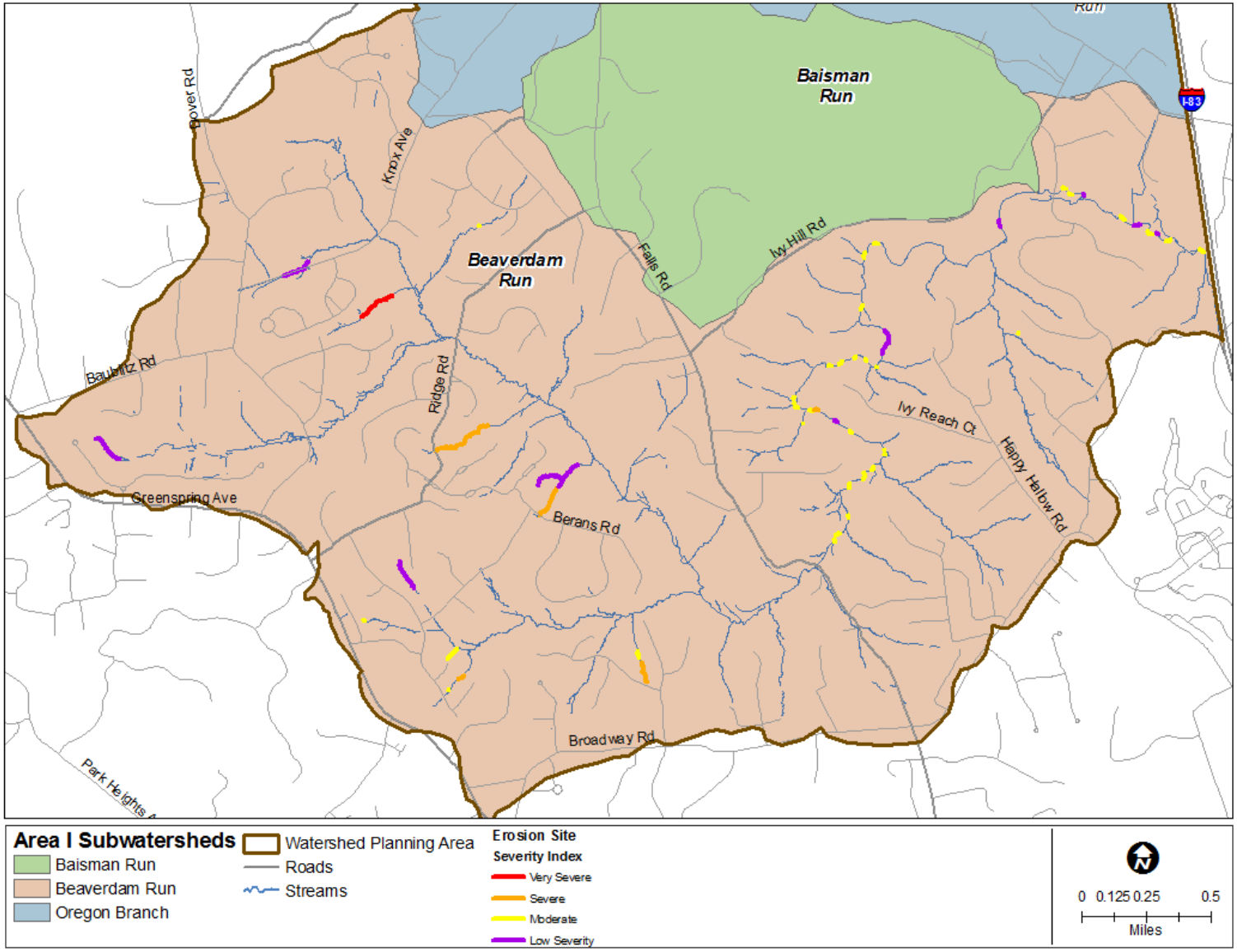


Figure 3-15: Beaverdam Run Subwatershed Erosion Sites

3.6.3.5 Pipe Outfalls and Exposed Pipes

Pipe outfalls include pipes or small manmade channels that discharge into the stream. These are considered a potential problem since they can carry untreated runoff and pollutants such as oil, heavy metals, and nutrients to a stream system. While all pipe outfalls were inventoried and assessed, a severity rating was given only if a discharge was present with indicators of pollution (e.g. color and odor). In addition, the pipe material type and size were also recorded.

Exposed pipes were also assessed and include any pipes that were either in the stream or along the immediate banks that could be damaged by a high storm flow event. Exposed pipes are susceptible to being punctured by debris which is a concern since liquids carried by the pipeline can leak into the stream causing water quality problems depending on the liquid type. Exposed pipes include manhole stacks, pipes exposed along the stream banks or under the stream bed, and pipes built over a stream but that are low enough to be affected during high storm flows.

There were fifty pipe outfalls observed in Area I. None of the outfalls were rated as severe or very severe and only eleven were rated as moderate severity. Eighty four percent of all outfalls are located in Beaverdam Run. Stormwater outfalls account for eighty percent of outfalls in Area I. Only one pipe outfall in the Beaverdam subwatershed was observed with a discolored discharge. The discoloration appeared to be due to a high concentration of iron which is naturally occurring in groundwater seeps, therefore it received a low severity rating. Table 3-29 summarizes the number of pipe outfalls associated in each subwatershed and their severity rating. Locations of pipe outfalls and exposed pipes are shown on Figures 3-17, 3-18, and 3-19. Appendix K provides tables of pipe outfalls and exposed pipes data ranked by severity for each subwatershed.

Table 3-29: Area I SCA Survey Results – Pipe Outfalls

Subwatershed	Severity Rating Inventory					
	Very Severe	Severe	Moderate	Low Severity	Minor	Total
Oregon Branch	0	0	0	0	4	4
Baisman Run	0	0	0	3	1	4
Beaverdam Run	0	0	11	27	4	42
Totals	**0**	**0**	**11**	**30**	**9**	**50**

There were only three Exposed Pipes in Area I. One is a 6 inch overflow pipe from a spring house in Oregon Ridge Park that was given a minor rating. The other two exposed pipes were underground natural gas lines on Baisman Run. Of the two exposed pipes, a severe rating

was assigned to a 48 inch pipe that was being undercut by the stream. Although an adjacent land owner said the utility company told him the line was inactive, it was still rated as a significant problem because the pipe is creating an extended area of scour on the downstream side of the pipe. This pipe also is located on the longest eroded stream reach in Area I. The third exposed pipe was given a moderate rating because there is some indication of abrasion on the outer wall of the metal pipe, possibly due to sediment scouring the pipe during high flow events. Figure 3-16 is a view of the downstream side of the two exposed underground natural gas lines; in the photos, the pipe site on the left (EP-BA-1726) has a severe rating and the pipe site on the right (EP-BA-1684) has a moderate rating. Table 3-30 summarizes the number of exposed pipes associated with each subwatershed and their severity rating.

Table 3-30: Area I SCA Survey Results – Exposed Pipes

Subwatershed	Severity Rating Inventory					
	Very Severe	Severe	Moderate	Low Severity	Minor	Total
Oregon Branch	0	0	0	0	1	1
Baisman Run	0	1	1	0	0	2
Beaverdam Run	0	0	0	0	0	0
Totals	**0**	**1**	**1**	**0**	**1**	**3**

Figure 3-16: Severe and Moderate Exposed Pipes on Baisman Run

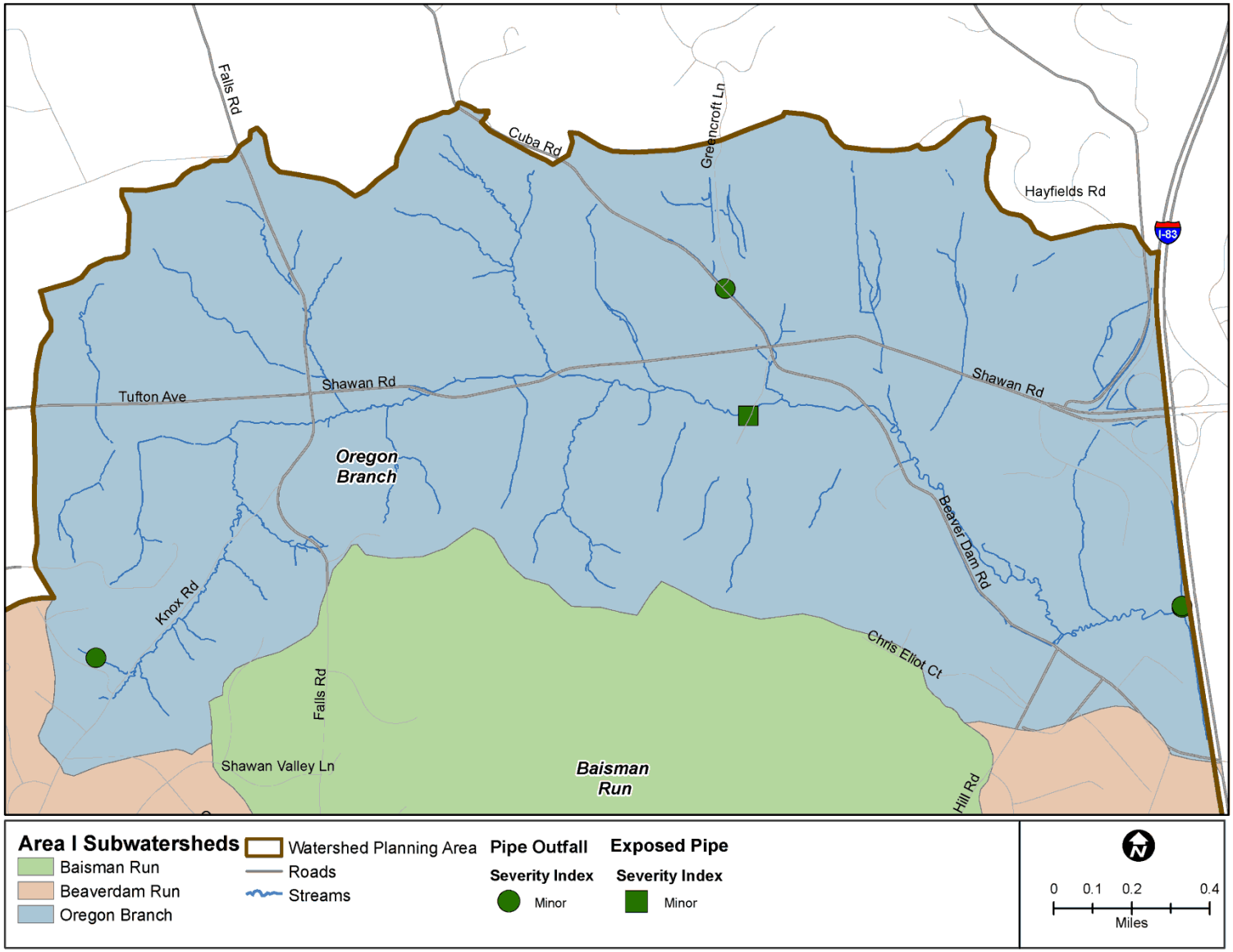


Figure 3-17: Oregon Branch Subwatershed, Pipe Outfalls and Exposed Pipes

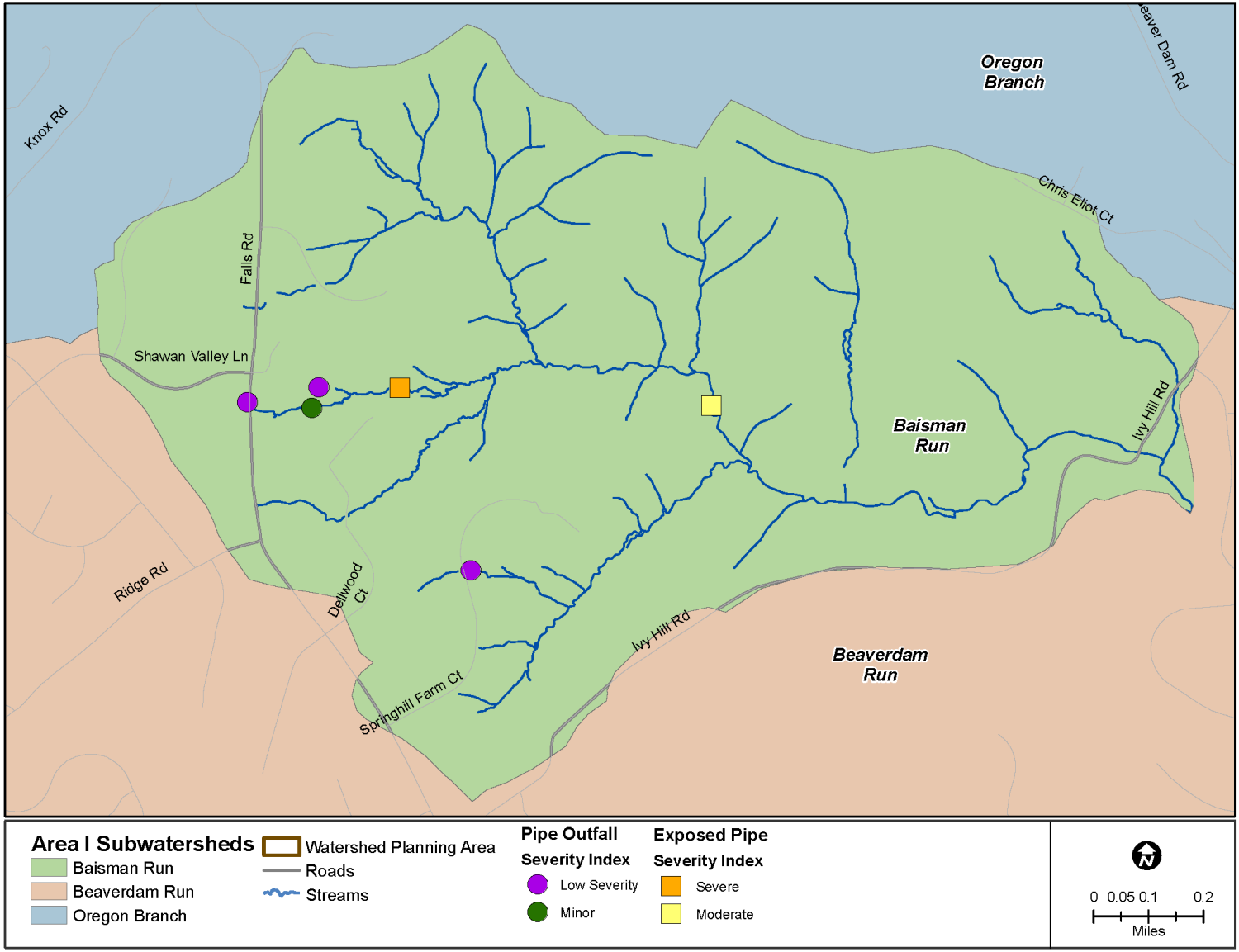


Figure 3-18: Baisman Run Subwatershed, Pipe Outfalls and Exposed Pipes

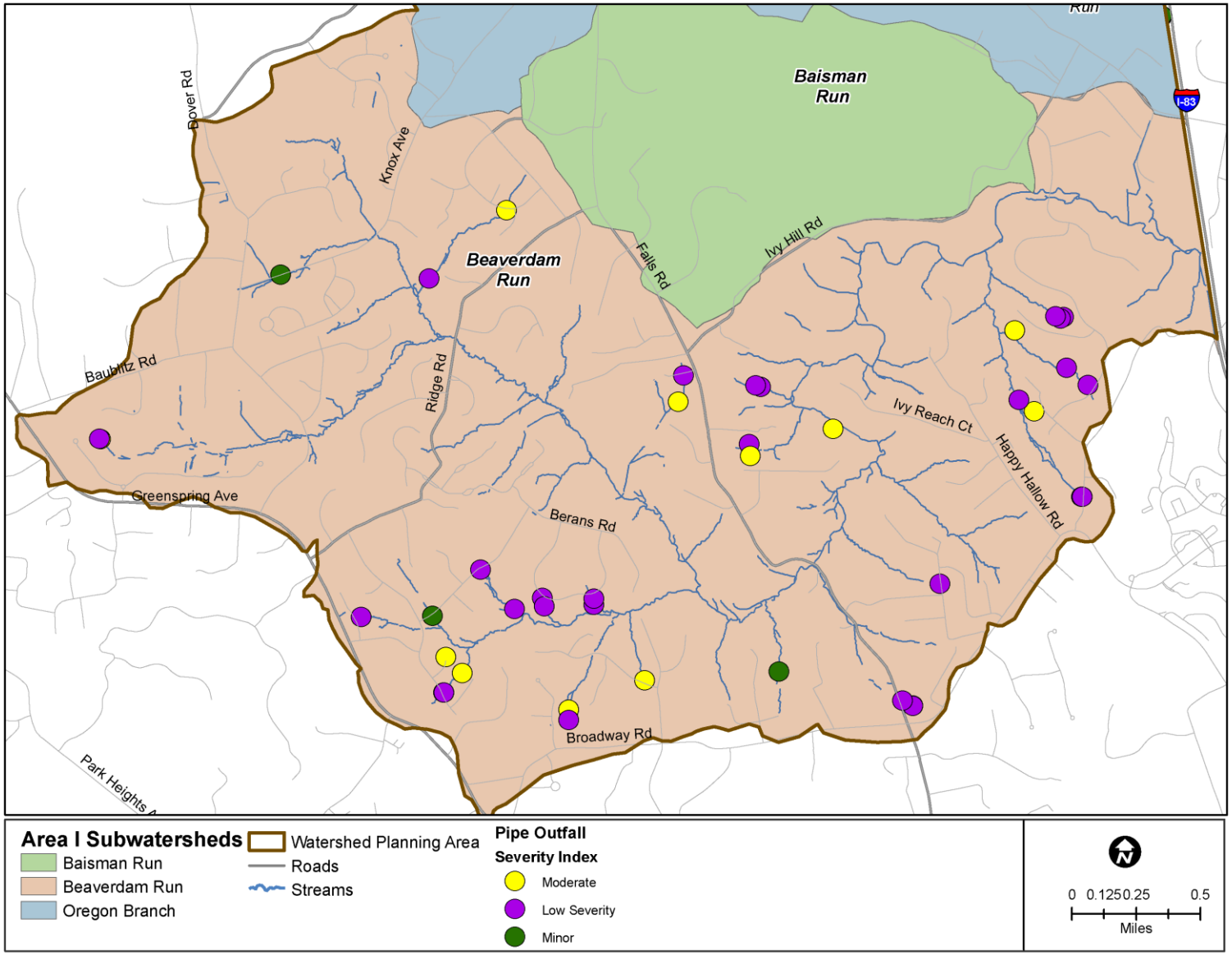


Figure 3-19: Beaverdam Run Subwatershed, Pipe Outfalls

3.6.3.6 Inadequate Stream Buffers

Forested buffer areas along streams are important for improving water quality and flood mitigation since they can reduce surface runoff, stabilize stream banks (root systems), shade streams, remove pollutants such as nutrients and sediment from runoff and provide habitat for various types of terrestrial and aquatic life including fish. For the SCA, a stream buffer was considered inadequate if it was less than 50 feet wide from the edge of the stream. Inadequate stream buffers were the third most commonly observed problem within Area I. The field teams identified 35 inadequate buffer sites with a total length of 25,723 feet or 18 percent of the total stream miles surveyed.

The severity of inadequate stream buffers was rated according to length and width. Due to the long history of agricultural land use it is not surprising that Oregon Branch had the greatest length of inadequate stream buffers. Conversely, Baisman Run had the shortest length of inadequate stream buffers due to the presence of Oregon Ridge Park. Beaverdam Run was intermediate in terms of actual length and percent of stream length impacted by inadequate stream buffers.

Table 3-31 summarizes the number of inadequate stream buffer sites associated with each severity ranking and the length of inadequate stream buffer observed by subwatershed. The table also presents the percentage of the total stream miles surveyed that are inadequately buffered by forest. Locations of inadequate stream buffers are shown on Figures 3-21, 3-22, and 3-23. Appendix K provides tables of inadequate stream buffers data ranked by severity for each subwatershed.

Table 3-31: Area I SCA Survey Results – Inadequate Stream Buffers

Subwatershed	Severity Rating Inventory						Length		% of Total Length Surveyed
	Very Severe	Severe	Moderate	Low Severity	Minor	Total	(ft)	(mi)	
Oregon Branch	0	4	3	5	2	14	13,618	2.58	9.6
Baisman Run	0	0	1	5	0	6	2,773	0.53	2.0
Beaverdam Run	0	1	5	8	1	15	9,332	1.77	6.6
Totals	**0**	**5**	**9**	**18**	**3**	**35**	**25,723**	**4.87**	**18.1**

Figure 3-20 shows two examples of the longest and severely rated buffer problem sites. The photo on the left (IB-BV-1586) is an old golf course in upper Beaverdam Run that is being converted into a large lot sub-division. Forest buffer plantings are required with the development project. The field next to the stream also has numerous old buried drain pipes and some new pipes that appear to be drains from new home sites. The photo on the right (IB-OR-1810) is at a golf course on the lower end of Oregon Branch, where it appears that some older trees have recently been removed.

Figure 3-20: Examples of Severe Inadequate Stream Buffers

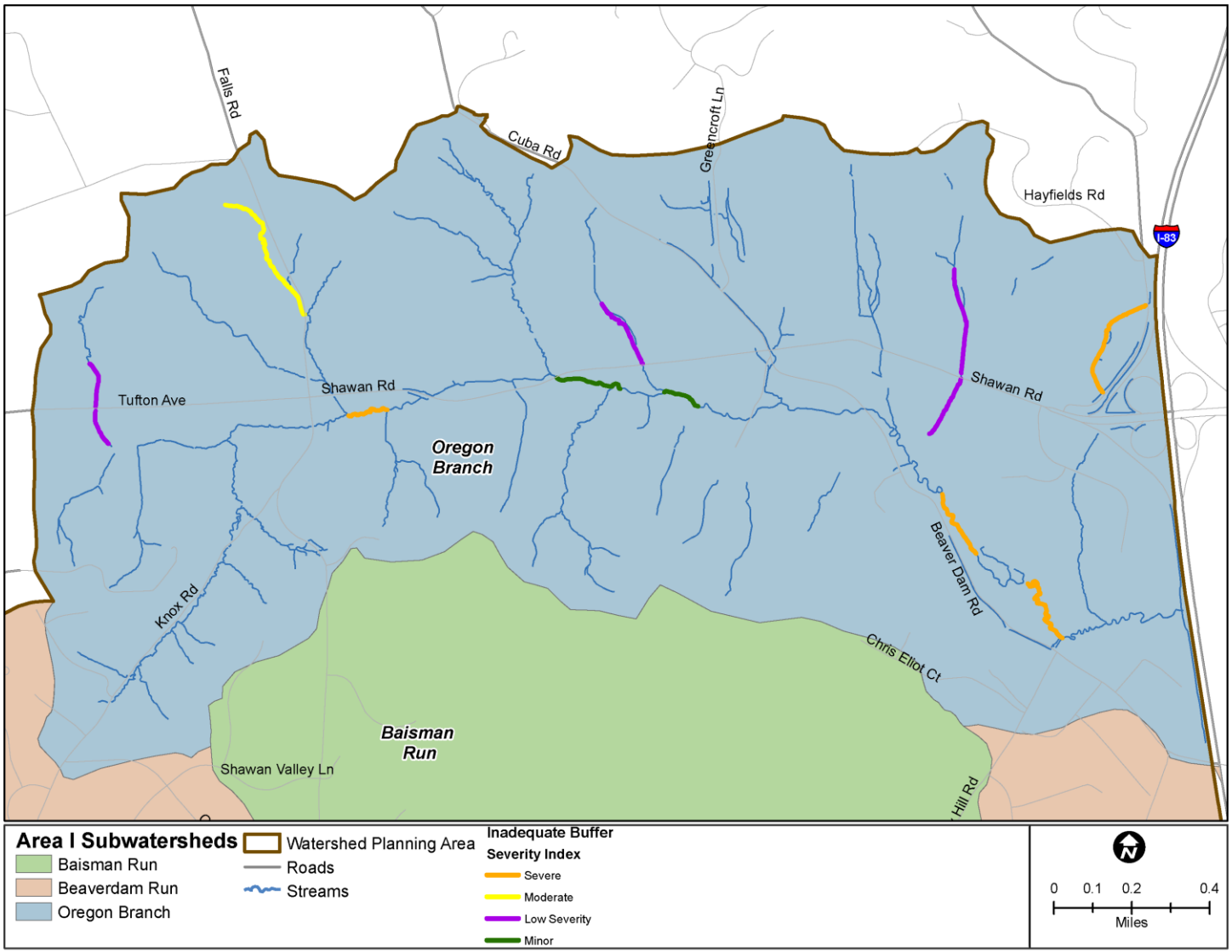


Figure 3-21: Oregon Branch Subwatershed, Inadequate Buffers *(Note that Individual buffer segments may not be easily distinguished from those they are adjacent to due to the map scale)*

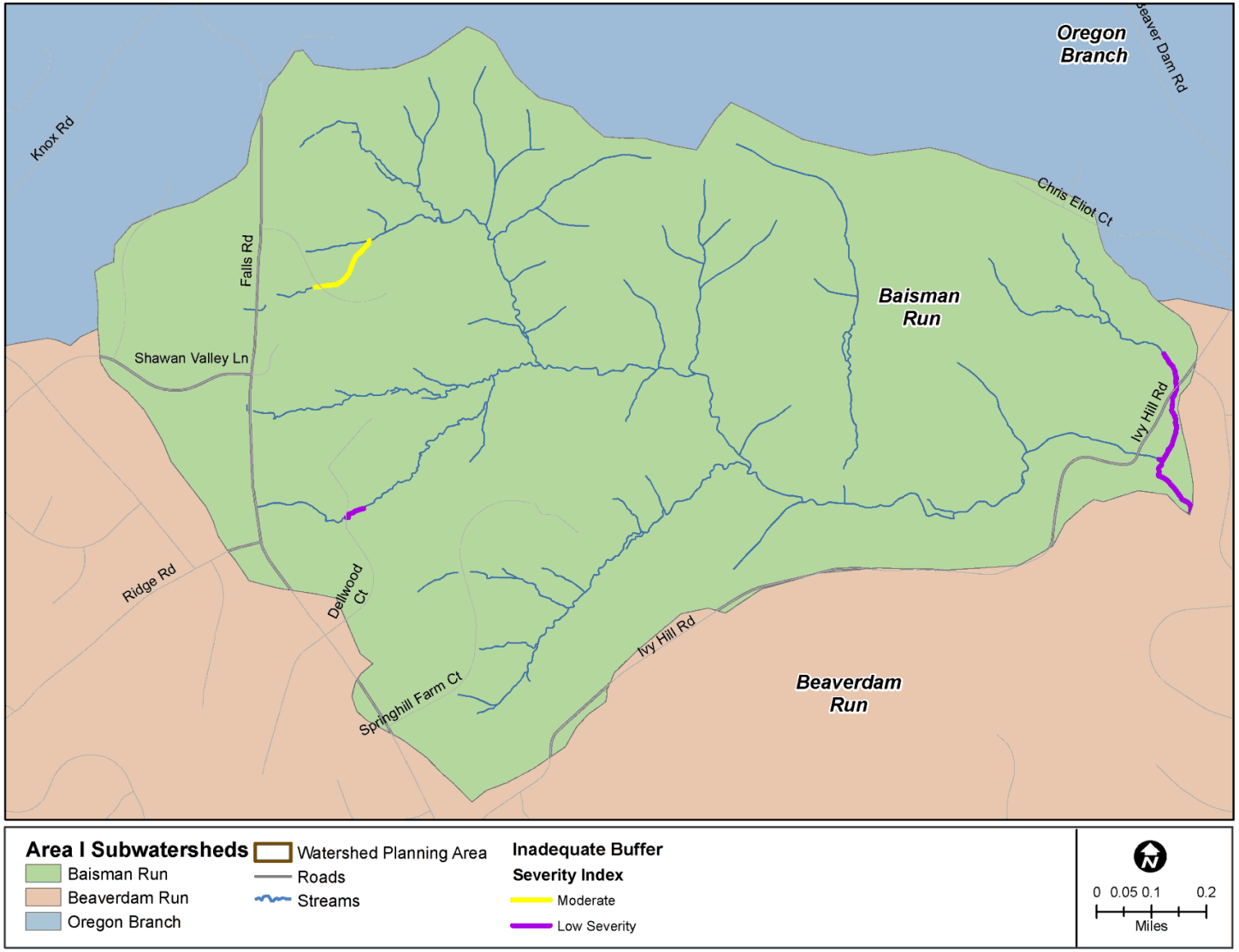


Figure 3-22: Baisman Run Subwatershed, Inadequate Buffers *(Note that Individual buffer segments may not be easily distinguished from those they are adjacent to due to the map scale)*

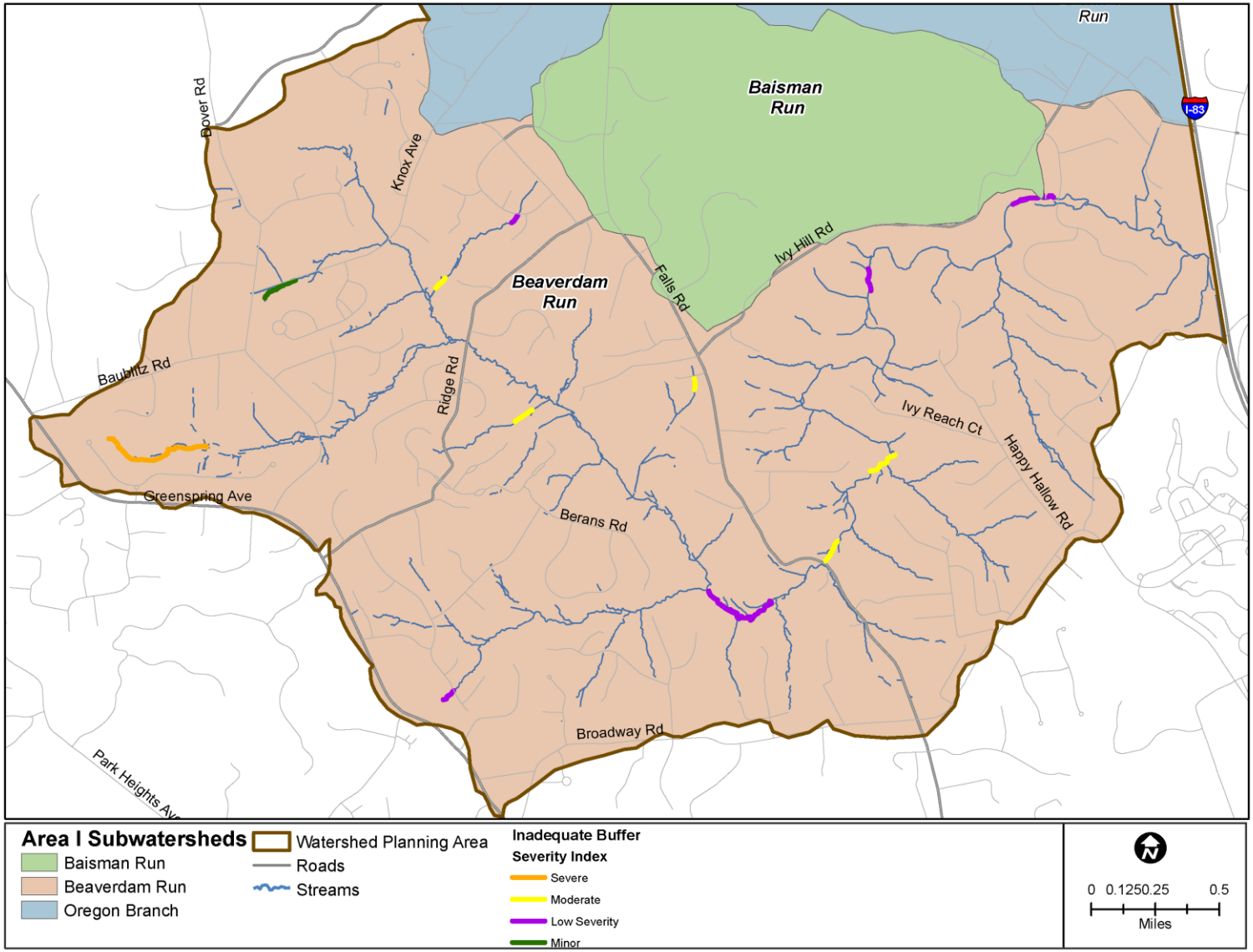


Figure 3-23: Beaverdam Run Subwatershed, Inadequate Buffers *(Note that Individual buffer segments may not be easily distinguished from those they are adjacent to due to the map scale)*

3.6.4 Stream Stability Assessment

The data from the stream stability assessment is used in conjunction with SCA ratings that include erosion and inadequate buffers, in addition to local geology and land use in order to prioritize unstable stream segments for further investigation, restoration, and/or preservation. This information may be useful to geomorphologists and stream restoration professionals when they are prioritizing potential stream restoration projects. The numbering sequence for the four stability categories follows Simon and Hupp (1986) progression of change in channel evolution after some type of physical disturbance. Based on this general theory of channel evolution, Area I could be described as relatively stable with some fairly obvious problem areas. These observations correlate with the general conditions further described in section 3.6.5 of this report.

Locations of stream stability assessment reaches are shown on Figures 3-26, 3-27, and 3-28. Tables summarizing data collected for stream stability assessment reaches are included in Appendix K, where the data is ranked according to stream stage for each subwatershed.

Table 3-32 provides a summary of the Stream Stability Stage conditions in Area I. Recovery and Reconstruction (Stage IV) made up the majority (64%) of the total stream length covered in this study. The second most common condition was Widening (Stage II), which made up 24% of the stream lengths. The predominance of these two conditions holds for each subwatershed as well as overall for Area I. Incision (Stage I) was ranked third (10%) in terms of total stream length and Deposition (Stage III) was the least observed condition (2.4%). The third and fourth place rankings of Incision (Stage I) and Deposition (Stage II) varied in the individual subwatersheds.

Table 3-32: Summary of Stream Stability Stage for Area I

Subwatershed	Stability Stage	Length (ft)	Length (mi)	Number of Reaches	Percent Stage Lengths (ft)	Percent Stage Reaches
Baisman Run	I Incision	4,790	0.91	9	13.6	17.6
	II Widening	8,138	1.54	9	23.0	17.6
	III Deposition	290	0.05	1	0.01	1.9
	IV Recovery and Reconstruction	21,986	4.16	32	62.5	62.7
Totals		35,204	6.66	51	--	--
Beaverdam Run	I Incision	9,110	1.73	17	13.1	17
	II Widening	20,338	3.85	27	29.2	27
	III Deposition	2,530	0.48	7	3.6	7
	IV Recovery and Reconstruction	37,565	7.11	49	54.0	49
Totals		69,542	13.17	100	--	--
Oregon Branch	I Incision	300	0.06	1	0.8	2.7
	II Widening	5,136	0.97	6	13.9	16.2
	III Deposition	657	0.12	1	1.8	2.7
	IV Recovery and Reconstruction	30,958	5.86	29	83.5	78.3
Totals		37,051	7.02	37	--	--

The second major stream stability assessment category is bed condition that provides a visual estimate of the dominant and secondary particle sizes in the stream reach. Bed condition / particle size estimate provides an indication of the stream bed's resistance to movement. Large particles are more resistant to erosion and therefore are more stable. The five particle size categories are: bedrock, boulder, cobble, gravel, sand, and silt/clay. Table 3-33 and Figure 3-25 provide a summary of the bed condition by subwatershed in Area I. The dominant bed material in Baisman Run and Oregon Branch is cobble, followed by sand and gravel, respectively. In Beaverdam Run, sand is the dominant bed material followed by cobble.

The second most abundant bed material was almost evenly distributed between cobble and gravel in Beaverdam Run and Baisman Run, while gravel was the second most abundant bed material in Oregon Branch. Table 3-34 and Figure 3-26 provide a summary of the secondary bed condition by subwatershed in Area I. A large disparity between primary and secondary particle size classes may provide additional insight on relative stream bed stability.

Table 3-33: Visual Estimates of Dominant Bed Material in Area I

Particle Size Category	Baisman Run (%)	Beaverdam Run (%)	Oregon Branch (%)
Bedrock	2	2	5
Boulder	8	3	0
Cobble	45	26	46
Gravel	12	15	35
Sand	33	32	11
Silt/Clay	0	22	3

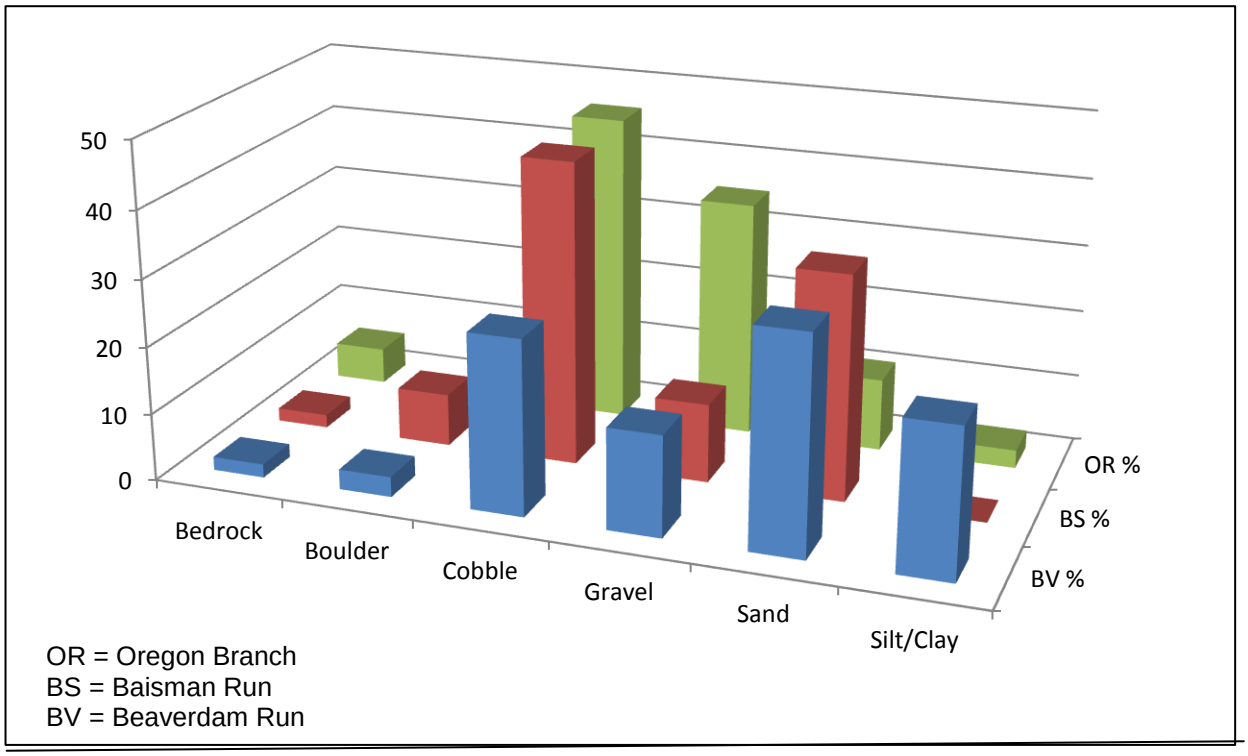


Figure 3-24: Dominant Bed Material Distributions in Area I

Table 3-34: Visual Estimates of Secondary Bed Material in Area I

Particle Size Category	Baisman Run (%)	Beaverdam Run (%)	Oregon Branch (%)
Bedrock	0	0	5
Boulder	4	3	0
Cobble	35	37	16
Gravel	37	32	49
Sand	16	16	22
Silt/Clay	8	12	8

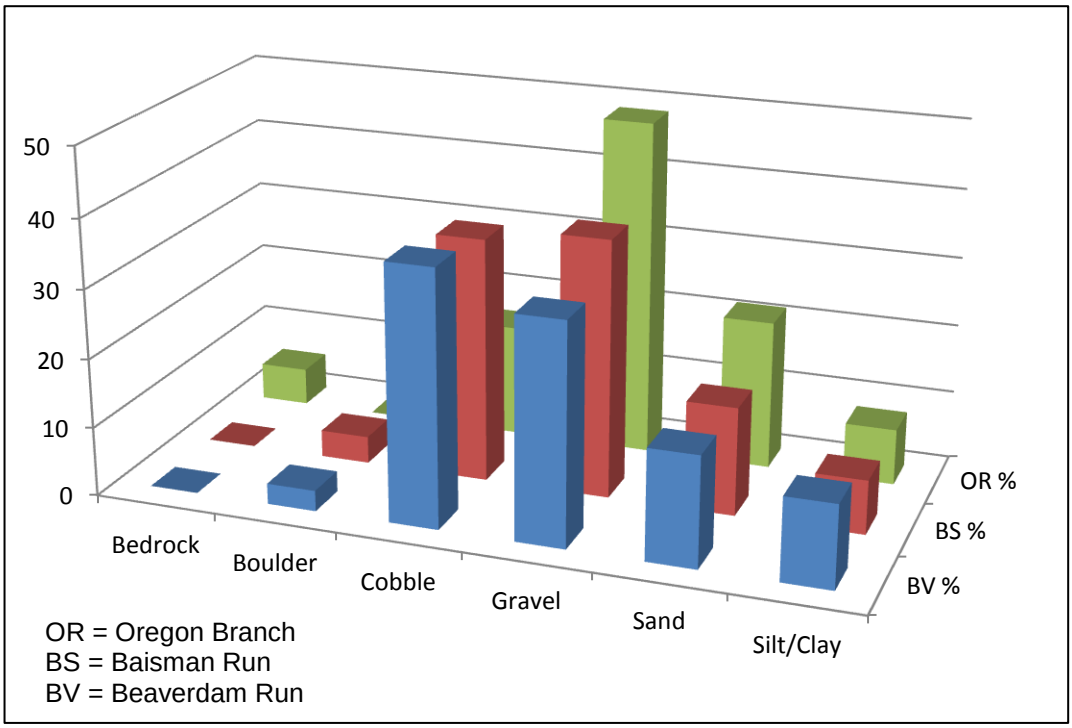


Figure 3-25: Secondary Bed Material Distributions in Area I

The third major Stream Stability Assessment category is Planform that consists of three categories: straight, meandering or braided. Fifty eight to seventy one percent of the streams were categorized as meandering. There were no braided stream segments in Baisman Run and only 2% and 3% of the streams in Beaverdam Run and Oregon Branch were braided, respectively. Straight channels made up the remainder of the streams. Table 3-35 provides a summary of the channel planform by subwatershed in Area I.

Table 3-35: Visual Estimates of Channel Planform in Area I

Channel Planform	Baisman Run (%)	Beaverdam Run (%)	Oregon Branch (%)
Braided	0	2	3
Straight	29	40	27
Meandering	71	58	70

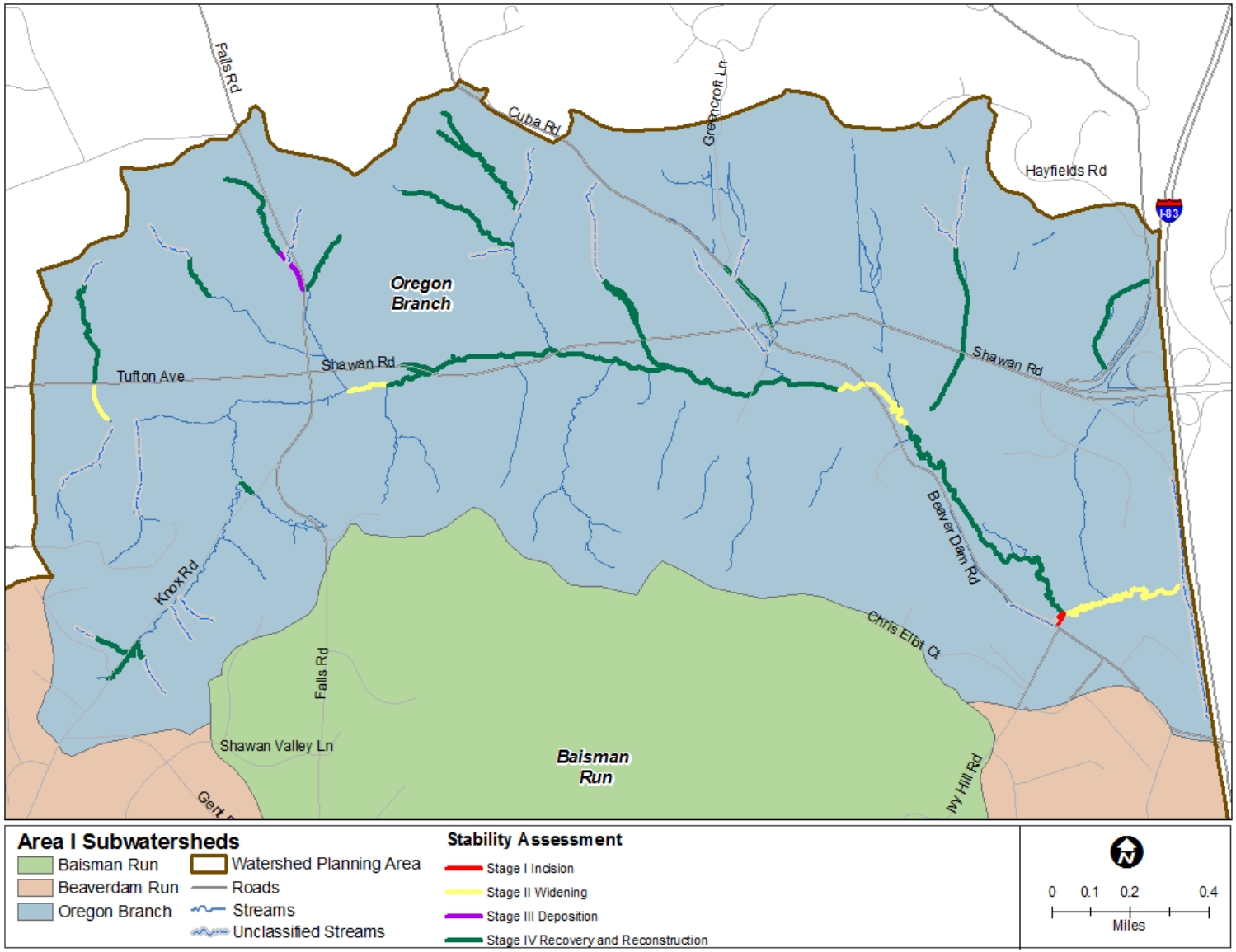


Figure 3-26: Oregon Branch Subwatershed, Stream Stability Assessments

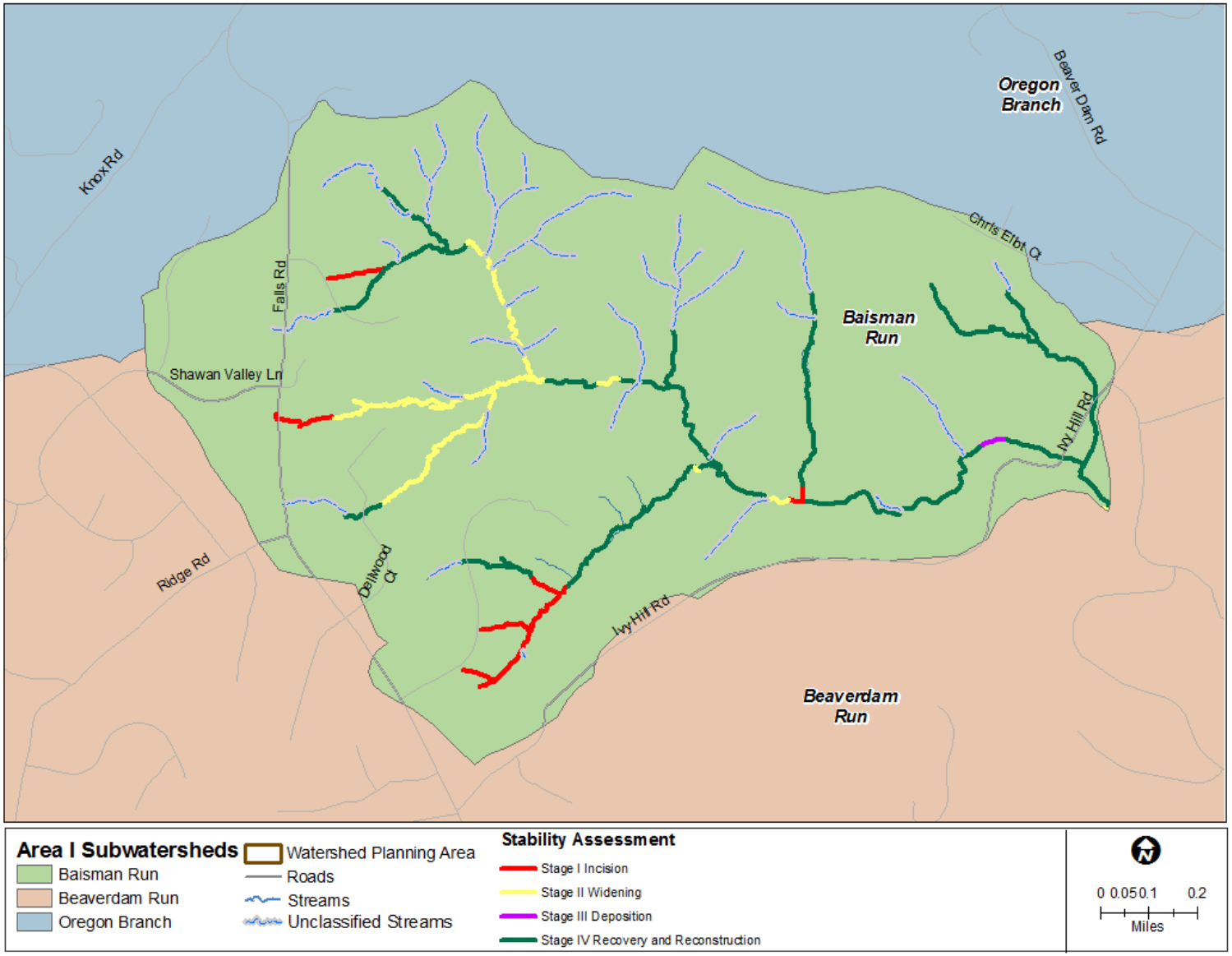


Figure 3-27: Baisman Run Subwatershed, Stream Stability Assessments

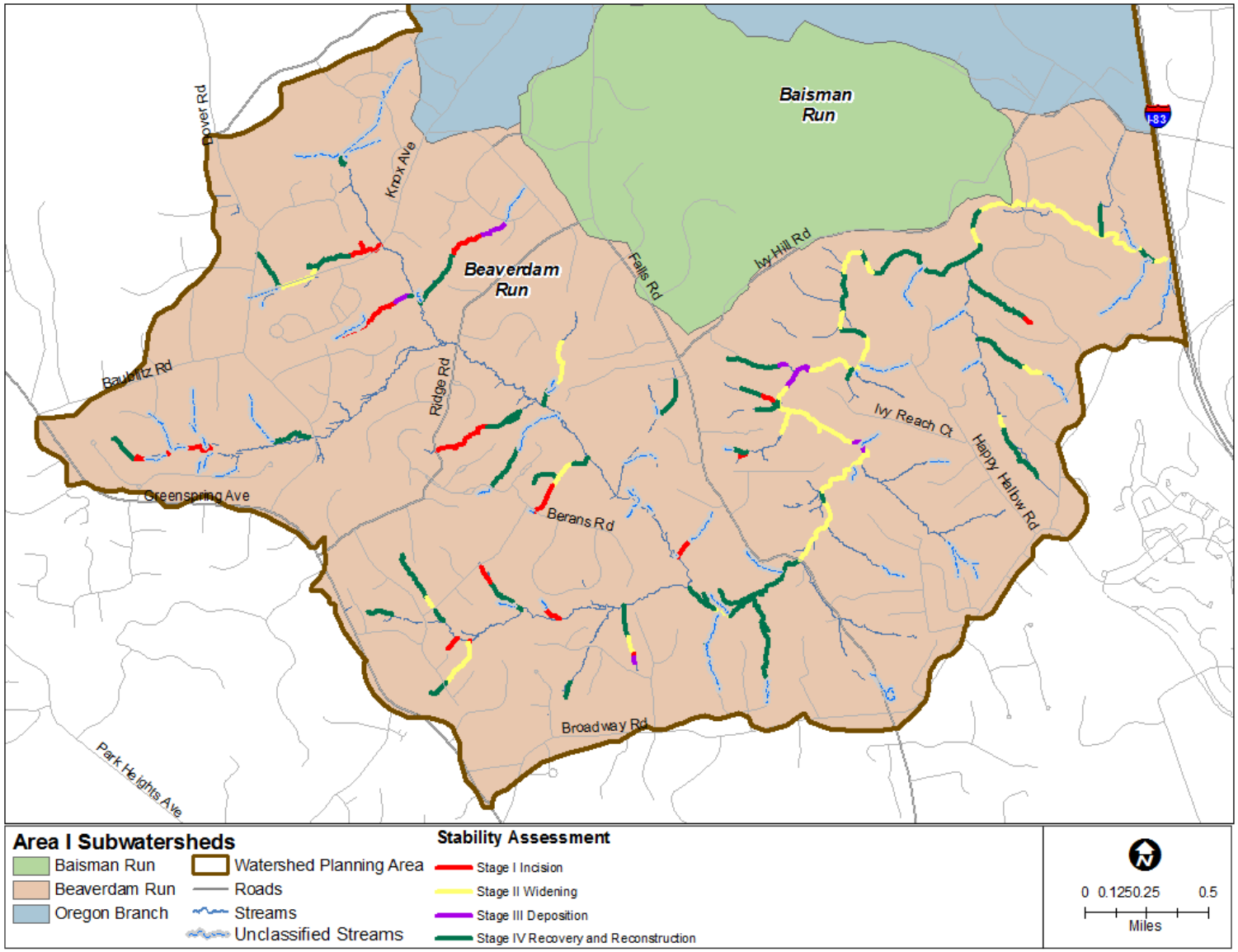


Figure 3-28: Beaverdam Run Subwatershed, Stream Stability Assessments

3.6.5 Summary of Stream Corridor Assessments

This section highlights the most significant observations of erosion and stream instabilities identified during the 2011 field surveys. Although this summary calls attention to particular erosion issues observed in 2011, the entire stream assessment data set should be considered when implementation activities are being prioritized for Area I watersheds. All of the individual findings have been discussed in the text above and the complete data tables are available in Appendix X.

While Area I streams are in relatively good condition, compared to more urbanized watersheds, there is a small collection of sites where unstable channels are concentrated. Fifty percent of the total channel erosion length surveyed in 2011 is concentrated at eleven sites within Baisman Run and Beaverdam Run subwatersheds (Table 3-36, Figure 3-29).

Baisman Run Subwatershed

The greatest concentration of unstable eroded stream channels occurs on two tributaries in the headwaters of Baisman Run (Figure 3-30). The Falls Road/Dellwood Court tributary system has one segment that was rated severe and six long, contiguous segments that were rated moderately eroded. The cumulative length of eroded channel was 5,795 feet. The remaining portions of significant erosion in the Baisman Run subwatershed are located in the adjacent tributary that drains Springhill Farm Court. While all the erosion on this tributary system was rated as moderate, the relatively long, contiguous nature of the channel disturbance makes these areas candidates for further watershed management attention.

Beaverdam Run Subwatershed

The Beaverdam Run subwatershed had three channel segments that were rated as severely eroded. All three sites were directly below road culverts that appeared to have concentrated stormwater flow and channel scour. The fourth segment in Beaverdam Run was rated as very severe due to the depth, width, and length of the channel disturbance. There is a large stormwater management facility above this reach but it does not treat all the runoff from the upper drainage basin. Although all the significant erosion segments in the Baisman Run and Beaverdam Run subwatersheds are surrounded by forest or shrubs, there appears to be potential construction access points from adjacent roads or utility right of ways.

Oregon Branch Subwatershed

During the 2011 survey, only four relatively short stream reaches exhibited some erosion problems (see Section 3.6.3.3). Due to their size and relative isolation, none of these sites were considered significant enough to warrant special attention in this overview section. However, the 1997 Water Quality Management Plan for Loch Raven Watershed did highlight another stream erosion problem area in the upper subwatershed. Livestock access to the stream was indicated as a source for channel erosion, inadequate buffers, and water chemistry impairments (Tetra Tech, 1997). Although this area was not covered by the 2011 survey, windshield survey observations from Tufton Avenue indicated that the conditions might not have improved significantly over the ensuing fourteen years. The available 1997 data has been included in Table 3-36 but the information is limited because the earlier report used different assessment techniques.

Table 3-36: Significant Erosion Sites

Map Site ID	Subwatershed	Site #	Type	Cause	Street connection	Avg. Exposed Bank Height (ft)	Severity	Erosion Length (ft)	Erosion Area (sf)
A	Baisman	BS041B3-ES14-1	Downcutting	Below road crossing	Falls Rd	5	Severe	2,606	13,031
B	Baisman	BS041C3-ES2-1	Widening		Falls Rd.	2	Moderate	1,006	2,013
C	Baisman	BS050B1-ES4-1	Widening		Dellwood Ct.	2	Moderate	2,183	4,365
D	Baisman	BS050C1-ES3-1	Downcutting	Other	Springhill Farm Ct.	5	Moderate	645	3,224
E	Baisman	BS050C1-ES2-1	Downcutting	Other	Springhill Farm Ct.	4	Moderate	758	3,030
F	Baisman	BS050C1-ES4-1	Downcutting	Land use change	Springhill Farm Ct.	3	Moderate	654	1,962
G	Baisman	BS050C1-ES1-1	Downcutting	Other	Springhill Farm Ct.	4	Moderate	399	1,595
Baisman Run Sites Total Erosion								**8,250**	**29,219**
H	Beaverdam	BV050A1-ES12-1	Downcutting	Other (Below SW outfall)	Long Ridge Rd.	9	Very Severe	852	7,672
I	Beaverdam	BV050B2-ES1-1	Downcutting	Below road crossing	Ridge Rd.	3	Severe	1,391	4,173
J	Beaverdam	BV050B3-ES3-2	Headcutting	Below road crossing	Berans Rd.	5	Severe	438	2,192
K	Beaverdam	BV050B2-ES4-1	Downcutting	Below road crossing	Barthel Rd.	3	Severe	699	2,097
Beaverdam Run Sites Total Erosion								**3,381**	**16,135**
L	Oregon Branch	1140-1		livestock	Tufton Ave.	N/A	N/A	1,542	N/A

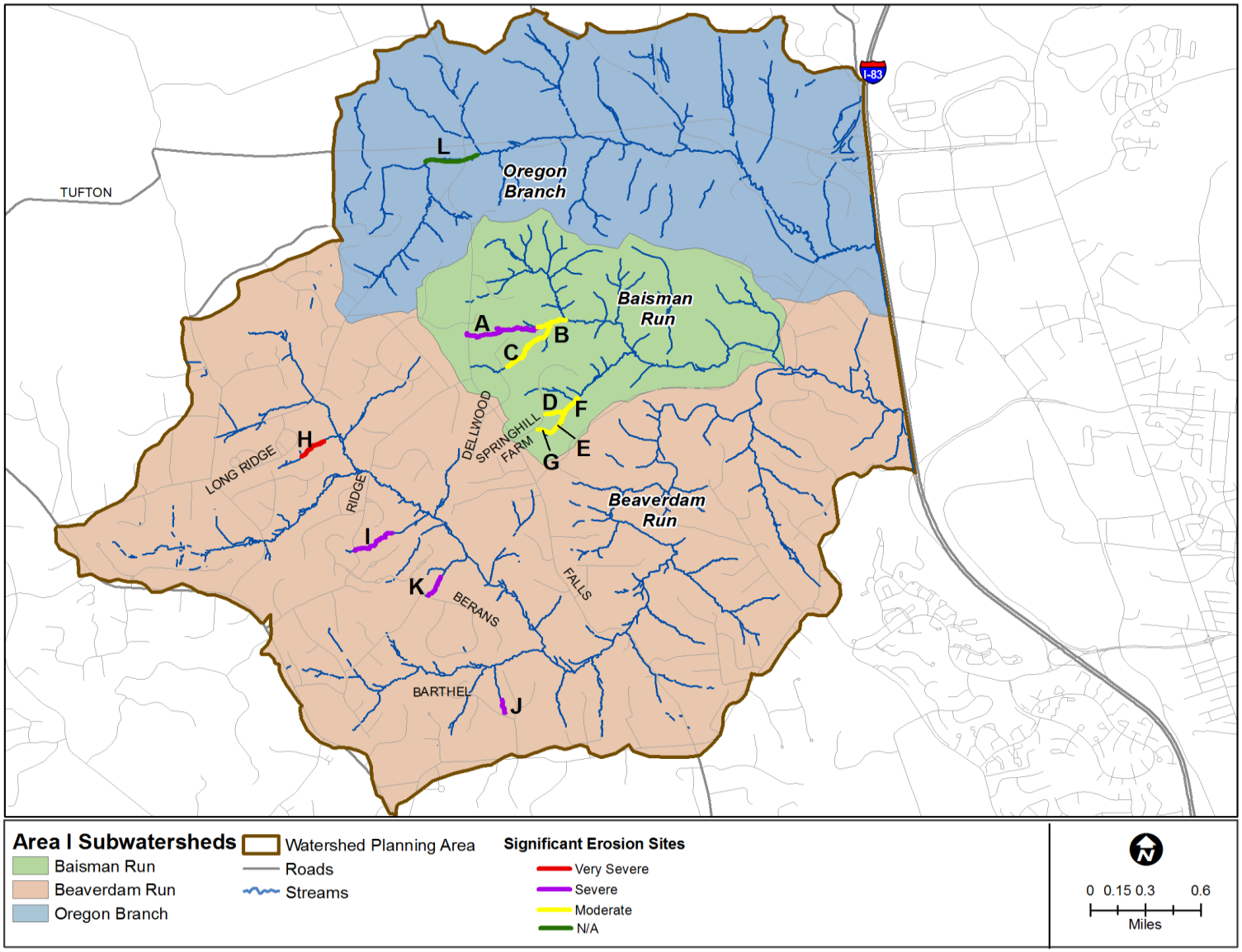


Figure 3-29: Area I Subwatersheds, Significant Erosion Sites

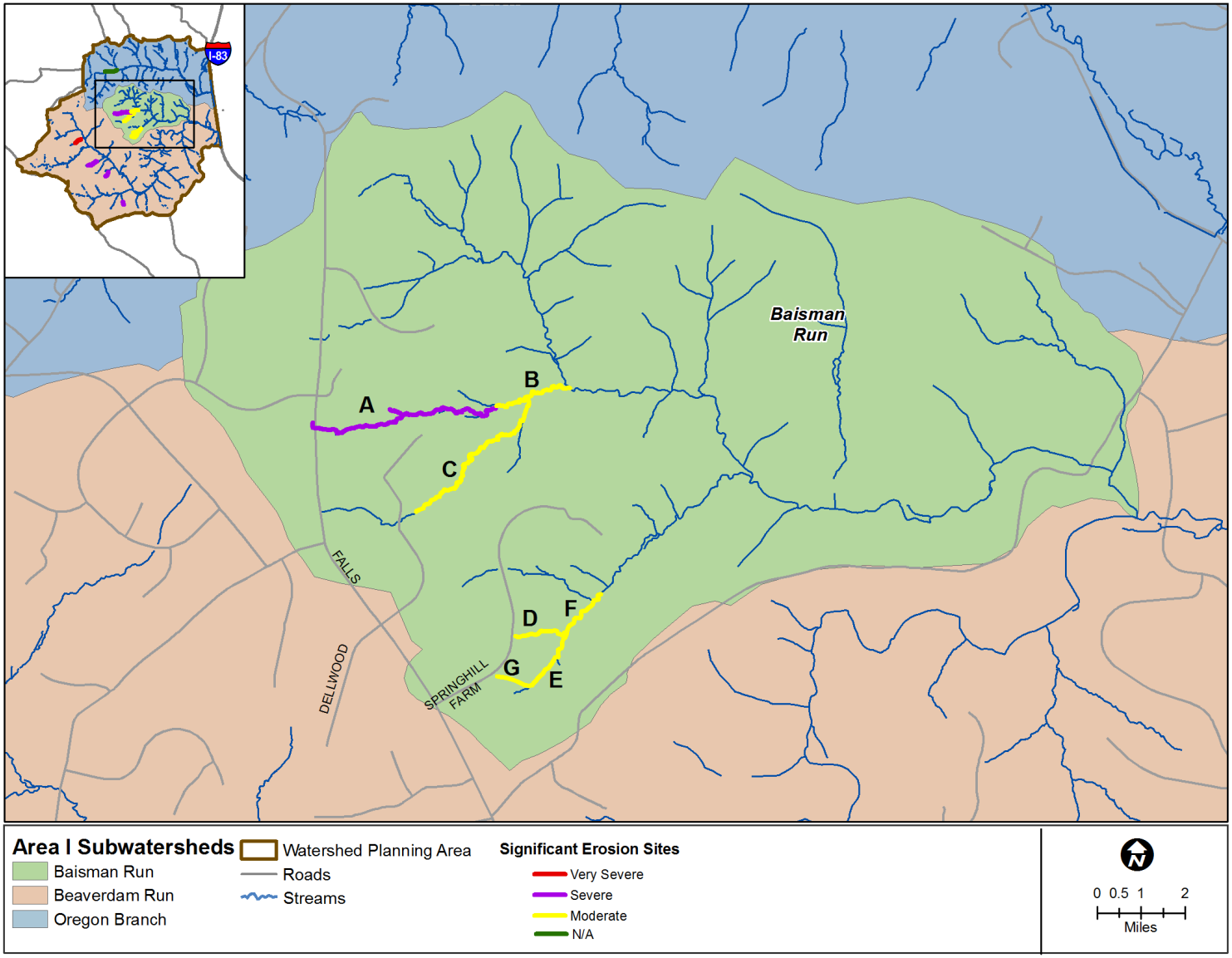


Figure 3-30: Baisman Run Subwatershed, Significant Erosion Sites

3.7 Stormwater Management Facilities

Existing SWM facilities within the Area I watershed were investigated for potential conversion to water quality management facilities. As discussed in Chapter 2.3.6.2, there are a total of 73 SWM facilities that have been built in the Area I watershed according to Baltimore County EPS database. These include dry and wet ponds, extended detention ponds, filtration and infiltration systems, proprietary systems, and wetlands (Table 2-14 and Figure 2-12). Approximately 78 percent of the SWM facilities in the watershed (57 out of 73) are either filtration/infiltration practices or extended detention facilities. These practices are considered to have higher pollutant removal capabilities, since stormwater has a chance to infiltrate into the ground or through plant roots, compared to conventional SWM techniques which are designed for quantity control without water quality improvement features.

Of the 73 existing SWM facilities, there are five dry detention ponds which are typically designed to address water quality only (flood control) and therefore, provide almost no pollutant removal. Dry ponds have the greatest potential for conversion to a type of facility that provides water quality benefits in addition to quantity control. The County EPS assessed the five dry detention pond facilities for their potential to be converted to an extended detention facility or other practice that provides greater water quality benefits. Dry extended detention ponds are designed to capture and retain stormwater runoff from a storm for a minimum duration (e.g., 24 hours) to allow sediment and pollutants to settle out while also being able to provide flood control if additional storage is incorporated into the design. The locations of the five dry detention ponds assessed in Area I are shown in Figure 3-31. Table 3-37 summarizes the available information for each dry detention pond obtained from Baltimore County EPS database including structure location, ownership, design capacity (i.e. drainage area, and storm event such as 2-year or 10-year storm), as-built date, and riser and barrel characteristics.

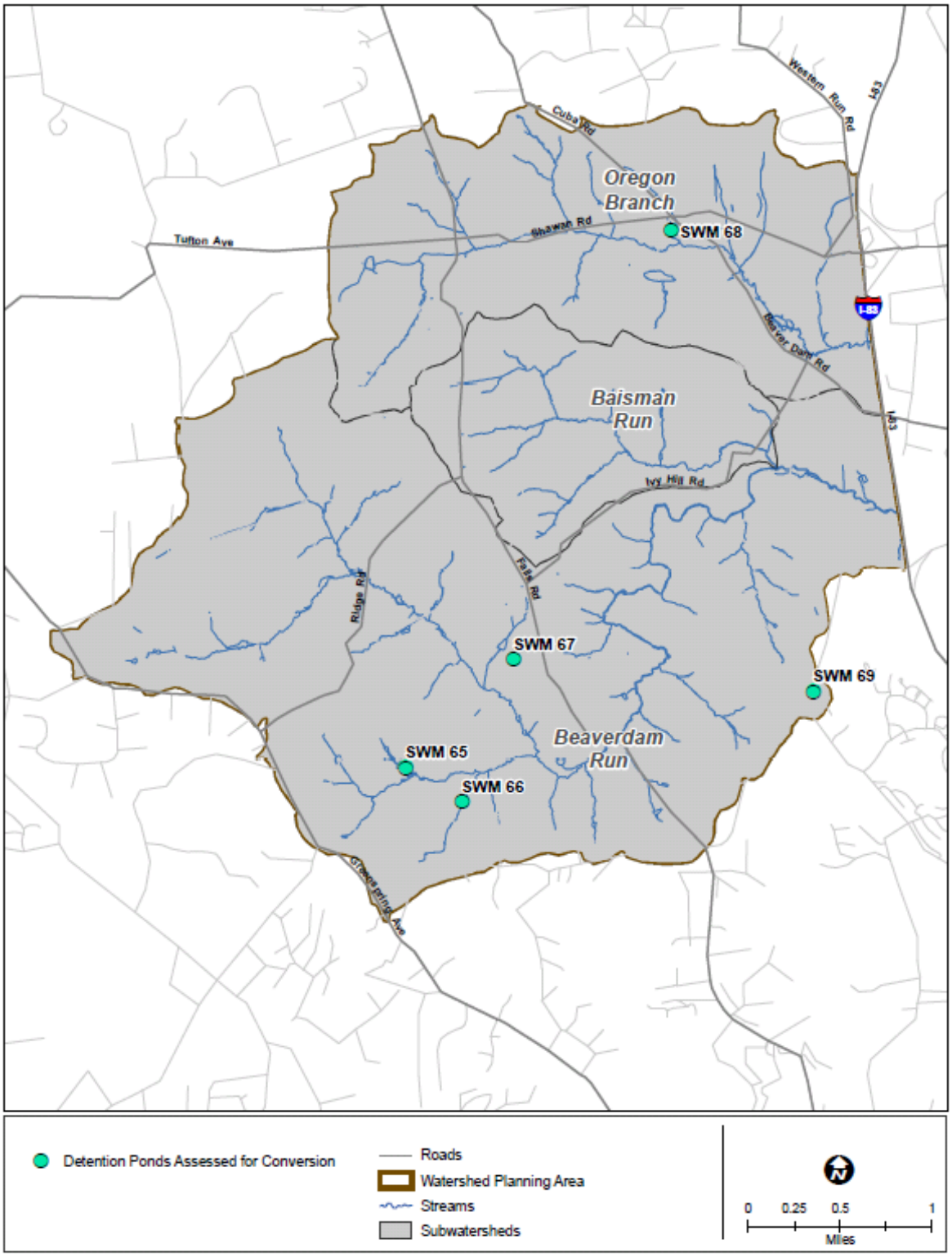


Figure 3-31: Dry Detention Ponds Assessed for Conversion in Area I

Table 3-37: Dry Detention Pond Information from Baltimore County Database

County Structure No.	Subwatershed	Structure Name	Nearest Road	Ownership
SWM-65	Beaverdam Run	The Woods (Built)	Harmony Woods Road	Public
SWM-66	Beaverdam Run	Broadridge Section 2	Barthel Road	Public
SWM-67	Beaverdam Run	Heather Hill	Falls Road	Private
SWM-68	Oregon Branch	Oregon Ridge Aka Kurtz Store	Beaver Dam Road	Private
SWM-69	Beaverdam Run	Padonia Farms	Cleghorn Road	Public

County Structure No.	Drainage Area (acres)	Pond Design (storm event)	Pond As-built	Pond Riser
SWM-65	43.56	2,10,100	No Date	Corrugated Metal Pipe
SWM-66	173.30	2,10,100	10/7/1987	Concrete Headwall (in-stream) with weir wall
SWM-67	21.49	2,10,100	No Date	Concrete box with weir overflow
SWM-68	3.02	2,10	No Date	Concrete riser structure with a metal rail
SWM-69	19.11	2,10,100	6/8/1993	Concrete

Information was collected in the field to assess the existing conditions and conversion potential of each dry detention pond in Area I. The field data findings are summarized in Table 3-38. This information was used as ranking criteria to score the ponds (Table 3-39).

Table 3-38: Stormwater Pond Field Findings

SWM ID	Field Pond Type	Pond Ownership	Drainage Area (Acres)	Pond Online	Accessibility	Flow Routing	Bottom Vegetation	Riser	Adj. Land Use	Conversion Factor
SWM-65	DP	Public	43.6	Yes	Difficult	Long	Wetland	Damaged	FOR	Good
SWM-66	DP	Public	173.3	Yes	Moderate	Long	Wetland, Trees	Good	FOR	Poor
SWM-67	DP	Private	21.5	No	Easy	Short	Grass	Good	RES	Good
SWM-68	DP	Private	3.0	No	Easy	Short	Grass	Good	COM	Good
SWM-69	DP	Public	19.1	No	Easy	Short	Grass	Good	RES	Good

Table 3-39: Stormwater Pond Ranking

SWM ID	TotalScore	Pond Ownership	Drainage Area	Pond Online	Accessibility	Flow Routing	Bottom Vegetation	Riser	Adj. Land Use	Conversion Factor
SWM-65	10	5	4	-10	1	1	-2	5	1	5
SWM-66	0	5	5	-10	3	1	-1	1	1	-5
SWM-67	22	1	4	5	5	-5	5	1	1	5
SWM-68	23	1	1	5	5	-5	5	1	5	5
SWM-69	25	5	3	5	5	-5	5	1	1	5

The results of the application of the ranking methodology are presented in Table 3-40. A higher total score represents a higher ranking that indicates a more feasible pond conversion. The table presents the ownership, drainage area to the facility, total score, rank and the subwatershed that the pond is in. Four of the five dry detention ponds assessed were identified for conversion to a SWM practice that provides greater water quality treatment. SWM-65 and 69 were identified as having potential to be converted to wetlands, and SWM-67 and 68 have the potential to be converted into bioretention systems. Each assessed dry pond is described briefly below including site photos.

Table 3-40: Potential Conversions of Dry Ponds to Improve Water Quality

Pond Number	Ownership	Acres	Total Score	Rank	Subwatershed
SWM-69	Public	19.1	25	High	Beaverdam Run
SWM-68	Private	3.0	23	High	Oregon Branch
SWM-67	Private	21.5	22	High	Beaverdam Run
SWM-65	Public	43.6	10	Medium	Beaverdam Run
SWM-66	Public	173.3	0	Low	Beaverdam Run

SWM-65 (Harmony Woods Road & Running Brook Court: ADC 17-H9)

This facility was constructed as a dry detention pond, and is located within a wooded area bounded by single family residences (Figure 3-32). Access to this facility is poor. This facility was constructed instream, and has a drainage area of 43.6 acres, based on existing mapping. Over time, the facility has developed a permanent pool with wetland characteristics. Some water quality treatment is being provided by the facility; however, the amount of this treatment is unclear. The facility is in immediate need of substantial maintenance and/or retrofit. Currently, the corrugated metal pipe riser is leaning substantially, and will eventually collapse. This will likely result in significant damage to the embankment, and could promote the washout of fill material. No sinkholes resulting from a failing spillway barrel were noted at the time of investigation. A great many trees, approximately 8 inches in diameter were noted along both the upstream and downstream sides of the embankment. Recommendations for this facility include making immediate repairs to the riser, slip lining and/or replacing the barrel, removing the woody vegetation from the embankment, and investigating the hydraulics of the facility to determine if capacity and freeboard are adequate. If the hydraulics are found to be acceptable the retrofit should include permanent conversion to a wetland. Some room is available upstream of the facility for excavation for additional storage volume; however, this will impact some existing forested wetlands and may not be justifiable.

Figure 3-32: Detention Pond SWM-65 (*Harmony Woods Road & Running Brook Court*)

SWM-66 (Barthel Road: ADC 17-H10)

This dry detention pond is located within a wooded area bounded by single family residential development and Barthel Court (Figure 3-33). This facility is instream, and has a drainage area of 173.3 acres, based on existing mapping. The control structure consists of a large concrete headwall, with attached weir wall on the upstream side of a corrugated metal culvert. The weir wall has a vertical opening to allow lower flows to pass through the structure. Currently, the vertical opening is partially clogged, resulting in a stream channel elevation approximately eighteen inches higher than the culvert invert, creating a fish migration blockage. Some aggradation within the floodplain appears to have occurred immediately upstream of the weir; however, the upstream channel appears to be incised. Removal of the blockage will exacerbate the upstream channel incision. There is little opportunity within this facility for conversion to a water quality facility. Current regulations discourage construction of instream facilities, and approval may be difficult. Impact to adjacent wetlands and forested areas would be substantial during any conversion. Efforts should focus on correcting the fish passage problems and stabilizing the upstream channel. The channel downstream of the culvert appeared relatively stable.

Figure 3-33: Detention Pond SWM-66 (*Barthel Road*)

SWM-67 (Heather Hill Lane: ADC 17-J8)

This facility is an existing dry pond with two primary inflows, consisting of riprap channels flowing from either side along the toe of the embankment (Figure 3-34). Roof leaders are tied into the facility along the back slope. The existing riser structure is a concrete box with a weir overflow. The principal spillway is a corrugated metal pipe, and an emergency spillway exists. The facility is in good condition; however, significant groundhog activity is present along the pond side slopes, and minor activity is present within the embankment. The low flow channels are short-circuiting the pond by providing a shortened flow path. Recommendations for this facility include removal of the riprap channels, and the addition of plunge pools to reduce velocities from the inflow pipes. Low flow berms to increase the flow path may be appropriate for this facility. Conversion of the facility to either a modified sand filter or bioretention is recommended. Because both of these proposed facility types require an underdrain, the feasibility of tying these into the existing riser structures should be investigated. Additionally, the groundwater elevation should be investigated to ensure that excavation within the facility is feasible.

Figure 3-34: Detention Pond SWM-67 (*Heather Hill Lane*)

SWM-68 (Oregon Grille, Kurtz Lane: ADC 18-B2)

This existing dry pond is located adjacent to Kurtz Lane, receiving approximately three acres of drainage from the Oregon Grille parking lot (Figure 3-35). The facility is privately-owned. It has a concrete riser structure with a metal rail for debris. The CMP principal spillway discharges into an existing stream channel on the far side of Kurtz Lane. The areas adjacent to the facility are grassed open space, allowing for the expansion of the stormwater facility if necessary. Recommendations for this facility include the installation of a trash rack on top of the existing riser structure, and conversion of the facility to bioretention. The invert of the stream channel is at the approximate elevation of the corrugated metal pipe principal spillway outfall, which could be an indication of high groundwater. Additionally, the stream channel invert will make lowering the principal spillway difficult; therefore, any underdrain associated with a bioretention facility will have to be tied into the existing riser.

Figure 3-35: Detention Pond SWM-68 (*Oregon Grille, Kurtz Lane*)

SWM-69 (Cleghorn Road: ADC 18-D8)

An existing dry detention pond is located adjacent to Cleghorn Road near West Padonia Road (Figure 3-36). This facility has two primary inflows: one is a small storm drain receiving primarily roadway drainage, and the other is a swale receiving drainage from the residential community south of the pond. Both inflows are located in close proximity to the existing concrete riser structure, and are likely short-circuiting the majority of the pond. Existing roadway inlets tie directly into the principal spillway barrel, bypassing the facility. The embankment, riser, inflows, and principal spillway appear to be in good condition. Recommendations include providing low-flow berms between the inflows and the riser to increase these flow paths. It is likely not feasible to route the drainage from the inlets bypassing the pond; however, inlets could be installed on both sides of the road upstream of these inlets to capture the currently untreated roadway drainage before it reaches these inlets. The new drainage system should tie into the pond near the swale inflow. On the north side, an existing inlet is draining to the facility. An additional inlet should be placed on the other side of the roadway to collect drainage along the curb before it reaches the inlets bypassing the facility. Drainage entering the new inlet should be tied into the existing inlet for discharge into the facility. A geotechnical investigation should be conducted to determine the groundwater elevation. If groundwater is not in close proximity to the facility, water balance calculations should be performed to determine if a shallow wetland is feasible within the facility. The shallow wetland could be excavated to prevent reduction in detention volumes.

Figure 3-36: Detention Pond SWM-69 (*Cleghorn Road*)

CHAPTER 4.0
Uplands Assessment

4.1 Introduction

Upland areas in the watershed were assessed to locate potential pollution sources that could influence water quality and to identify opportunities for restoration projects. This assessment was conducted according to the Unified Subwatershed and Site Reconnaissance (USSR) Manual developed by CWP (CWP, 2004). This manual provides detailed guidance for watershed groups, municipal staff and consultants to quickly identify major sources of stormwater pollution and to assess restoration potential for source controls, pervious area management and improved municipal maintenance (e.g., education, retrofits, street sweeping, open space management, etc.).

This chapter outlines the four major components of the USSR:

- Neighborhood Source Assessment (NSA)
- Hotspot Site Investigation (HSI)
- Institutional Site Investigation (ISI)

Each of these components is described in detail in the following sections. Site locations use the following naming convention: 'XYZ-I-123' where 'XYZ' is the type of assessment (NSA, HSI, or ISI), 'I' designates the Study Area I and '123' is the sequential number assigned to each field site investigated.

4.2 Neighborhood Source Assessment

4.2.1 Assessment Protocol

Prior to conducting NSAs in the field, neighborhoods were delineated in the office using GIS data, including tax parcels and aerial photographs. Neighborhoods were delineated based on groups of homes with similar characteristics such as lot size and age of development. These neighborhoods were then verified in the field. Adjustments to neighborhood boundaries were made as necessary in the field, either through grouping or dividing neighborhoods. If NSA boundaries were modified in the field, an additional letter was added at the end of the NSA naming convention.

The field team drove through every street in each defined neighborhood to identify potential pollution sources and restoration opportunities. General information was collected in each neighborhood for yards and lawns; driveways, sidewalks, and curbs; rooftop runoff; and common areas. These are each described briefly below. Stream buffer encroachment in neighborhoods is covered with the Stream Corridor Assessments in Chapter 3 (section 3.6.3.1.6 Inadequate Stream Buffers).

Yards and Lawns

In suburban residential areas, lawns typically represent a large portion of the pervious cover and can be a major source of pollutants such as pesticides and nutrients. Potential pollution sources evaluated by field teams under this category include grass cover and management status (i.e. fertilization and irrigation methods), bare soils, swimming pools and trash in yards. Existing tree cover and landscaping in each neighborhood was also noted to evaluate the potential to expand these areas to intercept additional stormwater runoff.

Driveways, Parking Lots, Sidewalks and Curbs

The presence of driveways, sidewalks and curbs was noted for each neighborhood assessed. Information was collected for potential or existing pollution sources from these areas such as stained or dirty driveways, lawn clippings or leaves on sidewalks, pet waste, trash and/or debris along curbs and long term car parking (i.e. unused cars can potentially leak oil and other pollutants).

Rooftops

Rooftops that are directly connected to other impervious surfaces through downspouts can contribute pollutants directly to stream systems. Disconnecting rooftops through downspout retrofits can reduce this potential source of pollution. In each neighborhood field teams estimated the percentage of downspouts discharging to impervious surfaces and evaluated the potential for implementing downspout retrofits.

Common Areas

Common areas within neighborhoods and in public parks are a good place to evaluate community behaviors such as pet waste disposal, trash dumping, storm drain marking, and buffer management. If present, stormwater management ponds are generally located in common areas (see section 4.2.3). Field teams noted the condition of common areas, the activities occurring there that could be a potential source of pollution, and opportunities for tree plantings.

Upon completion of the Neighborhood Source Assessments, specific actions were identified based on the overall assessment. The plan guides homeowners, community associations, watershed associations, and the local government toward specific actions where they are most needed. Potential actions generally include:

- Downspout disconnection
- Rain gardens
- Rain barrels
- Fertilizer reduction/education

- BayScaping
- Storm drain marking
- Street tree planting
- Trash management
- Multi-family parking lot or alley retrofit

Once all of the above neighborhood information was compiled, the final step of the NSA was to rate the overall neighborhood pollution severity and restoration potential. The severity of pollution generated by a neighborhood is denoted by the Pollution Severity Index (PSI). There are up to 17 potential pollution sources rated. Neighborhoods are given PSI ratings of severe (10 or more sources), high (5 to 10), moderate (1 to 5), or none (0).The neighborhood's potential for restoration projects is also rated with the Restoration Opportunity Index (ROI) in a similar fashion, with a ten potential opportunities, These are assigned a rating of high (5 or more), moderate (3 to 5), or low (1 or 2).

4.2.2 Summary of Sites Investigated

A total of 27 neighborhoods were assessed in Area I, as shown on Figure 4-1. The number of neighborhoods assessed in each subwatershed is shown on Table 4-1. Several neighborhoods cross subwatershed boundaries; in cases where there is a substantial area in more than one subwatershed it is counted in each subwatershed in which it falls. This resulted in a total of 34 unique neighborhoods by subwatershed.

Of the 27 neighborhoods in Area I, none were rated as having a severe PSI. Three were rated high and the other 24 neighborhoods received moderate PSI ratings. Two neighborhoods received high ROI ratings, 22 were rated moderate, and three had low ROI ratings. Neighborhoods should be prioritized to first address areas with both high PSI and high ROI ratings, followed by other neighborhoods. There were three neighborhoods that received high PSI ratings and either a high or moderate ROI rating. The majority of neighborhoods received moderate PSI and moderate ROI ratings. The distribution of the NSA ratings is shown on Figure 4-2.

Table 4-1: Neighborhoods Surveyed per Subwatershed

Subwatershed	# of NSAs	Acres
Baisman Run	3	1,056.0
Beaverdam Run	24	4,984.6
Oregon Branch	7	2,309.4
Total*	**34**	**8,350.0**

* Neighborhoods that cross subwatershed boundaries are counted more than once.

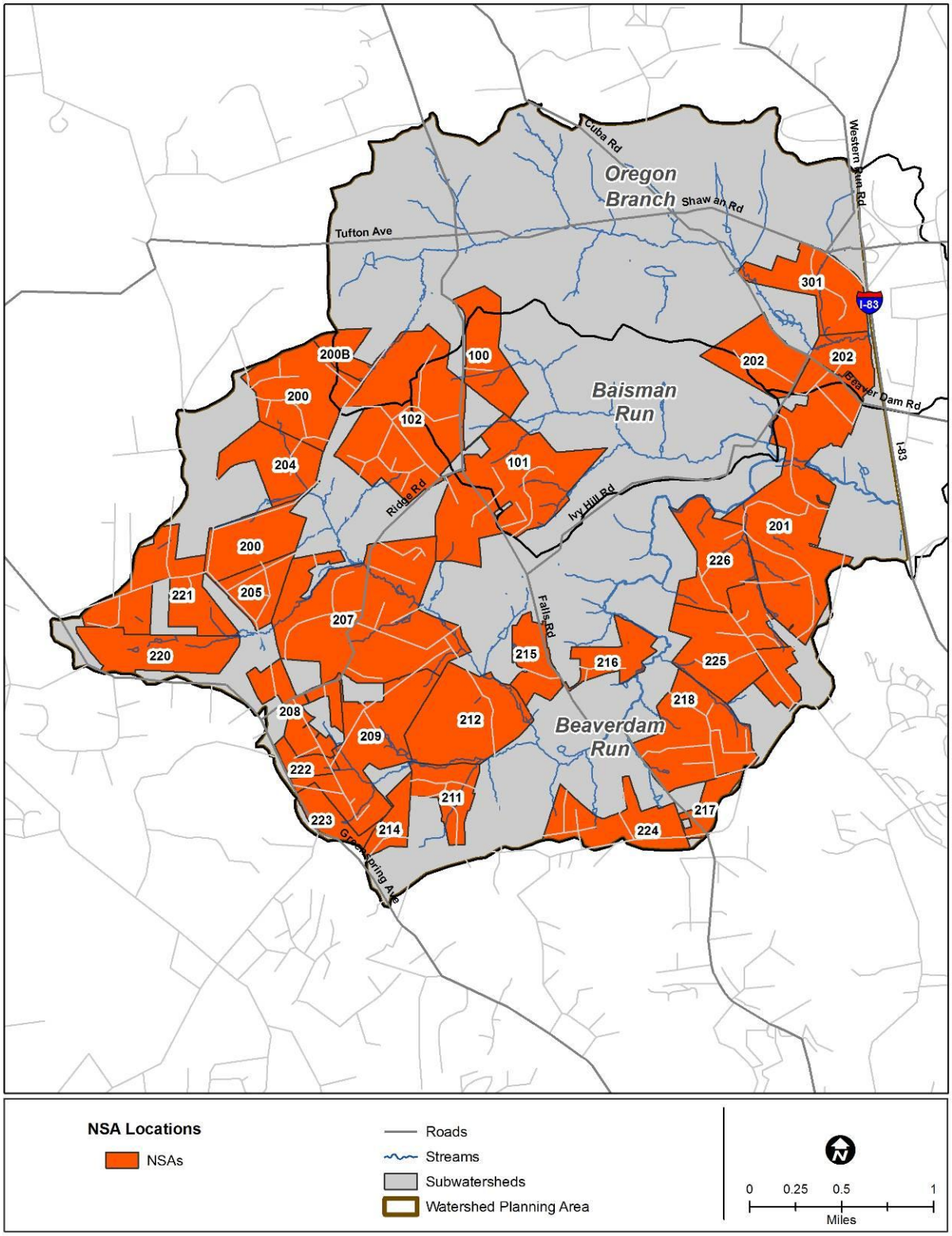


Figure 4-1: Neighborhood Source Assessment (NSA) locations in Area I

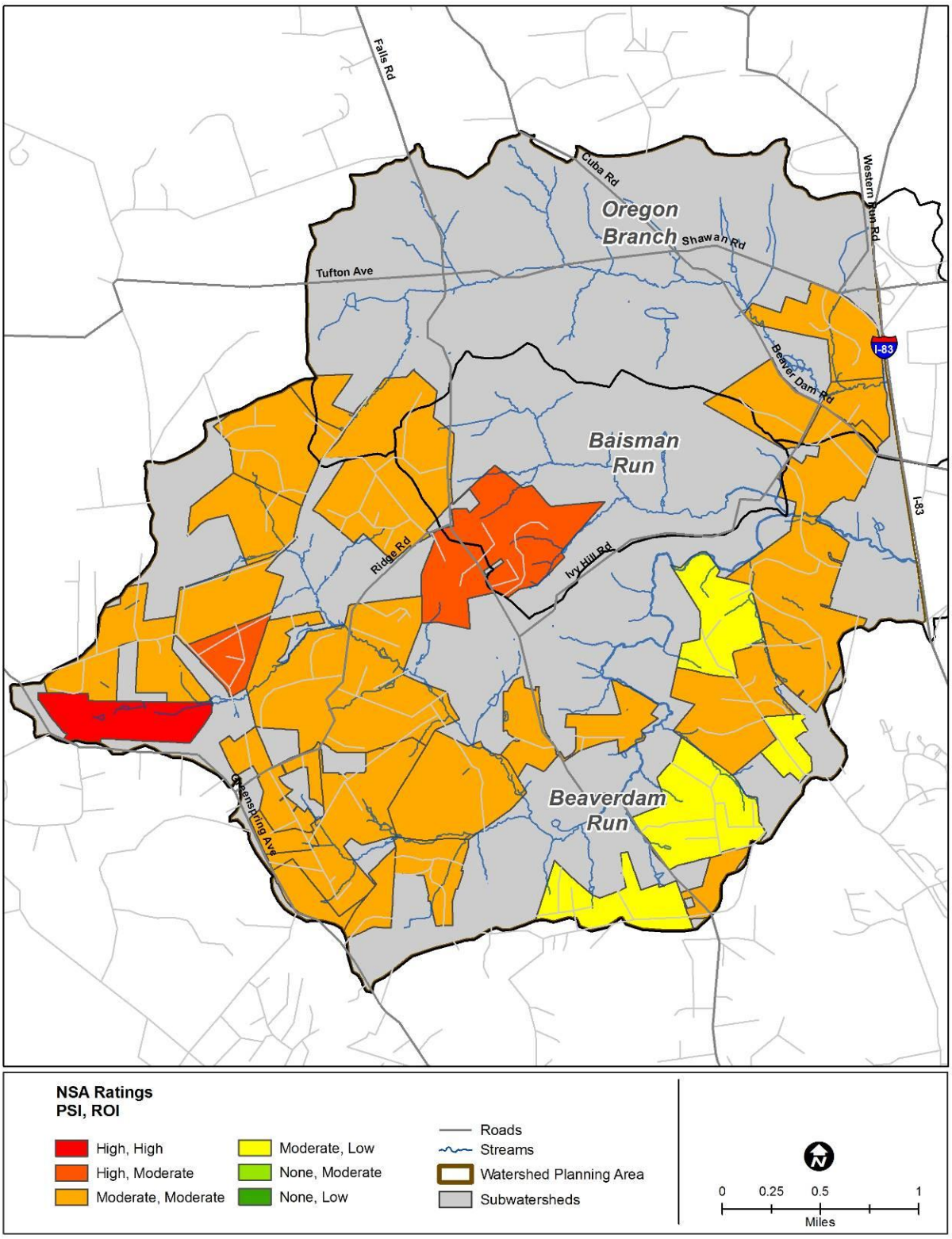


Figure 4-2: NSA Pollution Severity and Restoration Opportunity Indexes

4.2.3 General Findings

The following sections describe the actions for Area I based on the NSA results. A description of the methods and criteria used to evaluate the potential for each action are provided, in addition to figures that show the neighborhoods in which each action is recommended. Due to the low level of development in Area I, actions such as street tree planting, street sweeping, and trash management identified for other Small Watershed Action Plans were not relevant. Street trees were not appropriate for Area I given the lack of sidewalks and limited right of way beyond the edge of pavement. More effective methods of adding canopy cover such as bayscaping and increasing lot canopy are suggested. Area I also had very few problems with trash or litter in the public right-of-way, so street sweeping and trash management weren't recommended. Appendix L includes a summary of NSA data collected and the actions needed for each individual neighborhood. Figure 4-3 illustrates typical neighborhood conditions for Area I.

Figure 4-3: Typical example of large lot residential development in Area I

Fertilizer Reduction/Education

Lawn maintenance activities often involve over-fertilization, poor pest-management, and over-watering. Lawns with a dense, uniform grass cover or signs designating application of lawn chemicals indicate high lawn maintenance activities. The result is often polluted stormwater runoff that drains to local streams. The lawn care assessment was conducted in the summer.

Neighborhoods where 20 percent or more of the homes employ high lawn maintenance practices are identified for a fertilizer reduction/education program. Table 4-2: summarizes the number of neighborhoods identified for fertilizer reduction and the acres of lawn addressed if this were implemented. The acres of lawn addressed are based on the percentage of high maintenance lawns present in each neighborhood for which fertilizer reduction is identified. Table 4-2: also lists the percentage of total subwatershed area that would be addressed by this practice. The area treated in each neighborhood is based on the amount of lawn area. First, the lot area is found by taking the total acreage in each assessed neighborhood and subtracting out the acres of impervious roadway. This number is then multiplied by two factors estimated during the

NSA assessment; the average percentage of grass cover on each lot and the percentage of high maintenance lawns in the neighborhood area.

Table 4-2: Acres of Lawn Addressed by Fertilizer Reduction

Subwatershed	# of Neighborhoods Identified for Fertilizer Reduction	Acres of Lawn Addressed	% of Subwatershed Area Addressed
Baisman Run	3	191.5	18%
Beaverdam Run	22	1,148.8	23%
Oregon Branch	7	143.7	6%
Total	**32**	**1,484.0**	**18%***

* Percent of entire Watershed Area I

Figure 4-4: shows the locations of neighborhoods identified for fertilizer reduction/ education. Of the neighborhoods assessed, most had high percentages of high maintenance lawns, with almost half of the neighborhoods having 100 percent of the homes in that category. All but two of the neighborhoods are identified for fertilizer reduction/education. As shown on Table 4-2: , implementation of fertilizer reduction/education will only address 18 percent of the total area. This is due to a lower percentage of grass cover in a number of mostly wooded neighborhoods.

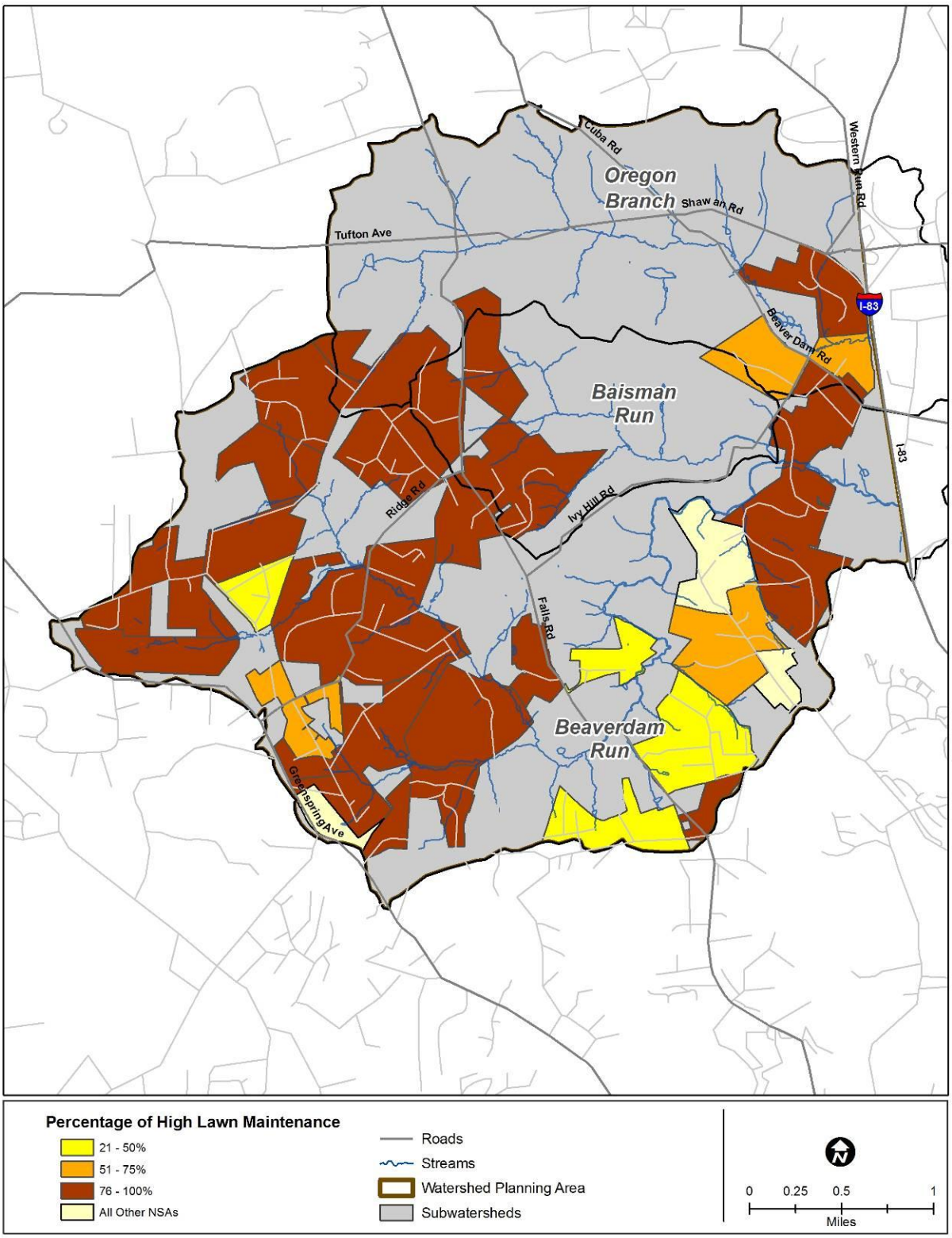


Figure 4-4: Percentage of high maintenance lawns in neighborhoods

BayScaping

BayScaping refers to the use of plants native to the Chesapeake Bay watershed for landscaping. Plants used in BayScaping are native to the region and therefore require less irrigation, fertilizers, and pesticides to maintain as compared to non-native or exotic plants. This means less stormwater pollution and lawn maintenance requirements.

BayScaping was identified for implementation in neighborhoods where the lots were at least ¼ acre in size, where less than 25 percent of the lots were already landscaped, and where there was sufficient open grass area available to implement BayScaping. All but three of the assessed neighborhoods met these criteria. Table 4-3: includes a summary of neighborhoods identified for BayScaping in each subwatershed and the total acres of land addressed. It also includes the percentage of total subwatershed area addressed. Area to be treated is based on the existing landscaped percentage of the lot, estimated during the NSA assessment. Lot area is found by taking the total acreage in each assessed neighborhood and subtracting out the acres of impervious roadway. This area is multiplied by the difference, in percent, between the target of 25 percent and the existing landscaped percentage. Figure 4-5: illustrates the location of the neighborhoods identified for BayScaping.

Table 4-3: Acres of Land Addressed by BayScaping

Subwatershed	# of Neighborhoods Identified for BayScaping	Acres of Land Addressed	% of Subwatershed Area Addressed
Baisman Run	3	59.7	6%
Beaverdam Run	21	404.3	8%
Oregon Branch	7	66.4	3%
Total	**31**	**530.4**	**6%***

* Percent of entire Watershed Area I

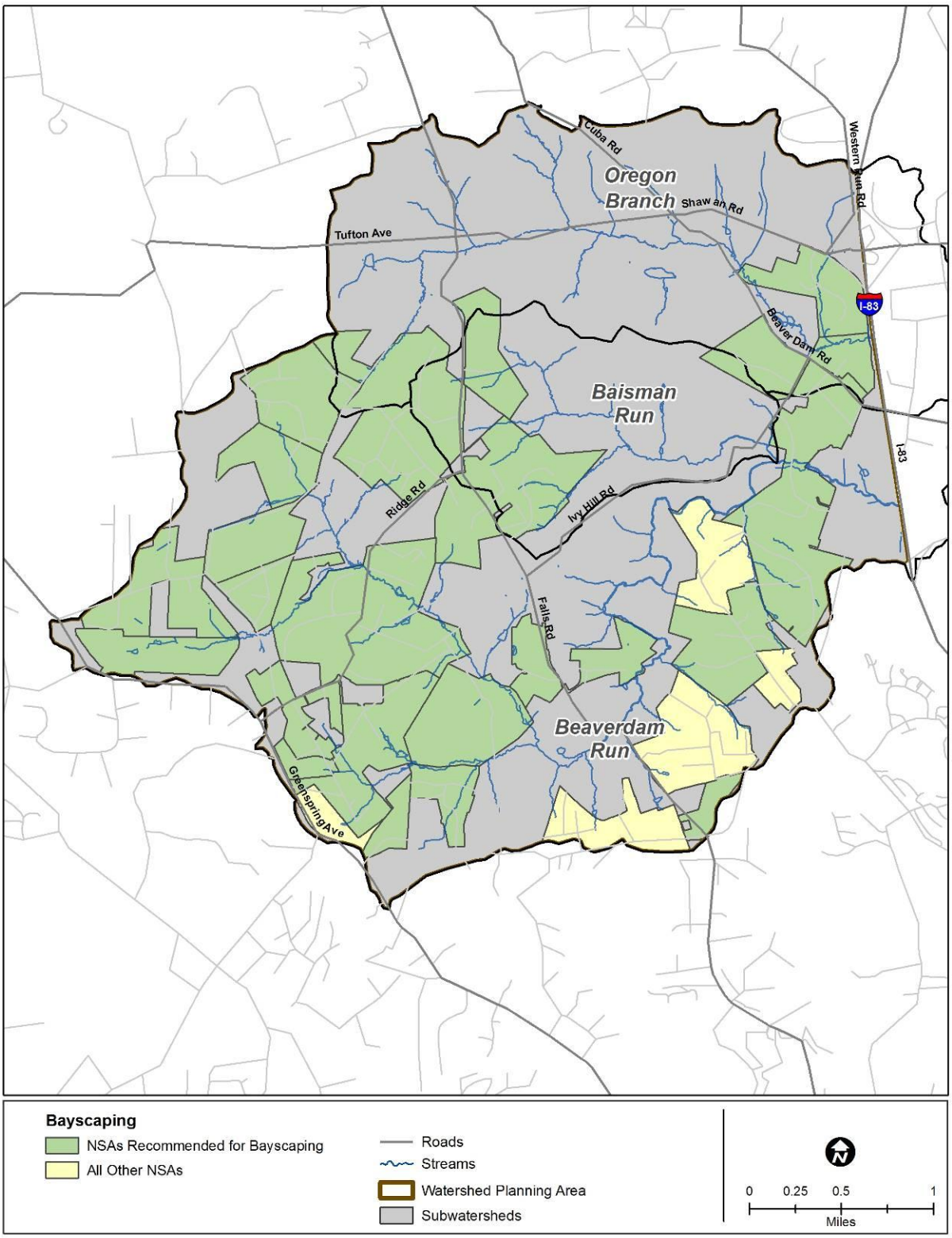


Figure 4-5: Neighborhoods identified for BayScaping

Storm Drain Marking

Most of the neighborhoods in Area I have roads with curb and gutter systems that include storm drain inlets that convey stormwater runoff quickly and directly to the stream system and ultimately to the Chesapeake Bay. None of the neighborhoods assessed had inlets with either stenciling or any other awareness indicator that the inlets drain untreated stormwater to Loch Raven Reservoir and the Chesapeake Bay. Storm drain marking indicates that the inlets drain to the Chesapeake Bay; this is a way to educate residents that anything collecting along the curbs and gutters such as trash and lawn clippings (potential for nutrient pollution) will be washed away after a storm event and end up in the nearest stream and eventually the Chesapeake Bay.

Neighborhoods recommended for storm drain marking have curb and gutter systems with inlets appropriate for marking. As shown in Table 4-4: , a majority of neighborhoods are recommended for storm drain marking. They are shown in Figure 4-6: . Area treated was calculated using the total area of each recommended neighborhood: streets, public and privately-owned lots, and common areas. The calculation of inlets to be marked was made by overlaying storm drain mapping with the NSA neighborhoods. All inlets draining to an outfall within a designated neighborhood were assumed to be candidates for marking. Because almost all of the storm drain network fell within the assessed areas, over 90 percent of the inlets in Area I were proposed to be marked.

Table 4-4: Acres of Land Addressed by Storm Drain Marking

Subwatershed	# of Neighborhoods Identified for Storm Drain Marking	Acres of Land Addressed	% of Sub-watershed Area Addressed	Approx # of Inlets Addressed	% of Sub-watershed Inlets Addressed
Baisman Run	3	317.4	32%	17	100%
Beaverdam Run	20	2,604.2	52%	123	91%
Oregon Branch	7	400.5	17%	28	90%
Total	**30**	**3,322.1**	**40%***	**168**	**92%**

* Percent of entire Watershed Area I

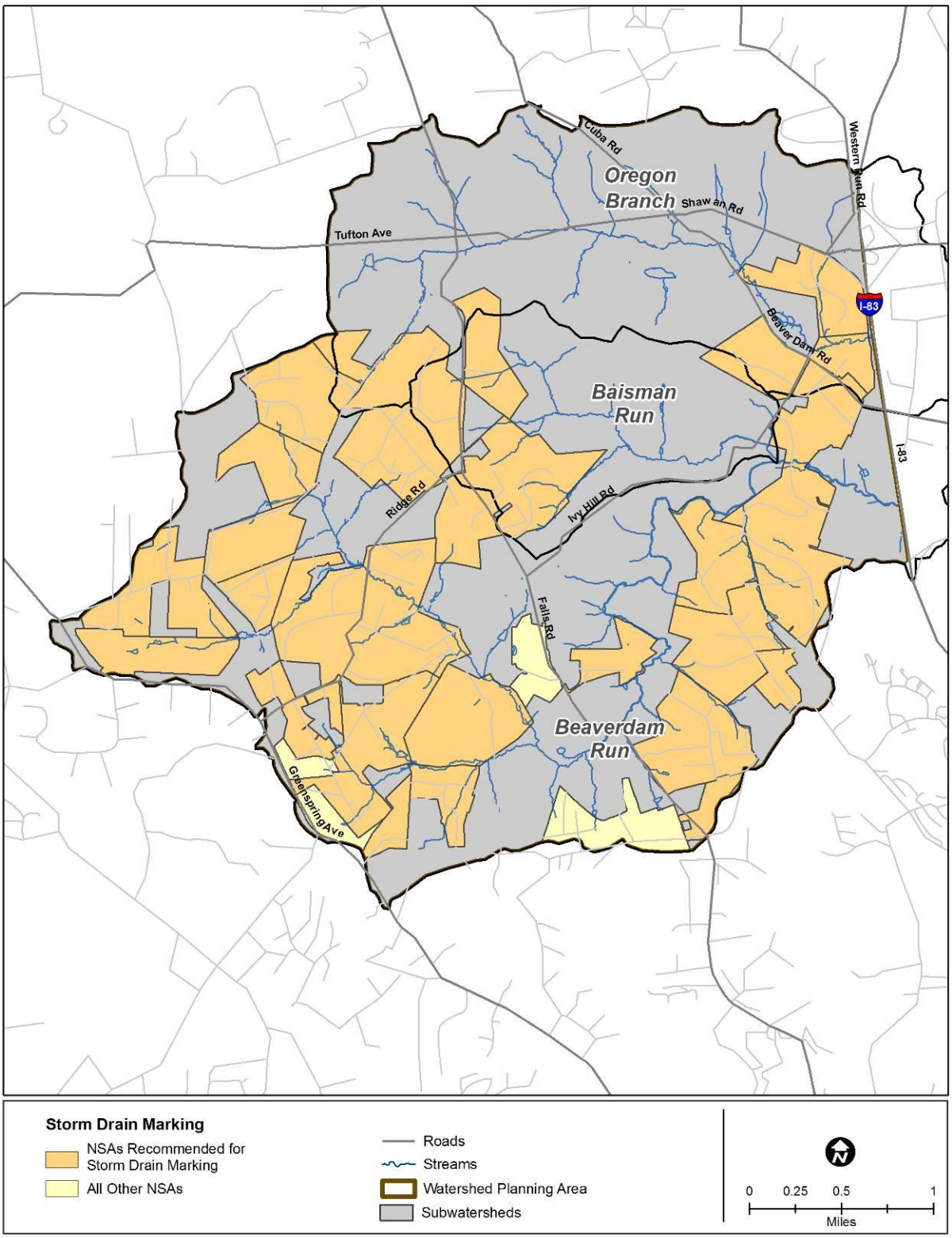


Figure 4-6: Neighborhoods identified for storm drain marking

Lot Canopy Improvement

Increasing the canopy cover in a watershed is an effective way of reducing runoff and peak flows, promoting infiltration to ground water, providing filtration for water quality, moderating the effect of summer heat spikes on stream temperature, and supplying food in the way of leaf litter for organisms at the base of the stream food web. Reforestation works with BayScaping and rain gardens to reduce the amount of lawn area and provide more terrestrial habitat in developed areas.

Outreach efforts to encourage canopy improvements were identified in neighborhoods where existing canopy coverage was less than 40 percent of the lot. All but six of the assessed neighborhoods met these criteria. Table 4-5: includes a summary of neighborhoods identified for canopy improvement in each subwatershed and the total acres of land addressed. It also includes the percentage of total subwatershed area addressed through implementation of canopy improvements. The area treated is based on the existing canopy cover of the lot, estimated during the NSA assessment. Lot area is found by taking the total acreage in each assessed neighborhood and subtracting out the acres of impervious roadway. This area is multiplied by the difference, in percent, between the target of 40 percent and the existing percentage of canopy cover. Figure 4-7: illustrates the location of the neighborhoods identified for lot canopy improvements.

Table 4-5: Acres of Land Addressed by Lot Canopy Improvement

Subwatershed	# of Neighborhoods Identified for Canopy Improvement	Acres of Land Addressed	% of Subwatershed Area Addressed
Baisman Run	3	59.8	6%
Beaverdam Run	20	345.4	7%
Oregon Branch	5	26.9	3%
Total	**28**	**432.1**	**6%***

* Percent of entire Watershed Area I

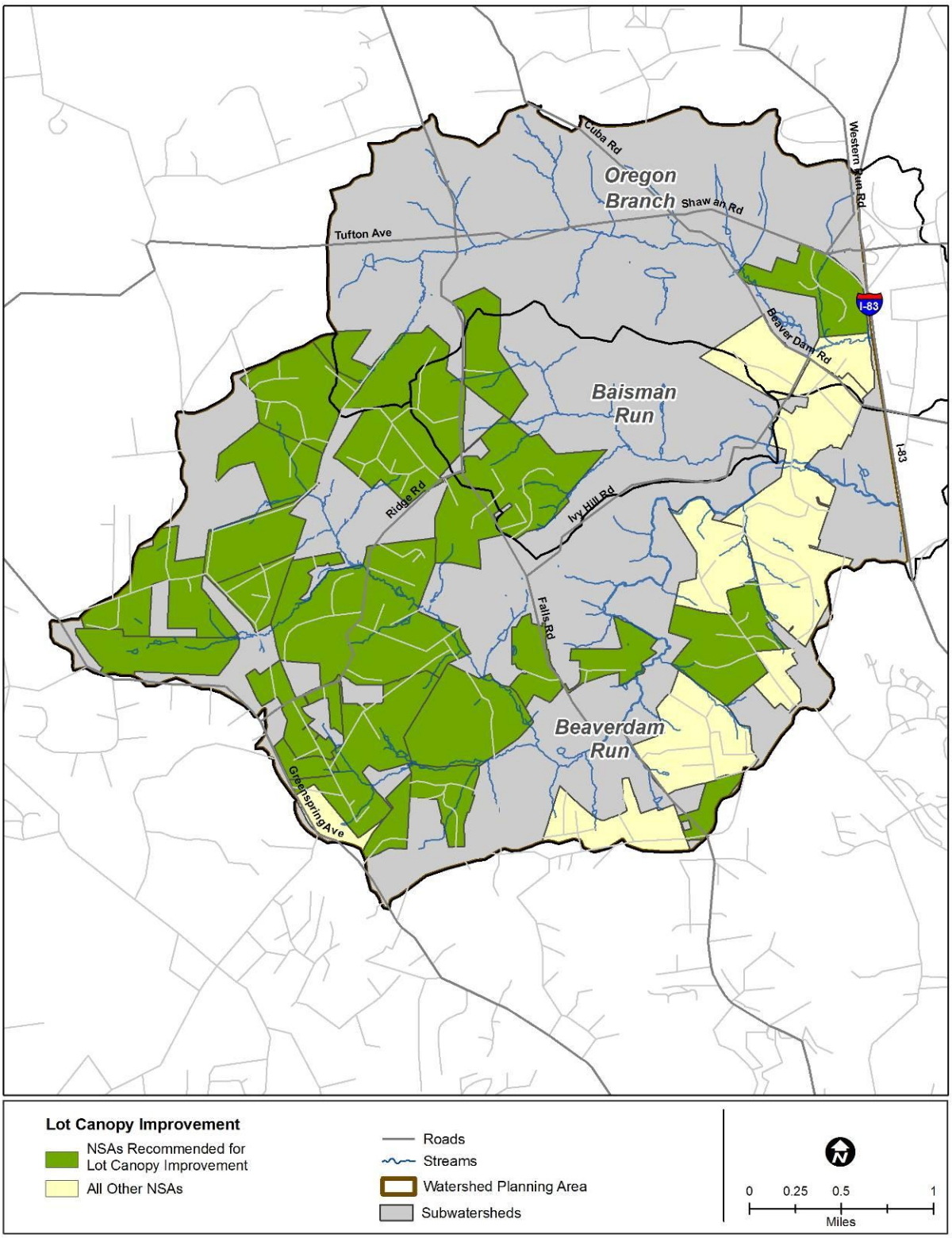


Figure 4-7: Neighborhoods identified for lot canopy improvement

Stormwater Retrofits

Potential sites for upland stormwater retrofits within the conveyance system were identified in several locations. Stormwater retrofits provide stormwater management in developed areas that do not currently have stormwater management. Conversion of grass ditches to wet or dry swales would provide water quality treatment in NSA_I_221, NSA_I_222 and NSA_I_301. This involves excavating at the roadside to install an underdrain and filter media, followed by topsoil and turf. A gravel area at the foot of Ridgemont Road in NSA_I_224 (

Figure **4-9**:) would provide a location for a retrofit that could treat the runoff from the upstream roadway and driveway impervious area. These could be designed as infiltration/filtration practices such as trenches, basins, or bioretention that incorporate vegetation and filter media through which storm water infiltrates for pollutant removal prior to groundwater recharge or entering the stream system. There are several potential sites for bioretention retrofits in cul-de-sacs (NSA_I_207 and NSA_I_209), roadway medians (NSA_I_207 and NSA_I_220) or at storm drain inlets (NSA_I_220).

The two swale retrofit sites are shown in

Figure 4-8: . The photo on the left is the swale conversion opportunity in Stanson (NSA_I_222), and the photo on the right shows Weil Mandell Way in NSA_I_301.

Figure 4-8: Potential swale retrofit opportunities in NSA_I_222 and NSA_I_301

Figure 4-9: Potential stormwater retrofit opportunities in NSA_I_224 and NSA_I_220

4.3 Hotspot Site Investigation (HSI)

Stormwater hotspots are areas that have potential to generate higher concentrations of stormwater pollutants than typically found in urban runoff and/or have a higher risk of spills, leaks, or illicit discharges due to the nature of their operations (CWP 2004). These generally include commercial, industrial, municipal, or transport-related operations. Stormwater pollutants generated as a result of hotspot operations depend on the specific site activities, but typically include nutrients, hydrocarbons, metals, chloride, pesticides, bacteria, and trash.

Commercial hotspots include a range of businesses and activities. Operations characteristic of commercial hotspots include waste or wash water generation, outdoor material storage, fuel handling, or vehicle repair. Common commercial hotspots include auto repair shops, car dealers, car washes, parking facilities, gas stations, marinas, garden centers, construction equipment and building material lots, swimming pools, and restaurants.

Industrial operations utilize, generate, handle, and/or store pollutants that can be washed off with stormwater, spilled, or mistakenly discharged into the storm drain. Many industrial hotspots are regulated under National Pollution Discharge Elimination System (NPDES) industrial discharge permits. Like industrial operations, many municipal hotspots are subject to NPDES stormwater permits. Many are regulated and include uses such as airports, ports, highway construction, and trucking centers.

The purpose of the HSI is to evaluate pollution potential from hotspot operations and identify potential restoration practices that may be necessary. The following subsections describe the methods used to identify and assess the hotspots in Area I.

4.3.1 Assessment Protocol

Because there are few operations in Area I that qualify as stormwater hotspots, it was possible to identify all the sites in the office through a desktop assessment. The HSIs were focused on unregulated hotspots since regulated hotspots are previously known pollutant sources. Regulated stormwater hotspots are already subject to NPDES permit regulations.

While hotspots have unique operations, drainage systems, and pollutant-related risks, stormwater quality problems can be characterized and evaluated by operations and activities common to most hotspots. The HSI provides an evaluation of six common operations at each potential hotspot: vehicle operations, outdoor materials, waste management, physical plant, turf/landscaping, and stormwater infrastructure. The field team walked the entire property of each potential hotspot to determine water quality impacts and restoration opportunities. These six categories were used to standardize the HSI process and be able to prioritize potential restoration efforts. These categories are described briefly below.

Vehicle Operations

Vehicle operations include maintenance, repair, recycling, fueling, washing or long-term parking. The presence of any of these activities was noted for each site since they can be a major source of metals, oil and grease, and hydrocarbons. Outdoor activities including vehicle storage, repair, fueling, and washing were also noted as potential pollution sources.

Outdoor Materials

Stormwater quality issues result from improper handling or storage of outdoor materials at hotspots. Locations where materials were loaded or unloaded were examined to see if they were uncovered and draining to a storm drain inlet. Storage areas were also evaluated for types of materials stored outdoors and their potential for entering the storm drain system. The field team looked for improperly labeled storage containers, lack of secondary containment for liquids, and whether the storage area was directly or indirectly connected to the storm drain system. If any of these were observed, they were marked as potential pollution sources.

Waste Management

Every hotspot generates waste as a result of daily operations that can be potentially hazardous or a source of stormwater pollution depending on the type of waste and how it is stored. The field team noted the type of waste generated (e.g., hazardous, garbage, etc.) and the condition of dumpsters. Dumpsters with no cover or open lids, with leaks, damaged/in poor condition, and/or overflowing were noted as potential pollution sources. Dumpsters located near storm drain inlets or lacking runoff diversion methods were also recorded as potential pollution sources.

Physical Plant

Common physical plant practices include cleaning, maintaining, or repairing the building, outdoor work areas, and parking lots. For each hotspot, the condition of the building itself was evaluated. Similarly, parking lots that were stained, dirty, breaking up, and/or impervious were recorded as potential pollution sources.

Turf/Landscaping

Ground maintenance activities for turf/landscaped areas were also evaluated at hotspot sites. High turf management and improper irrigation practices were noted since they are potential pollution sources of nutrients, fertilizer, and pesticides. The field team also determined whether landscaped areas drained directly to storm drains or if organics such as leaves and grass accumulated on impervious surfaces.

Stormwater Infrastructure

If stormwater treatment practices were not present, this was flagged as a potential pollution source. Private storm drains were also evaluated for pollution potential. Storm drains with considerable amounts of sediment, organics, and/or trash was identified as potential pollution sources.

For each operation on the HSI field form, there is an observed pollution source box that is checked when there is clear evidence of pollution problems at a site. One example would be trash spilling over the edges of the dumpster and directly into a local stream while the trash was being compacted. After walking the entire property and evaluating hotspot operations, one or more of the potential follow-up actions listed below were identified based on initial field observations:

- Refer for immediate enforcement
- Follow-up on-site inspection
- Test for illicit discharge
- Future education effort
- On-site non-residential retrofit

The overall pollution prevention potential for each hotspot site is assessed based on observed sources of pollution and the potential of the site to generate pollutants that would likely enter the storm drain network. There are up to 28 potential pollution sources rated in the assessment. Sites are classified into four hotspot severity categories:

- Low – no observed pollutant; less than 5 sources noted
- Potential– no observed pollution; five to ten sources noted
- Confirmed– pollution observed; 10 to 15 sources noted
- Severe– multiple polluting activities directly observed, more than 15 sources noted

4.3.2 Summary of Sites Investigated and General Findings

There were two hotspot candidates investigated in Area I, as shown on Table 4-6: . Both were commercial establishments (i.e. restaurants) investigated primarily for opportunities to improve waste management, parking areas, downspouts, landscaping or stormwater management. Both sites were rated low for severity. However, the sites could be improved by better waste management (i.e. dumpsters and grease traps at HSI_I_300) and adding rain barrels at downspouts (HSI_I_300). Additionally, a drain pipe was found flowing directly to the stream at HSI_I_300 with an unknown source. This should be investigated further and could be an additional improvement at this site. Figure 4-10 provides photos of the two hotspots and Figure 4-11: shows the locations of the two sites investigated in Area I.

Table 4-6: Summary of Hotspot Sites Investigated in Area I

Site ID	Type	Subwatershed	HSI Status
HSI_I_300	Commercial	Oregon Branch	Low Severity
HSI_I_301	Commercial	Oregon Branch	Low Severity

Figure 4-10: Opportunity for improved waste management at hotspot sites

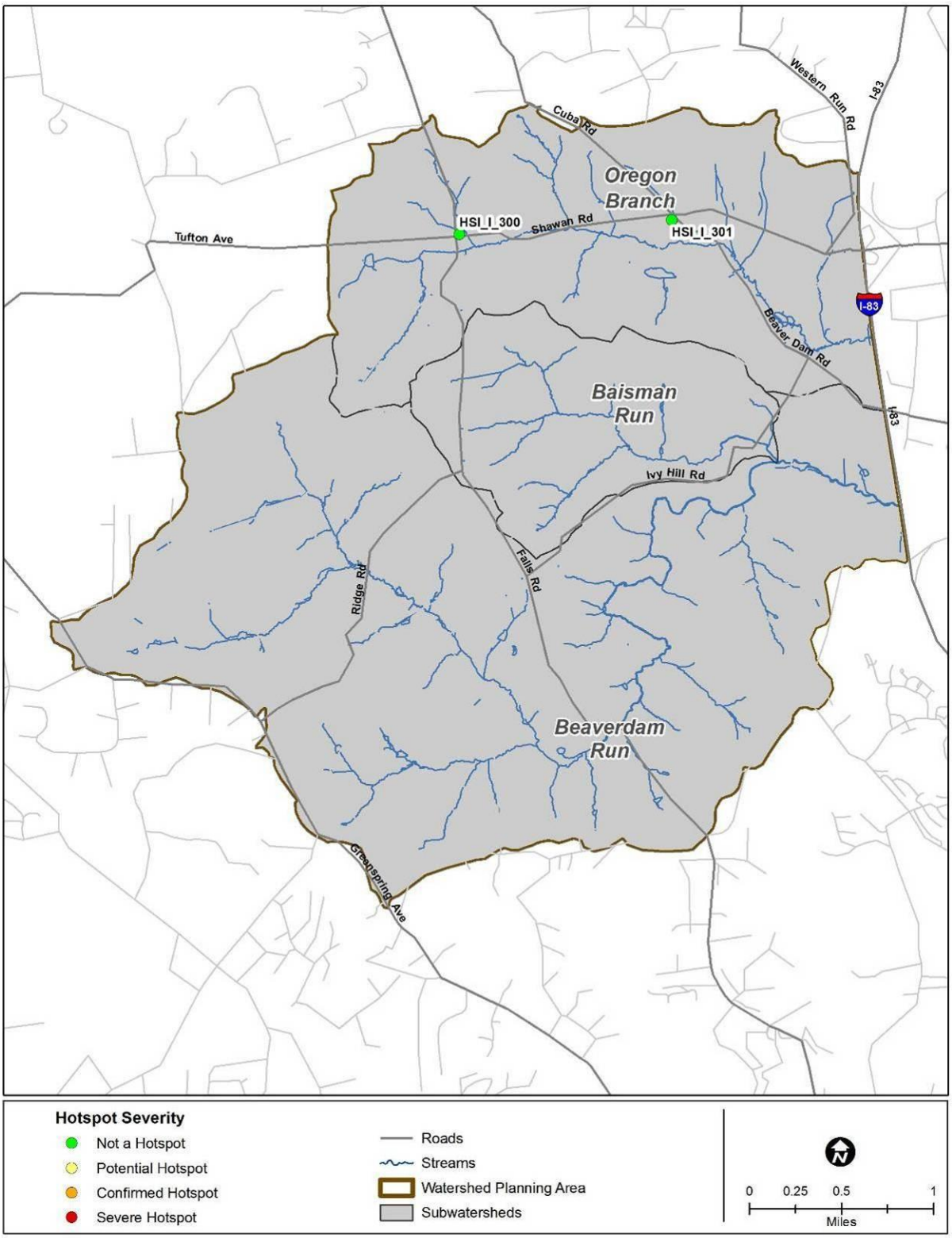


Figure 4-11: Locations of Hotspot Site Investigations (HSIs) in Area I

4.4 Institutional Site Investigations (ISI)

The USSR manual does not treat institutional sites as a separate component of the uplands survey; instead, institutions can be assessed using HSI protocols. Consistent with earlier SWAP projects, a modified version of the HSI field form was used to assess institutional sites since HSI protocols do not exactly match conditions encountered on institutional properties. The ISI method was first developed and implemented for the Upper Back River study and was also used for the Tidal Back River watershed. As there were few institutional sites within Area I, institutions surveyed as part of this study included faith-based facilities. The following subsections describe the methods used to identify and evaluate pollution sources and restoration potential at institutional facilities.

4.4.1 Assessment Protocol

Institutional properties were identified in the office prior to conducting the field assessment using GIS tax parcel information, land use data, aerial photographs, and an ADC map. In the field, sites were visited to collect necessary data and take photographs. The ISI field form includes many of the pollution source categories used on the HSI form that include an assessment of vehicle operations, outdoor materials, waste management, turf/landscaping areas, and stormwater infrastructure. Some of the restoration opportunities and actions from the NSAs are also incorporated into the ISI. The focus of ISIs is to identify potential restoration opportunities, educate the community, and provide water quality benefits. The information collected for each of the pollution sources and restoration categories is briefly described below.

Tree Planting

Potential tree planting locations at an institution were marked on aerial photographs while at the property. The total number of trees that could be planted at the site was estimated based on a 15- to 20-foot spacing between trees. More accurate numbers were determined during the post-fieldwork desktop analysis after restoration opportunities were selected and prioritized.

Exterior

The exterior category is similar to the physical plant category in the HSI, except it also includes restoration opportunities. The condition of the building(s) and parking lot(s) were noted. Stained, dirty, damaged/breaking up surfaces were noted as potential pollution sources for both of these components. If no stormwater management was provided for impervious parking areas, this was also considered as a potential pollution source. Exterior storm drain inlets were inspected for evidence of maintenance or wash water dumping and poor erosion/sediment control, cleaning, or material storage practices for construction activities. Any observations of staining, discoloration, or mop threads around a storm drain inlet indicated a potential pollution source as a result of these activities. Building downspouts that were directly connected to the storm drain system or indirectly connected to impervious surfaces were also recorded as potential pollution sources.

Waste Management

Every institution generates waste as a result of daily operations but unlike hotspots, it is typically just garbage. The field team noted the type of waste generated (e.g., hazardous, garbage, etc.) and the condition of dumpsters. Dumpsters with no cover or open lids, with leaks, damaged/in poor condition, and/or overflowing were noted as potential pollution sources. The field team also observed whether trash was present that could leave the site with wind or rain. Dumpsters located near storm drain inlets or lacking runoff diversion methods were also recorded as potential pollution sources.

Vehicle Operations

Most institutions do not have vehicle operations but a few may have buses on-site. Vehicle operations include maintenance, repair, recycling, fueling, washing or long-term parking. The presence of any of these activities was noted for each site since they can be a source of metals, oil and grease, and hydrocarbons.

Outdoor Materials

Materials such as mulch piles, storage drums, and de-icing salt are sometimes stored on institution grounds. Locations where materials were loaded or unloaded were examined to see if materials were uncovered and draining to a storm drain inlet. Storage areas were also evaluated for types of materials stored outdoors and their potential for entering the storm drain system. Uncovered materials and stained storage areas were used as indicators of poor outdoor storage practices and potential pollution sources.

Turf/Landscaping

The percentage of forest canopy, turf grass, landscaping, and bare soil covering the pervious area of a site was recorded on the field form. Sites with more than 20 percent of bare soil were noted as a potential source of sediment pollution. Ground maintenance activities for turf/landscaped areas were also evaluated. High turf management and improper irrigation practices (i.e. non-target/over-watering) were noted since they are potential pollution sources of nutrients, fertilizer, and pesticides. The field team also determined whether landscaped areas drained directly to storm drains or if organics (i.e. leaves, grass) accumulated on impervious surfaces. Evidence of buffer encroachment and whether the buffer was adequately planted was also recorded for evaluating restoration potential.

Stormwater Infrastructure

The field team checked whether storm drains were marked and whether stormwater treatment practices were present. These were evaluated for potential pollution sources and restoration potential.

After evaluating the categories discussed above, one or more of the follow-up actions listed below were identified based on initial field observations:

- Storm drain marking
- Tree planting
- Downspout disconnection
- Stormwater retrofit
- Education
- Impervious cover removal
- Pervious area restoration
- Stream buffer improvement
- Trash management

4.4.2 Summary of Sites Investigated and General Findings

There were four institutions assessed in Area I; three churches and one golf course. Information about these sites and identified actions for each one are summarized in

Table 4-7: . Figure 4-12: shows institutional sites in Area I and Figure 4-13: shows the locations of these sites.

Figure 4-12: Opportunity for tree planting at ISI_I_200 (left) and rain barrels at ISI_I_201 (right)

Table 4-7: Types of Institutions Assessed by Subwatershed and Identified Actions

Site ID	Subwatershed	Identified Actions		
		Tree Planting	Stormwater Retrofit	Downspout Disconnection
ISI_I_200	Beaverdam Run	120	N	N
ISI_I_201	Beaverdam Run	0	N	Y
ISI_I_300	Oregon Branch	520	N	N
ISI_I_301	Oregon Branch	600	N	N

Tree Planting

It was estimated that a total of 1,240 trees were identified to be planted at the church site in the Beaverdam Run subwatershed, and at one church site and the golf course in the Oregon Branch subwatershed. These numbers are planning level estimates only and would need to be refined through a follow-up site investigation prior to planting. It is important to note that the tree planting identified on the golf course is a single area of approximately three acres that would not affect areas of play.

Downspout Disconnection

Downspout disconnection was identified for the church site investigated in Beaverdam Run. Specifically, rain barrels are identified for the downspouts currently discharging to the parking lot. There are no downspout disconnection opportunities in Oregon Branch.

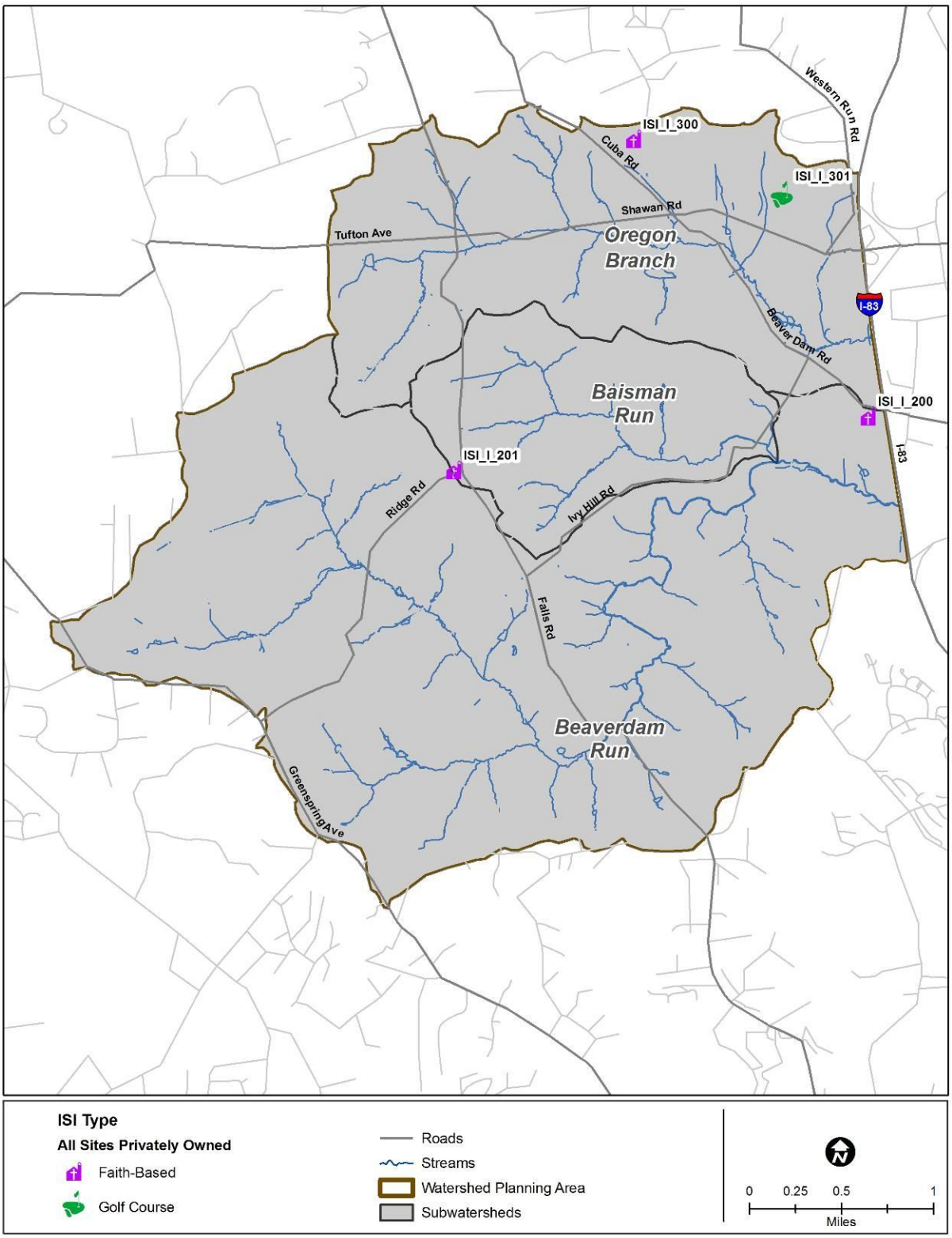


Figure 4-13: Institutional Site Investigation (ISI) Locations in Area I

CHAPTER 5.0

Restoration and Preservation Options

5.1 Introduction

This chapter presents an overview of the best management practices (BMPs) identified for the Area I watershed based on the information derived from the office and desktop analyses and collected during the field assessments. There is a significant difference in land cover and runoff characteristics between residential and agricultural areas, and the difference extends to stormwater BMPs as well. For that reason, potential treatment approaches for Area I are discussed based on those that apply to developed areas and those applicable to agricultural lands. In addition, citizen awareness activities, volunteer restoration programs, and land preservation options are discussed.

5.2 Best Management Practices for Developed Areas

5.2.1 County Capital Programs

5.2.1.1 Stormwater Management Upgrades

Stormwater Management Conversion

Older stormwater management facilities were typically designed only for flood control and have little or no pollutant removal capacity. Dry detention ponds have the greatest potential for conversion to an extended detention pond, or other facility, which is designed to capture and retain stormwater runoff to provide water quality benefits that allow sediments and pollutants to settle out while also providing flood control.

Four of the five existing dry detention ponds assessed during the SWM facility survey were determined to have potential for conversion for improved water quality treatment. Results of the survey are discussed in more detail in Chapter 3.

Stormwater Retrofits

Stormwater retrofitting involves implementing controls in developed areas where previous practices did not exist. Stormwater retrofits improve water quality by capturing and treating runoff before it reaches receiving water bodies. Retrofits target specific objectives depending on BMP type including stormwater quality, soil stabilization, stormwater flow control, and stream restoration. Several considerations must be taken into account to select

appropriate stormwater treatment measures such as space requirements, cost, and community acceptance.

5.2.1.2 Stream Corridor Restoration

Stream corridor restoration practices are used to enhance the appearance, stability, and aquatic function of urban stream corridors. These types of practices can range from simple stream clean-ups and localized bank stabilization to comprehensive repairs such as channel redesign and re-alignment. Stream restoration practices are often combined with stormwater retrofits and riparian management practices to meet subwatershed restoration objectives. Primary practices for Area I stream corridors include stream restoration, buffer restoration, and wetland restoration.

Stream Restoration

Stream restoration includes a number of techniques to stabilize eroded stream banks, restore habitat, and protect infrastructure such as private property, buildings and utilities. Stabilizing the stream channel improves water quality by preventing eroded soils, and the pollutants contained in them, from entering the stream. In addition, protecting infrastructure such as sewer and storm drain pipes reduces and/or eliminates water quality impacts associated with leaking sewer pipes and manholes.

The goal of stream restoration is to return the stream to a stable state in which it does not significantly erode or fill with sediment, is connected to its floodplain, and has an improved habitat condition. Besides being undertaken to restore stability, stream restoration projects may be proposed to restore physical, biological, or ecological function to a stream which has become degraded due to manmade changes in the channel or the watershed, such as channel straightening, armoring with concrete or gabions, or culvert installation.

Stream restoration design should take into account what is occurring upstream in the watershed. The hydrology and stormwater management practices upstream of a restoration site will dictate the quantity and speed of runoff that will reach a site. In addition, the sediment supply of the upstream channel is also an important consideration during the design of stream restoration repairs.

Buffer Restoration

Forested buffers are wooded areas along rivers, stream and shorelines which help stabilize banks, prevent erosion, filter pollutants such as sediment and nutrients, and provide wildlife habitat. Several portions of the Area I stream system have inadequate buffers as a result of human development activities. This restoration strategy is to enhance or reforest these areas with a variety of methods including:

- Buffer planting with native trees and other native vegetation
- Targeted education programs – These programs are designed to teach private and institutional property owners the water quality benefits of buffers that are forested or planted with native vegetation. Stream buffer signs are one way to remind residents of the importance of stream buffers. Educational programs can teach residents that allowing their streams to have natural buffers can help preserve their property as well as provide water quality benefits.

Wetland Restoration

Wetlands are highly valuable lands in terms of their abilities to both improve water quality by filtering and slowing runoff, and as critical habitat for many species. A wetland is an area of land where the soil is wet or covered with water and has vegetation that is adapted to or tolerant of wet soils. Swamps, marshes, and bogs are types of wetlands. This strategy entails the reintroduction of wetlands in settings where they have been lost in the past.

5.2.2 County Management Programs

Municipal management programs can directly support subwatershed restoration efforts through services, monitoring and development review. Street sweeping, inlet cleaning, trash and recycling collection are services that help protect water quality. The Illicit Discharge Detection and Elimination Program monitors the water flowing from stormwater outfalls to identify any potential contamination. The land development review process imposes a rigorous review of impacts to natural resources. This section describes these municipal programs.

5.2.2.1 Street Sweeping

Baltimore County has an active street sweeping program to remove debris, dirt and pollutants from the roads before they enter the storm drain system. Effective street sweeping usually involves using a vacuum assisted sweeper, and a schedule that takes into account factors such as trash pickup days and seasonal changes such as leaf litter in the fall and more frequent lawn care activities by residents in spring and summer.

5.2.2.2 Inlet Cleaning

The Baltimore County storm drain system consists of approximately 388 miles of storm drainpipe, 14,400 inlets, and 3,460 outfalls. In order to keep the entire system clean of trash, debris, and sediment, the Department of Public Works maintains three storm drain cleaning vehicles and employs three crews of two men each on a daily basis to clean the storm drains and pipes. Removing the material from the storm drain system reduces street flooding, a potential safety hazard, and aids in the detection of illicit connections.

5.2.2.3 Illicit Discharge Detection and Elimination Program

The county's illicit connection program ensures that all discharges to and from the municipal separate storm sewer system that are not composed entirely of stormwater are either permitted by MDE or eliminated. The County is required to screen a minimum of 150 storm drain outfalls annually for the purposes of detecting and removing these unpermitted discharges. The illicit connection program is responsible for performing outfall screenings, reporting screening data, and coordinating remedial actions. The illicit connection program also investigates illicit connection complaints from other agencies, citizens or volunteers in the Stream Watch Program. This program allows citizens to adopt a stream, which includes tracking the health of the stream and reporting problems or potential problems they observe.

Routine outfall screenings for detection of illicit connections compliment citizen complaints of problems they observe. The routine outfall screenings catch the chronic problems that may be missed by the public, such as chlorine leaks from the municipal water supply. Citizens provide surveillance at a level beyond that of the monitoring staff. A majority of the time citizens call while they are actually observing a problem and often can provide immediate local information that increases the chance of eliminating illicit connections.

5.2.2.4 Land Development Review

New development and redevelopment projects undergo a rigorous review for impacts to natural resources. Regulations are in place for the protection of stream buffers, forests, tidal shorelines, groundwater, and stormwater runoff. In addition on-site inspections take place during the construction process for erosion and sediment control. Post construction follow-up inspections review the stream buffers, forests, tidal shoreline and stormwater facilities before a development project is released for occupancy. The following are the current regulatory programs applicable to the development and redevelopment plan review process and follow-up inspections.

Riparian Forest Buffers

Baltimore County enacted the Regulations for the Protection of Water Quality, Streams, Wetlands and Floodplains in 1991. These regulations require development designs to include a 75 or 100 foot stream buffer and provisions for expansion of the riparian buffer for steep slopes, wetlands and floodplains. Development plans must minimize road crossings, have stormwater management facilities and outfalls outside of the riparian buffer, and place utilities outside the buffer to the extent possible. In cases where fish passage is an issue, stream crossings should be either open bottom bridges or provide for low flow fish passage. These design considerations are intended to maintain the integrity of the riparian buffer.

Forest Conservation

The main purpose of the Maryland Forest Conservation Act, enacted in 1991, is to minimize the loss of Maryland's forest resources during land development by making the

identification and protection of forests and other sensitive areas an integral part of the site planning process. EPS oversees local implementation of these regulations during the development review process and conducts inspections during the construction and post-construction closeout process. Of primary interest are areas adjacent to streams or wetlands, those on steep or erodible soils or those within or adjacent to large contiguous blocks of forest or wildlife corridors. Identification of priority areas is completed prior to design of the development plan. Any activity requiring an application for a subdivision, grading permit or sediment control permit on areas 40,000 square feet (approximately one acre) or greater is subject to the Forest Conservation Act and requires a Forest Conservation Plan prepared by a licensed forester, licensed landscape architect, or other qualified professional.

Chesapeake Bay Critical Area

The Chesapeake Bay Critical Area law and criteria were designed to foster more sensitive land use and development activity along the tidal shorelines and to ensure the implementation of appropriate long-term conservation measures to protect important habitats. The law identified the "Critical Area" as all land within 1,000 feet of the mean high water line of tidal waters or the landward edge of tidal wetlands. The Critical Area Act, passed in 1984, was significant and far-reaching, and marked the first time that the state and local governments jointly addressed the impacts of land development on habitat and aquatic resources. (There is no Critical Area in Area I.)

Groundwater Management

The Groundwater Management section of EPS is charged with the responsibility of managing and protecting the groundwater resources of Baltimore County. It handles issues related to drinking water wells, septic systems, and removal of residential underground storage tanks. These systems are regulated during the development review process and property title transfers to protect residents and groundwater resources.

Stormwater Management

Stormwater management in the State of Maryland has evolved over time, with the initial emphasis on quantity control in the mid to late 1980s, to quantity and quality control in the 1990s, to the more recent emphasis on channel protection (one year storm management) and diffusing stormwater over the site (Low Impact Development). Baltimore County implements stormwater management as a critical companion to riparian buffers. The control of erosive flows through stormwater management augments the riparian forest buffer in the protection of natural resources.

Erosion and Sediment Control

Baltimore County has delegated authority from the Maryland Department of the Environment to enforce the State Erosion and Sediment Control Program. The main function of this program is to monitor best management practices (BMPs) for sediment from new

development and redevelopment during the construction phase. These practices prevent sediment and other pollutant inputs into the storm drain system and stream network. The sediment control BMPs are specified in the sediment and erosion control plan for each development site. Sediment control plans are required for any construction activity disturbing an area greater than 5,000 square feet. The standard plan for erosion and sediment control is used for residential construction activity disturbing less than 30,000 square feet and for all other construction activity disturbing less than 20,000 square feet.

5.2.2.5 Trash and Recycling

Single Stream Recycling

Baltimore County began Single Stream Recycling in 2010. All recyclables (e.g., plastics, glass, metals, paper, and cardboard) are collected co-mingled by the curbside each week. Under this program, recycling rates increased as a result of a greater number of accepted materials, convenience of only needing one bin, and weekly pickup. Recycling saves energy, helps protect natural resources, and reduces air and water pollution.

Household Hazardous Waste Collection

In response to numerous requests from citizens and elected officials concerned with disposal of hazardous wastes from their own homes, Baltimore County citizens can drop off household hazardous waste materials for recycling or proper disposal at a permanent processing facility located at the Eastern Sanitary Landfill Solid Waste Management Facility. Materials dropped off for processing include unwanted household chemicals, such as paints, flammable cleaning solvents, automotive fluids, pesticides, pool chemicals, acids, mercury thermometers, gasoline, corrosive material, etc. In addition, EPS holds two one-day collection events annually, in the spring and fall, at different locations around Baltimore County.

5.3 Agricultural Best Management Practices

There are a large number of agricultural practices that are used by farmers to reduce soil loss, trap nutrients, and minimize the amounts of nutrients and pesticides used on the land. The Chesapeake Bay Program recognizes many of these agricultural BMPs with specific reduction efficiencies for nitrogen, phosphorus, and sediment assigned to each practice. The following description of agricultural BMPs is derived from MDE, 2010.

5.3.1 Farm Conservation Plans

A Soil Conservation and Water Quality Plan (SCWQP) is a comprehensive plan that addresses natural resource management on agricultural lands and describes BMPs which will be used to control erosion and sediment loss and manage runoff. SCWQPs include management practices such as crop rotations and structural practices such as sediment basins and grade stabilization structures. At the request of a farmer, a Soil Conservation District, Maryland

Department of Agriculture (MDA) or USDA professional provides assistance to determine the group of practices needed to address specific runoff concerns on the farm. The practices are designed to control erosion within acceptable levels and to be compatible with management and cropping systems. A SCWQP can be used for up to ten years without revision if substantial changes in management do not occur. Nutrient reduction is only one of many benefits derived from SCWQPs. Also included in a SCWQP are recommendations concerning forestry management, wildlife habitat and plantings, pond construction and management, and other natural resource management practices. Best Management Practices that can be included in a SCWQP that applies to Area I are discussed below.

Streamside Buffers

Streamside forest buffers are wooded areas along rivers and streams that help filter nutrients, sediments and other pollutants from runoff as well as remove nutrients from groundwater and slow erosion. In addition to their ability to improve water quality, their value at enhancing terrestrial and aquatic habitat make forest buffers an important BMP for natural resources managers.

Streamside grass buffers are strips of grass or other non-woody vegetation maintained between the edge of fields and streams, rivers or tidal waters that help filter nutrients, sediment and other pollutant from runoff, as well as remove nutrients from groundwater.

Cover Crops

Cover crops are small grains such as wheat or rye that are planted in the fall after the harvest of corn, soybeans and other summer crops to absorb unused fertilizers that may remain in the soil. During the winter, these nutrients, particularly nitrate, are subject to leaching to groundwater. In addition, the plants and roots of cover crops help anchor the soil to decrease erosion and reduce phosphorus loss, add organic matter to soil and help suppress weeds. By timing the springtime cover crop burn or plowdown, the trapped nitrogen can be released and used by the following crop.

Stream Protection with Fencing

Stream protection with fencing incorporates both alternative watering and installation of fencing along streams to exclude livestock. The fenced areas may be planted with trees or grass, but are typically not wide enough to provide the benefits of buffers. Stream fencing should be implemented so as to substantially limit livestock access to streams; however, it can allow for the use of limited hardened crossing areas where necessary to accommodate access to additional pastures or for livestock watering. By preventing or limiting access of livestock to streams, erosion from hooves and bacteria contamination is curtailed.

Tree Planting

The tree planting BMP includes any tree planting on agricultural lands, except those used to establish riparian forest buffers. This program targets lands that are highly erodible or identified as critical resource areas. Tree planting on previously cleared land is also called afforestation because it involves growing trees and converting the land use from agricultural to forest over time.

Off-Stream Watering

Off-stream watering provides cattle an alternative drinking water source away from streams. By providing an off-stream watering source, cattle will reduce the time they spend near and in streams and stream banks. This will reduce animal waste deposition and heavy traffic areas near streams to more upland locations. This practice works in conjunction with the practice of stream protection with fencing.

Conservation Tillage

Conservation tillage involves planting and growing crops with minimal disturbance of the surface soil. Conservation tillage requires two components, (a) a minimum 30% residue coverage at the time of planting and (b) a non-inversion tillage method. No-till farming is a form of conservation tillage in which the crop is seeded directly into vegetative cover or crop residue, with little disturbance of the surface soil. Minimum tillage farming involves some disturbance of the soil, but uses tillage equipment that leaves much of the vegetation cover or crop residue on the surface. The overall benefit is to reduce surface soil erosion.

Animal Waste Management

Animal waste management systems are practices designed for proper handling, storage, and utilization of wastes generated from animal operations. They include a means of collecting, scraping or washing wastes and contaminated runoff into appropriate waste storage structures.

Continuous No-Till

Continuous no-till (CNT) conservation is a crop planting and management practice in which soil disturbance by plows, disk or other tillage equipment is eliminated. CNT involves no-till methods on all crops in a multi-crop, multi-year rotation. When an acre is reported under continuous no till, it is not eligible for additional reductions from the implementation of cover crops and nutrient management application reductions because these benefits are accounted for in the CNT.

Runoff Control Systems

Runoff control systems use a variety of techniques to direct stormwater to places where it will not cause nutrient runoff or soil erosion. Gutters and downspouts on barns and grading of the land are examples of ways to redirect runoff away from sensitive areas. Runoff controls

include methods of retrofitting animal waste storage structures to reduce the potential for pollution. Controls can also be designed to prevent runoff from upslope areas and roofs from reaching feedlot or "loafing" areas of animals, reducing the potential for washoff of animal waste and nutrients.

5.3.2 Nutrient Management Plans

Nutrient management plan (NMP) implementation refers to a comprehensive plan that describes the optimum use of nutrient inputs for crop yield to minimize loss of excess nutrients to the environment. A NMP details the type, rate, timing, and placement of nutrients for each crop. Soil, plant tissue, manure and/or sludge tests are used to assure optimal application rates. Plans are prepared by either the University of Maryland Extension or certified private consultants and are typically revised every year but may be written for up to three years to incorporate management, fertility and technology changes.

5.4 Citizen Awareness Activities

Residents and businesses engage in behaviors and activities that can negatively influence water quality, including over-fertilizing lawns (Figure 4-3), using excessive amounts of pesticides, poor housekeeping practices such as inappropriate disposal of paints, household cleaners or automotive fluids, and dumping into storm drains. Alternatively, positive behaviors such as tree planting, disconnecting downspouts, and picking up pet waste can help improve water quality. Whether a pollution prevention program is designed to discourage negative behaviors or encourage positive ones, targeted education is needed to deliver a specific message that promotes behavior changes. Local watershed organizations, and other civic groups such as the Master Gardeners, are in a position to influence these changes using pollution prevention education and outreach to teach citizens how to properly care for the watershed.

5.4.1 Stormwater Runoff

A survey regarding people's knowledge about stormwater was conducted in 2007 by the Herring Run Watershed Association and the Jones Falls Watershed Association (both organizations are now part of Blue Water Baltimore) in conjunction with OpinionWorks. (See study in its entirety at: http://www.opinionworks.com/StormwaterStudy_v3.pdf) It concluded that even people who want to improve stormwater runoff, don't realize how they adversely impact it. By slowing and reducing the amount of stormwater runoff, more water can infiltrate into the ground and lessen damaging stormwater surges into streams. Annually, Baltimore County holds a one-day truckload sale of rain barrels for citizens to purchase. There is more detail on this and other ways that homeowners can help reduce stormwater runoff in section 5.5.

5.4.2 Pet Waste/ Bacteria Awareness

Pet waste is one of the contributors of bacteria to streams and can cause health problems in humans. A pet waste station is a sign reminding pet owners of the importance of proper disposal of pet waste and it usually includes a supply of bags for pet waste cleanup. Often it is located next to an existing trashcan or it includes one. Pet waste stations can help neighborhoods to reduce bacteria flowing into their local streams and help to keep their neighborhood park or school site clean. Citizens can participate by monitoring the supply of bags to make sure they are continually available. In collaboration with other county agencies, EPS is developing an awareness campaign for better pet waste management. Additional sites for installation of pet waste stations are to be identified.

5.4.3 Fertilizer Reduction

A well-manicured and responsibly maintained lawn can be an asset to the watershed. Too often however, over fertilization and irresponsible pest management result in pollutant charged runoff to local streams. Significant reductions of total nitrogen to stormwater can be achieved through careful fertilizer management, or better yet, by going organic. Homeowners should be reminded to follow the fertilizer application instructions so that it is applied in the correct amount, during the right season, and does not wash away in a rainstorm. Citizens can be more cognizant about fertilizer placement so that it doesn't land on driveways and sidewalks where it may wash directly into the street and storm drain system. The County also promotes eco-friendly lawn care including the use of mulching lawn mowers, which reduce the need for fertilizer and decrease the amount of material handled by the yard waste collection.

5.4.4 Trash and Recycling

Compost Bins

Baltimore County holds a one-day compost bin sale for residents to purchase bins for composting yard waste in their backyards. By composting leaves and weeds in backyard bins, the amount of material handled by the municipal yard waste collection is reduced. Use of compost is an environmentally friendly way of improving soil and avoids chemical application of fertilizer. This event is held in conjunction with the annual rain barrel sale.

Stewardship Projects

EPS provides assistance in planning and advertising local stewardship projects such as Project Clean Stream, an annual stream cleanup hosted by the Alliance for the Chesapeake Bay.

Reuse Directory

Online and in print, this is a directory of reuse organizations for Baltimore County residents and businesses. It lists all the places that you can take unwanted items for reuse, including construction materials, appliances, office supplies, clothing, household items, automobiles, food, medical equipment, and more. By donating reusable items, you will: help

other people and organizations, reduce disposal costs, reduce air and water pollution, and conserve space in the landfill. The directory is published by the Baltimore County Bureau of Solid Waste Management. (http://resources.baltimorecountymd.gov/Documents/Public_Works/2009onlinereusedirectrevised101018.pdf)

The Re-Source Newsletter

An online newsletter about Baltimore County's solid waste reduction, reuse, recycling, and refuse disposal programs. This newsletter is published quarterly on the web.

5.4.5 Environmental Awareness and Education

Outreach and education programs are intended to educate the public on how to reduce the potential for pollutants to reach waterways. These programs are designed to change pollutant-causing behaviors by providing information on how behavior affects water quality and to recommend types of changes that can be made to reduce impacts. There are also a number of activities that can reduce runoff or improve water quality that don't involve pollution prevention, such as landscaping improvements, which could be the target of an outreach program.

A pollution prevention program can be designed to discourage negative behaviors and/or encourage positive behaviors. Either way, the goal is to deliver a specific message through targeted education to promote behavior changes. Local watershed organizations such as the Gunpowder Valley Conservancy can help influence these changes using pollution prevention education and outreach to teach citizens how to properly care for the watershed. The upland assessments described in Chapter 4 identified pollution prevention or source control education programs which could be effective in Area I.

Community-based facilities present good opportunities for educating the public about water quality issues and improvement methods for the watershed. This can be accomplished by implementing water quality BMPs such as rain gardens and bioretention areas at these sites. In addition to environmental education, these BMPs have water quality and aesthetic benefits for property users. Tree plantings present great opportunities for community involvement and education, as well as water quality sampling and monitoring of stormwater management.

5.4.6 Maryland Green School Award

Baltimore County uses *The Maryland Green School Awards Program* to provide a framework for integrating environmental learning and community involvement in local schools. EPS supports workshops and site-based meetings for teachers and provides local and regional resources to enhance staff development opportunities and increase the environmental awareness and interest of local school principals, teachers, and facilities managers. A requirement of each Green School is to demonstrate Best Management Practices at their site. These may include:

water conservation, energy conservation, solid waste reduction, and habitat restoration using the school grounds.

5.5 Volunteer Restoration Programs

There are several restoration activities that citizens in the watershed can do to help restore and protect the watershed. These activities are described in the following sections and include downspout disconnection, BayScaping, tree canopy improvement, fertilizer reduction/education, planting open space trees, and engaging in a citizen stream watch program.

5.5.1 Downspout Disconnection

In addition to road runoff, rooftops also contribute stormwater directly into streams. Many downspouts are connected directly to the storm drain system through underground pipes, others are funneled toward driveways and sidewalks, which then are connected to the street. By redirecting downspouts to a pervious area, this runoff is allowed to filter across pervious areas such as gardens and lawns.

Downspout disconnection refers to several practices that capture or treat rooftop runoff from individual downspouts through either a simple disconnection that allows the runoff to spread across the lawn or yard where it filters or infiltrates into the ground, a rain barrel that captures the runoff for re-use in watering gardens, or a rain garden that filters the runoff. Several of the neighborhoods assessed in the Area I planning area were recommended for downspout disconnection because they are draining to impervious surfaces such as driveways, sidewalks, or the curb and gutter system.

Simple downspout disconnection can be achieved if the downspouts are relocated to drain onto pervious areas (i.e. lawn). This will allow rooftop runoff to be filtered by vegetation, and soak into the ground. This decreases flow to local streams during storm events, reducing erosion and pollutant loads to streams.

The use of rain barrels for the collection and reuse of the runoff is a highly sustainable practice, and is effective even if there is limited space on the property. Downspouts can be directed into rain barrels, where rooftop water is captured and stored for later use to water the yard or garden, or simply to be released onto a pervious area on a dry day.

Finally, most of the lots in the watershed have sufficient room for rain gardens, which are the most desirable option in terms of water quality. Rain gardens capture runoff from impervious surfaces such as roofs, roads, patios and driveways. They are planted with native perennials and shrubs that are compatible with wet soils. A downhill area that naturally collects rain water is an

ideal location for a rain garden. The garden temporarily holds runoff, allowing it to gradually percolate into the ground, thus replenishing groundwater and reducing floods. Garden plants naturally filter pollutants and improve the water quality.

5.5.2 BayScaping

Numerous water quality benefits are achieved from converting turf into landscaping and through increasing the urban tree canopy. A BayScape is a landscape using native plants to provide habitat for local and migratory animals, improve water quality, and reduce the need for chemical pesticides and herbicides. BayScaping plants, such as trees, shrubs and perennials, are able to make better use of rain water than typical lawn grasses, and so require less watering once established. They are also better at trapping and removing nitrogen and pollutants from rain water so that it is not released into nearby waterbodies. A BayScape is also valuable for the gardener or landowner because it offers greater visual interest than lawn, reduces the time and expense of mowing, watering, fertilizing and treating lawn and garden areas, and can address areas with problems such as erosion, poor soils, steep slopes or poor drainage. Removal of exotic invasive plant species also benefits native plant and animal species.

5.5.3 Tree Canopy Improvement

Programs to promote tree planting in residential yards and commercial open space can increase the tree canopy, increasing evapotranspiration and interception, slowing runoff and allowing more infiltration as it is absorbed into the ground. Trees also reduce erosion by holding soil and by reducing the impact of rain to bare ground. These types of programs also provide an opportunity to involve volunteers from neighborhoods, businesses and schools to help plant trees throughout the watershed while also educating the community about the importance of trees for air and water quality.

- Baltimore County’s Growing Home Campaign – Designed to help homeowners increase the tree canopy on their lots, this program is a public/private partnership between Baltimore County, neighboring jurisdictions, local retail nurseries and garden centers, and homeowners to encourage planting new trees on private residential land. The program provides education about the multiple benefits of planting trees and a $10 savings on the purchase of qualifying trees. The cost of the coupon is shared between the county and the local nursery.
- Big Tree Sale – Baltimore County has its own native tree nursery for county reforestation projects. Twice a year, in the spring and fall, trees from the nursery are made available to the public to encourage planting of native trees, especially oaks, which have exceptional water quality, air quality, and wildlife benefits. Trees are sold at one-day sale events.
- The State of Maryland's TREE-MENDOUS program provides high-quality, native trees and shrubs available at reasonable prices for plantings on public lands. The trees may be planted in places such as community open spaces, school grounds, government facilities, and rights-of-way. They may not be planted at private residences.

5.5.4 Fertilizer Reduction / Education

Proper lawn and turf care practices can reduce excess nitrogen, phosphorus, insecticides and herbicides from getting into local streams. Education on soil testing, fertilizer application and pesticide use is intended to reduce the amount of these materials applied to the land.

5.5.5 Stream Watch Program

The Stream Watch Program is intended to develop citizen stewardship through participation of citizen volunteers in the program who actively assume the role of caring for segments of the stream network by observing changes in the system, by providing stream clean-ups, and participating in planting activities. The Stream Watch Program also includes identification of potential restoration projects for possible inclusion in the Waterway Capital Improvement Program and provides a valuable addition to the county's Illicit Connection Program through reports by Stream Watch participants.

5.5.6 Open Space Trees

Pervious areas and natural area remnants provide important natural groundwater recharge functions within a subwatershed, and should be optimized to promote natural infiltration. These areas also present an opportunity for reforestation in the watershed. Reforestation is generally the highest priority in terms of improving the infiltration and recharge functions, however other techniques such as soil aeration, amendments, and establishing native plantings or meadows also serve a higher function than turf grass. Priority sites have little evidence of soil compaction, invasive plants, and trash/dumping, and can be reforested with minimal site preparation.

5.6 Institutional Initiatives

5.6.1 Parking Lot Retrofits

Often large parking surfaces are included in commercial and institutional development projects for events that occur very infrequently. If reducing the impervious cover is not an option, then filtering practices can provide a substantial benefit when applied over large areas. Onsite commercial and institutional retrofit practices often include the use of sand filters, bioretention, and grass swales adjacent to parking lots. Larger redevelopment projects often include underground storage or filtering systems. Several research groups are exploring innovative parking surfaces to develop a surface that is both durable and porous. These surfaces are another option for providing better filtering of runoff, while still allowing for the same amount of parking spaces.

5.6.2 Open Space Planting

An increasing number of faith-based institutions show interest in adopting conservation landscaping principles. This begins primarily by removing unused turf areas at these institutions.

These areas are then replaced by an assortment of more sustainable and environmentally friendly practices. Options include: planting trees, restoring wildlife habitat, introducing no-mow zones, and creating meadows, all of which also improve stormwater runoff and can increase energy efficiency.

5.7 Land Preservation

Land preservation complements the implementation of BMP's by insuring that specific non-urban land uses remain intact over time on specific parcels. Land preservation includes areas such as parks and watershed protection zones where non-extractive uses predominate, as well as areas that are intensively managed for agriculture.

These parcels may be large, such as parks, or small, protecting a single farm. Land preservation reflects societal priorities and decisions to limit urban and residential development, and provides broad benefits. However, while there is a benefit from not being converted to a more intensive land use the degree of environmental protection is based upon the requirements of the specific Deed of Conservation Easement. The requirements vary from those required by the Program Open Space for parks to individual easement programs such as Maryland Environmental Trust or agricultural preservation programs.

For purposes of watershed management, an understanding of existing protected lands can provide a starting point in prioritizing potential protection and restoration activities. In some cases, protected lands may provide opportunities for restoration projects because owners of these lands may value natural resource protection or enhancement goals. A summary of current conservation easements is provided in Chapter 2.

Descriptions of the programs or mechanisms through which land in Area I may be preserved follows.

5.7.1 Maryland and County Rural Legacy Program

Baltimore County participates in the State's Rural Legacy Program which was developed in 1997 to protect large, continuous tracts of valuable cultural and natural resource lands through state grants made to local land trusts (DNR 2007). Baltimore County has five Rural Legacy Areas that aim to protect large blocks of farmland, forest, wetlands, and other environmental resources that seek to protect the Chesapeake Bay both directly and indirectly. Protection is afforded through the purchase of development rights and the placement of a perpetual Conservation Easement on the property. The easements are held by the private land trust, state or county, or a combination. In all cases, the land trust and the governmental co-holder of the easement is responsible for monitoring the property to assure compliance with the easement. Only the northwestern corner of Area I lies within a Rural Legacy Program boundary.

5.7.2 Maryland Environmental Trust and Local Land Trusts

Created by the Maryland General Assembly in 1967 to protect Maryland's natural environment, the Maryland Environmental Trust (MET) seeks donated easements on farms and forestlands, wildlife habitats, waterfront acreages, natural areas, historic sites, and other valuable and scenic features. In 1974, a landowner in Baltimore County was one of the first to protect their property through this program. Today, Baltimore County remains a leader in the state, with county landowners preserving over 12,000 acres through donations. Although both MET and local land trusts prefer to accept donations on lands greater than 50 acres, local land trusts are often willing to work with smaller property owners. Donations are accepted throughout the year. Landowners may qualify for a significant tax deduction and/or credit. MET also provides loans to qualified groups for the purchase of land for preservation.

5.7.3 Maryland Agricultural Land Preservation Foundation

Created in 1979, this program has been dedicated to preserving farmland and fostering commercial agriculture. With joint funding by the county and the state, over 17,000 acres of farmland have been preserved in Baltimore County. To qualify for this program, a farm must be a minimum of 50 acres or located adjacent to a preserved property. Applications to sell development rights may be made annually by July 1st following enrollment in an Agricultural District. Landowners receive cash payments for participating in the easement program.

5.7.4 Baltimore County Agricultural Land Preservation Program

Created in 1994 to preserve working family farms, this Baltimore County program has used innovative and collaborative funding mechanisms for land preservation. Landowners have protected over 1,300 acres through this program. To participate, a farm must be 50 acres in size or located adjacent to a preserved property.

5.7.5 Baltimore County Department of Recreation and Parks

Oregon Ridge Park is the county’s largest park, preserving over 1,000 acres in a predominantly forested setting. It is located entirely within SWAP Area I.

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APPENDIX F:

TMDL of Phosphorus and Sediments for Loch Raven Reservoir

Total Maximum Daily Loads of Phosphorus and Sediments for Loch Raven Reservoir And Total Maximum Daily Loads of Phosphorus for Prettyboy Reservoir, Baltimore, Carroll and Harford Counties, MD York County, PA

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List of Abbreviations

BMP	Best Management Practice
BOD	Biological Oxygen Demand
CBOD	Carbonaceous Biochemical Oxygen Demand
CE-QUAL-W2	U.S. Army Corps of Engineers Water Quality and Hydrodynamic Model, Version 3
Chla	Active Chlorophyll *a*
COMAR	Code of Maryland Regulations
CWA	Clean Water Act
CWAP	Clean Water Action Plan
DO	Dissolved Oxygen
DPW	Baltimore City Department of Public Works
EPA	Environmental Protection Agency
FSA	Farm Service Administration
HSPF	Hydrological Simulation Program Fortran
ICPRB	Interstate Commission on the Potomac River Basin
LA	Load Allocation
lbs/yr	Pounds per Year
MD	Maryland
MDA	Maryland Department of Agriculture
MDE	Maryland Department of the Environment
MDP	Maryland Department of Planning
MGS	Maryland Geological Survey
mg/l	Milligrams per Liter
MGD	Million Gallons per Day
MOS	Margin of Safety
MS4	Municipal Separate Storm Sewer System
NBOD	Nitrogenous Biochemical Oxygen Demand
NMP	Nutrient Management Plan
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System

NPS	Nonpoint Source
POM	Particulate Organic Matter
PO4	Phosphate
RTG	Reservoir Technical Group
SCWQP	Soil Conservation and Water Quality Plan
SOD	Sediment Oxygen Demand
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TSI	Trophic State Index
TSS	Total Suspended Solids
W2	CE-QUAL-W2
WLA	Wasteload Allocation
WQIA	Water Quality Improvement Act
WQLS	Water Quality Limited Segment
WRAS	Watershed Restoration Action Strategy
WWTP	Waste Water Treatment Plant
µg/l	Micrograms per Liter

EXECUTIVE SUMMARY

This document, upon approval by the U.S. Environmental Protection Agency (EPA), establishes Total Maximum Daily Loads (TMDLs) for phosphorus and sediments in Loch Raven Reservoir (basin code 02-13-08-05) and for phosphorus in Prettyboy Reservoir (basin code 02-13-08-06).

Prettyboy Reservoir and Loch Raven Reservoir were identified on the 303(d) list submitted to EPA by the Maryland Department of the Environment (MDE) as impaired by nutrients (1996), sediments (1996 – Loch Raven), metals (1996), bacteria (2002 – Prettyboy), mercury in fish tissue (2002), and impacts to biological communities (2002 & 2004). This document upon approval from EPA, establishes TMDLs for the nutrient and sediment impairments. TMDLs were completed in 2002 for both reservoirs for the mercury listings. Water Quality Analyses were completed for both reservoirs for the metals listings in 2003. Other impairments within these watersheds will be addressed separately at a future date.

The water quality goal of the nutrient TMDLs is to reduce high chlorophyll *a* (Chla) concentrations that reflect excessive algal blooms, and to maintain dissolved oxygen (DO) at a level supportive of the designated uses for Prettyboy and Loch Raven Reservoirs. The water quality goal of the sediment TMDL for Loch Raven Reservoir is to increase the useful life of the reservoir for water supply by preserving storage capacity.

The TMDLs for the nutrient total phosphorus were determined using a time-variable, two-dimensional water quality eutrophication model, CE-QUAL-W2 ("W2"), to simulate water quality in each reservoir. The TMDLs are based on average annual total phosphorus loads for the simulation period 1992-1997, which includes both wet and dry years, and thus takes into account a variety of hydrological conditions. Chla concentrations indicative of eutrophic conditions can occur at any time of year and are the cumulative result of phosphorus loadings that span seasons. Thus, average annual phosphorus total loads are the most appropriate measure for expressing the nutrient TMDLs for Prettyboy and Loch Raven Reservoirs. Similarly, the sediment TMDL for Loch Raven Reservoir, which is based on the water quality modeling performed for the nutrient TMDLs, is expressed as an average annual load in keeping with the long-term water quality goal of preserving the storage capacity of the reservoir.

The TMDLs include (1) a wasteload allocation (WLA) to municipal wastewater treatment plants and municipal storm sewer systems, (2) a load allocation (LA) to nonpoint sources, and (3) a 5% margin of safety (MOS) for the nutrient TMDLs and an implicit MOS for the sediment TMDL. The table below summarizes the nutrient and sediment TMDLs.

Summary of Nutrient and Sediment TMDLs for Prettyboy and Loch Raven Reservoirs

Waterbody	Constituent	TMDL	WLA	LA	MOS
Prettyboy Reservoir	TP (lbs/yr)	23,192	2,940	19,072	1,160
Loch Raven Reservoir	TP (lbs/yr)	54,941	22,010	30,184	2,747
Loch Raven Reservoir	Sediment (tons/yr)	28,925	1,151	27,774	Implicit

Six factors provide assurance that these TMDLs will be implemented. First, National Pollutant Discharge Elimination System (NPDES) permits for both wastewater treatment plants and urban stormwater systems will play important roles in assuring implementation. Second, Maryland has several well-established programs that may be drawn upon, including Maryland's Tributary Strategies for Nutrient Reductions developed in accordance with the Chesapeake Bay Agreement. Third, Maryland's Water Quality Improvement Act of 1998 requires that nutrient management plans be implemented for all agricultural lands throughout Maryland. Fourth, local jurisdictions, along with MDE and other stakeholders, have implemented a formal agreement, the Reservoir Watershed Management Agreement, to protect water quality in the reservoirs. A Watershed Restoration Action Strategy (WRAS) is currently in development for the Prettyboy Reservoir. Finally, Maryland has adopted a watershed cycling strategy, which will assure that routine future monitoring and TMDL evaluations are conducted.

1.0 INTRODUCTION

Section 303(d)(1)(C) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (EPA) implementing regulations direct each State to develop a Total Maximum Daily Load (TMDL) for each water quality limited segment (WQLS) on the Section 303(d) list, taking into account seasonal variations and a protective margin of safety (MOS) to account for uncertainty. A TMDL reflects the total pollutant loading of the impairing substance a waterbody can receive and still meet water quality standards.

TMDLs are established to achieve and maintain water quality standards. A water quality standard is the combination of a designated use for a particular body of water and the water quality criteria designed to protect that use. Designated uses include activities such as swimming, drinking water supply, and shellfish propagation and harvest. Water quality criteria consist of narrative statements and numeric values designed to protect the designated uses. Criteria may differ among waters with different designated uses.

Prettyboy Reservoir and Loch Raven Reservoir (also referred to as the Gunpowder Reservoirs) were identified on the 303(d) list submitted to EPA by the Maryland Department of the Environment (MDE) as impaired by nutrients (1996) – due to signs of eutrophication, expressed as high chlorophyll *a* (Chla) levels, sediments (1996 – Loch Raven), metals (1996), bacteria (2002 – Prettyboy), mercury in fish tissue (2002), and impacts to biological communities (2002 and 2004). Eutrophication is the over-enrichment of aquatic systems by excessive inputs of nutrients, especially nitrogen and/or phosphorus. The nutrients act as a fertilizer leading to the excessive growth of aquatic plants, which eventually die and decompose, leading to bacterial consumption of dissolved oxygen (DO). Prettyboy Reservoir is also listed as impaired because of seasonal DO concentrations less than 5.0 mg/l in the hypolimnion. This document upon approval from EPA, establishes TMDLs for the nutrient and sediment impairments. TMDLs were completed in 2002 for both reservoirs for the mercury listings. Water Quality Analyses were completed for both reservoirs for the metals listings in 2003. Other impairments within these watersheds will be addressed separately at a future date.

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting and Source Assessment

Both Prettyboy and Loch Raven Reservoirs lie in the Gunpowder Falls Watershed (Figure 1). Gunpowder Falls drains into Chesapeake Bay north of the City of Baltimore. The portion of the watershed draining to the reservoirs lies primarily in Baltimore and Carroll Counties, but also includes small portions of Harford County and York County, PA. Both reservoirs are part of the water supply system for Baltimore City and surrounding jurisdictions. Water supply intakes in Loch Raven Reservoir feed Baltimore City's Montebello Water Treatment Plant. Prettyboy Reservoir, which is upstream of

Loch Raven Reservoir, is used as a secondary reservoir to maintain capacity in Loch Raven Reservoir.

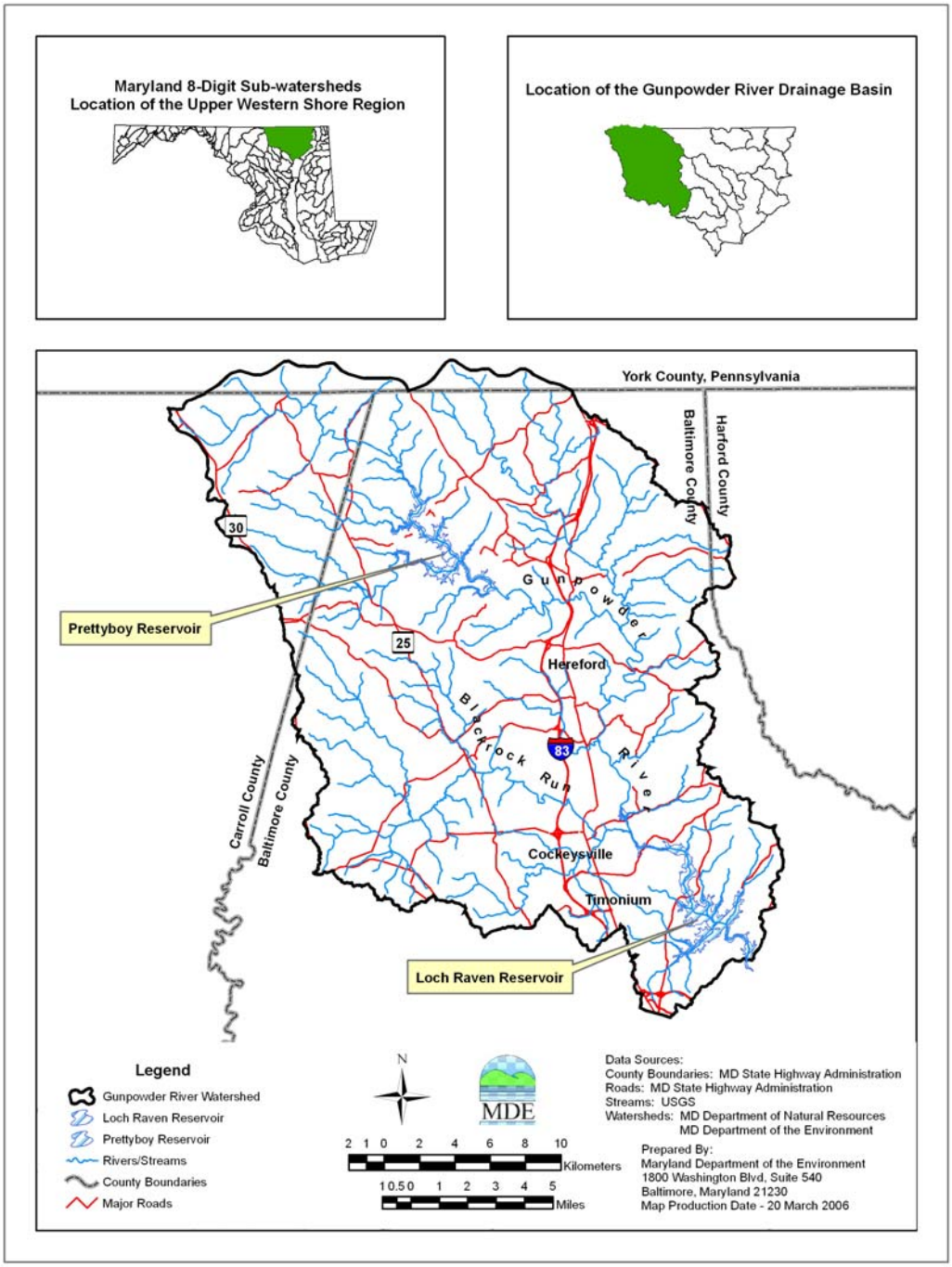

Figure 1: Location of Prettyboy and Loch Raven Reservoirs

Several relevant statistics for Prettyboy and Loch Raven Reservoirs are provided below in Table 1.

Table 1: Current Physical Characteristics of Prettyboy and Loch Raven Reservoirs

Characteristic	Prettyboy	Loch Raven
Location:	Baltimore County, MD Lat. 39˚ 37' 12" N Long. 76˚ 42' 36" W	Baltimore County, MD Lat. 39˚ 25' 48" N Long. 76˚ 32' 24" W
Surface Area:	1500 acres (65,340,000 ft^2)	2400 acres (104,544,000 ft^2)
Normal Reservoir Depth:	98.5 feet	76.0 feet
Purpose:	Water Supply Recreation	Water Supply Recreation
Basin Code:	02-13-08-06	02-13-08-05
Volume:	60,100 acre-feet	72,700 acre-feet
Drainage Area to Reservoir:	80.0 mi^2 (51,200 acres)	303 mi^2 (193,1920 acres)
Average Discharge:	24,500 ft^3s^{-1}	27,000 ft^3s^{-1}

Source: Inventory of Maryland Dams and Hydropower Resources (Weisberg et al., 1985).

2.1.1 Land Use

Figure 2 shows the land use in the Prettyboy and Loch Raven watersheds. The land use is based on 1997 Maryland Department of Planning Land Use/Land Cover data. The Prettyboy Reservoir watershed covers approximately 49,000 acres or 77 square miles. About half of the watershed is in crops or pasture, 39% in forest, and 12% in residential, commercial, or industrial land uses (Figure 3). The Loch Raven Reservoir watershed, excluding the drainage to Prettyboy Reservoir, covers approximately 240,000 acres or 218 square miles. Approximately 35% of the watershed is developed and 38% is forest, with the remainder in crops or pasture (Figure 4).

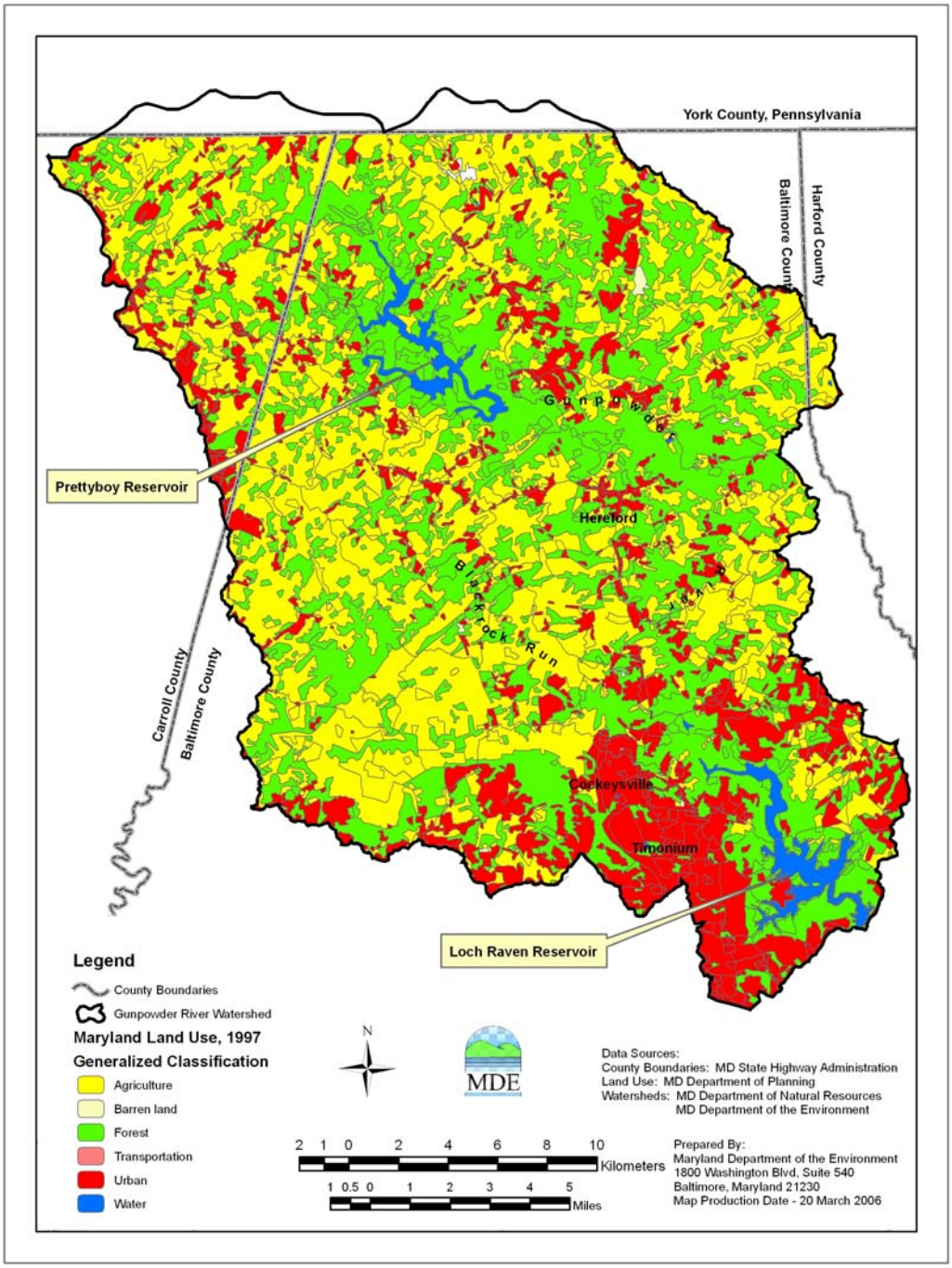

Figure 2: Land Use in Gunpowder Falls Watershed

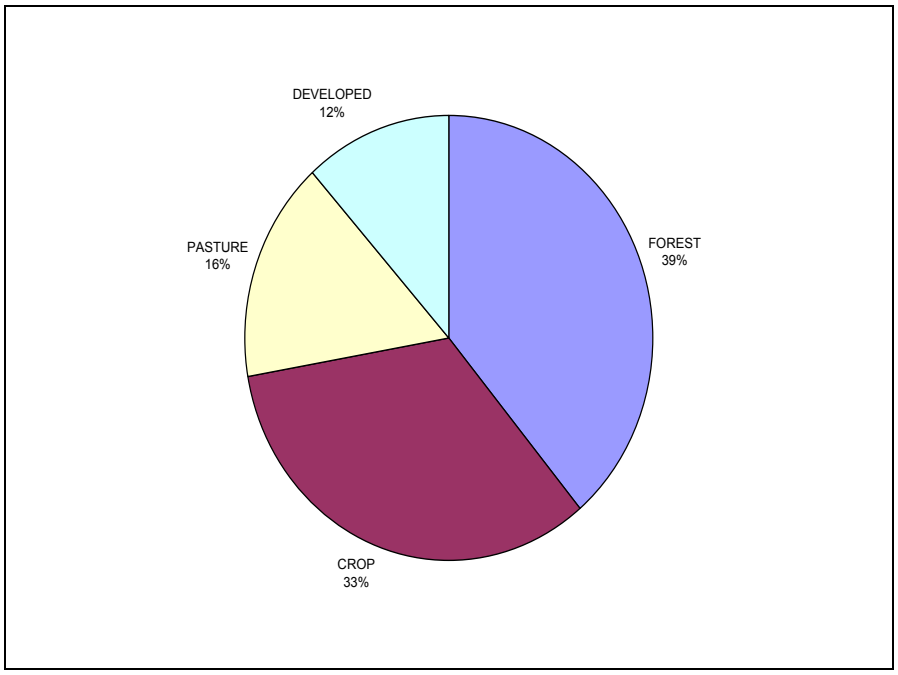

Figure 3: Proportion of Land Use in the Prettyboy Reservoir Watershed

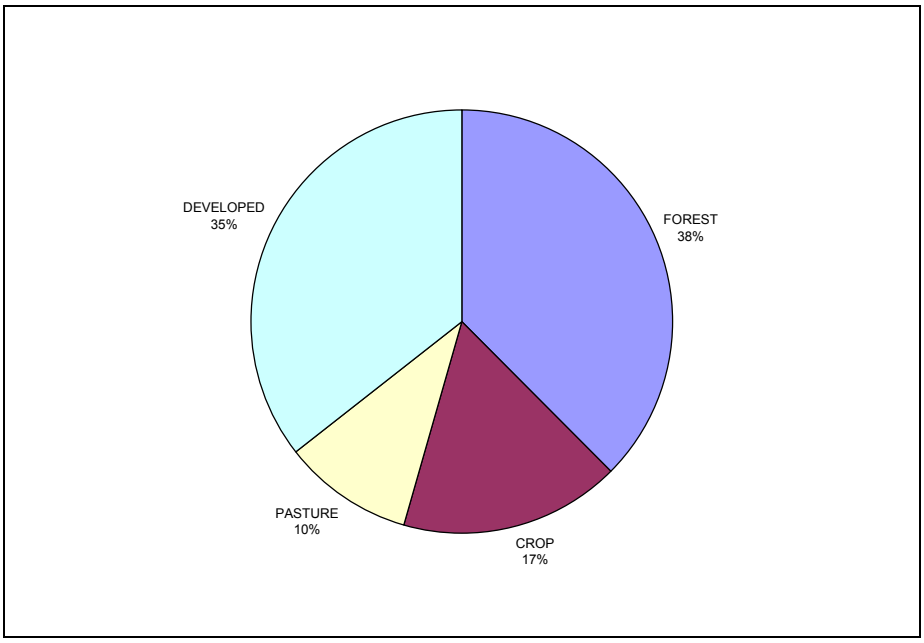

Figure 4: Proportion of Land Use in the Loch Raven Reservoir Watershed

2.1.2 Geology and Soils

The watersheds of Prettyboy and Loch Raven Reservoirs lie in the Piedmont physiographic province. The surficial geology is characterized by metamorphic rock of Precambrian and Cambrian age. Prettyboy schist is the underlying bedrock of the Prettyboy Reservoir watershed (MDE, 2004). The underlying metamorphic rock complex of the Loch Raven watershed downstream of Prettyboy consists mainly of crystalline schists and gneiss with smaller areas of marble. The underlying marble formations, Cockeysville Marble and the Patuxent Formation, are less resistant to weathering than the schists and gneiss and consequently occur mainly in valleys.

The primary soil associations in the watershed are the Manor-Glenelg, Chester-Glenelg, Baltimore-Conestoga-Hagerstown, Beltsville-Chillum-Sassafras, Glenelg-Chester-Manor, and Mt. Airy-Linganore associations. These soils are mainly deep and well-drained to moderately well-drained (Reybold and Matthews, 1976; Matthews, 1969). Within the stream floodplains, alluvial, Codorus and Hatboro soil series predominate. Nearly 85% of the soils in the watershed below Prettyboy Reservoir are classified as Hydrologic Group B, which means that they have low to moderate surface runoff potential, moderate infiltration rates, and moderately fine to moderately coarse soil texture (Tetra Tech, 1997).

2.1.3 Point Sources and Wastewater Treatment Plant Loads

The development of nutrient TMDLs for Prettyboy and Loch Raven Reservoirs was based on computer simulation modeling of water quality conditions from 1992 to 1997. During that time, the Hampstead municipal wastewater treatment plant (WWTP) discharged within the Prettyboy Reservoir watershed, and the Manchester municipal WWTP, along with ten small industrial sources, discharged within the Loch Raven Reservoir watershed. Table 2 shows the annual phosphorus and sediment loads from the municipal WWTPs during the simulation period, 1992-1997.

Table 2: Annual Municipal Wastewater Treatment Plant Loads 1992-1997

	Manchester (MD0022446)			Hampstead (MD0022578)		
Year	PO4 (lbs/yr)	Organic P (lbs/yr)	TSS (tons/yr)	PO4 (lbs/yr)	Organic P (lbs/yr)	TSS (tons/yr)
1992	192.33	177.84	2.77	276.41	173.39	0.27
1993	300.08	275.61	4.15	489.03	291.04	0.35
1994	382.14	370.30	7.06	254.56	195.37	0.39
1995	195.65	37.44	0.89	139.16	146.87	0.40
1996	90.65	80.92	0.83	168.81	107.44	0.85
1997	126.78	114.59	3.30	207.61	88.88	0.39
Average	214.60	176.11	3.16	255.93	167.16	0.44

Currently, the Manchester WWTP discharges through spray irrigation from April 1 through November 30, and in March if weather permits. Its current design flow is 0.5 million gallons per day (MGD). The Hampstead WWTP's current design flow is 0.9 MGD.

There are no industrial sources permitted for discharging phosphorus. Three facilities are permitted to discharge total suspended solids. Only one of them, a limestone quarry and concrete production facility owned by co-permittees Lafarge Mid-Atlantic and Imerys, has the potential to discharge solids in significant quantities.

2.1.4 Nonpoint Source Loads and Urban Stormwater Loads

Nonpoint source loads and urban stormwater loads entering the Prettyboy and Loch Raven Reservoirs were estimated using the Hydrologic Simulation Program-Fortran (HSPF). The HSPF model is used to estimate flows, suspended solids and nutrient loads from the watershed's sub-basins, which are linked to two-dimensional CE-QUAL-W2 models of each reservoir. These are used to determine the maximum loads of total phosphorus (TP) that can enter each reservoir while maintaining the water quality criteria associated with their designated uses. The water quality modeling framework is addressed in more detail in Section 4.2.

The simulation of the Loch Raven and Prettyboy Reservoir watersheds used the following assumptions: (1) variability in patterns of precipitation were estimated from existing National Oceanic and Atmospheric Administration (NOAA) meteorological stations; (2) hydrologic response of land areas were estimated for a simplified set of land uses in the basin; and (3) agricultural information was estimated from the Maryland Department of Planning (MDP) land use data, the 1997 Agricultural Census Data (U. S. Department of Commerce, 1997), and the Farm Service Agency (FSA). The HSPF simulates nonpoint source and urban stormwater loads and integrates all natural and human induced sources, including direct atmospheric deposition, and loads from septic tanks, which are associated with river base flow during low flow conditions. Details of the HSPF watershed model developed to estimate these urban and non-urban loads can be found in *Modeling Framework for Simulating Hydrodynamics and Water Quality in Prettyboy and Loch Raven Reservoirs* (ICPRB and MDE, 2006).

Figures 5 and 6 show the relative size of the contribution of point and nonpoint sources of total phosphorus to Prettyboy and Loch Raven Reservoirs, respectively, 1992-1997. Figure 7 shows the relative size of the contribution of sediment sources to Loch Raven Reservoir over the same period.

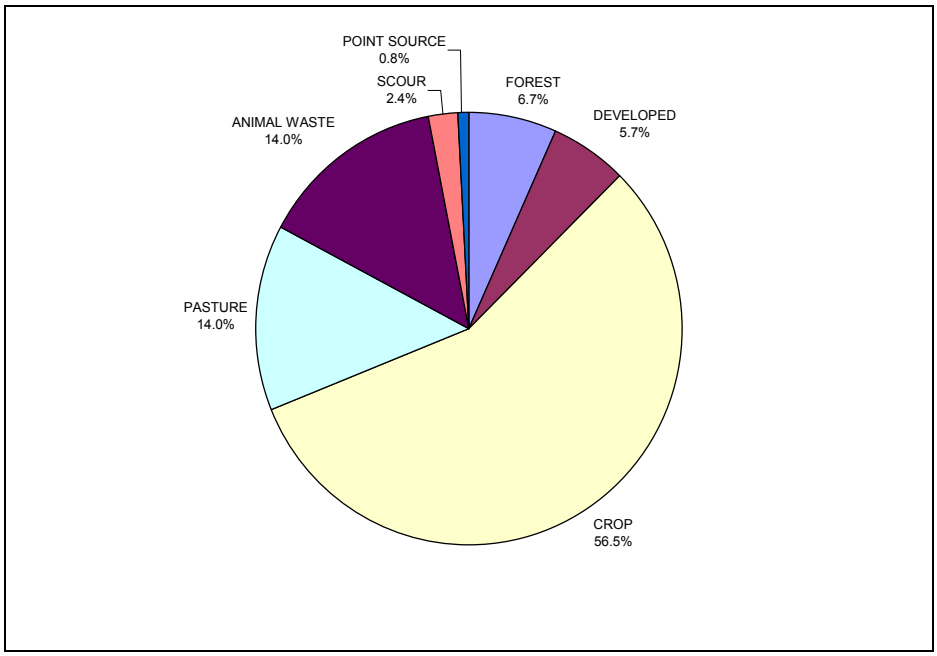

Figure 5: Percent Contribution of Sources to Total Phosphorus Loads to Prettyboy Reservoir

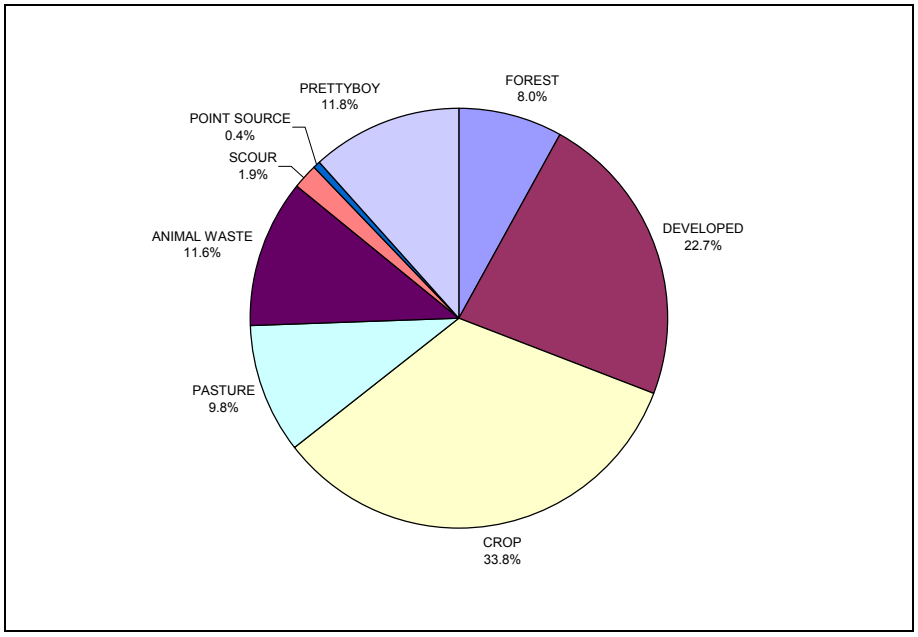

Figure 6: Percent Contribution of Sources to Total Phosphorus Loads to Loch Raven Reservoir

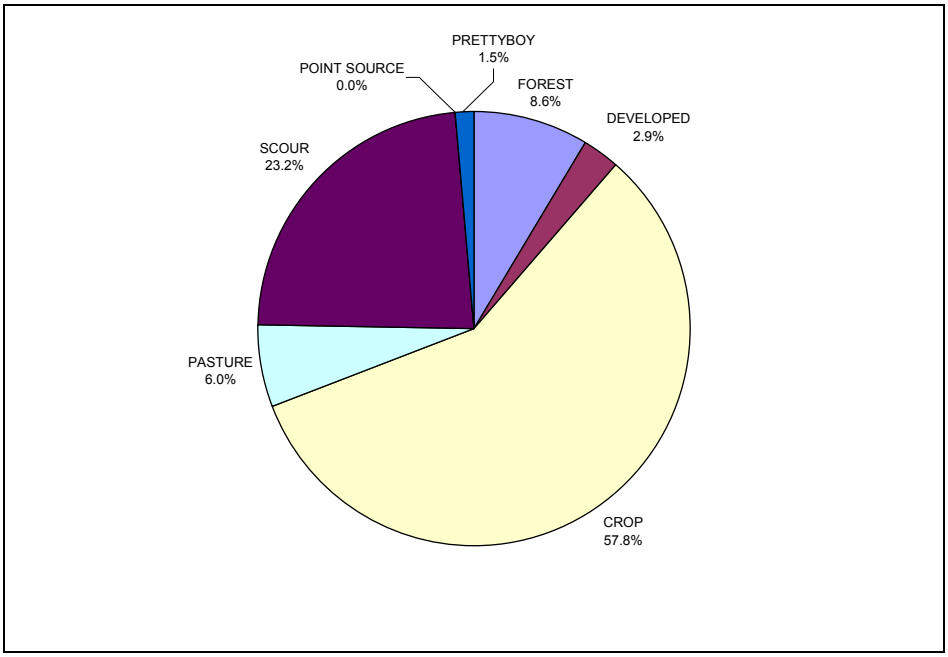

Figure 7: Percent Contribution of Sources to Sediment Loads to Loch Raven Reservoir

2.2 Water Quality Characterization

2.2.1 Baltimore City Department of Public Works Monitoring Program

Baltimore City Department of Public Works (DPW) is the only agency that monitors water quality in the reservoirs. DPW samples at three locations in Prettyboy Reservoir, and at five locations in Loch Raven Reservoir. Figures 8 and 9 show the sites of these sampling locations. Not all locations are sampled at the same time. Sampling is performed by boat at locations GUN0399, GUN0171, and GUN0190 weather permitting; otherwise, in the winter months, sampling is at fixed locations GUN0401, GUN0156, and GUN0174. Sampling at GUN0142 and GUN047 can occur either by boat or from a fixed platform.

Samples are analyzed for water temperature, dissolved oxygen, total phosphorus, ammonia, nitrate, turbidity, and Secchi depth, among other constituents. Samples are not analyzed for phosphorus species, organic or total nitrogen, or suspended sediment. Starting at the surface, samples are taken every five feet up to sixty feet; samples are taken at ten-foot intervals thereafter.

Not every sample is analyzed for the entire suite of constituents. Generally, only field measurements like temperature and dissolved oxygen are measured at every depth

sampled. Lab analysis is performed for Chla for each sample collected at the surface and at ten-foot depths down to 50 feet. In Loch Raven, chemical analysis is performed on samples collected at the surface and every ten feet down to sixty feet. In Prettyboy, chemical analysis is performed on samples taken at the surface and at 10, 20, and 40 feet below the surface, with an additional sample taken at either 60 feet below the surface, in the case of GUN0437, or 80 feet below in the case of the other two stations.

For the purpose of data analysis and the presentation of results, the locations in Loch Raven sampled by boat and the locations with fixed sampling positions have been paired to yield an annual representation of the middle and upper portion of the reservoir. Stations GUN0399 and GUN401 in Prettyboy have been paired to represent the lower portion of the reservoir. GUN0437 by itself represents the middle portion of Prettyboy. There are no sampling locations in the upper portion of Prettyboy reservoir. Table 3 summarizes how the sampling locations are grouped together in this report.

Table 3: Characterization of Reservoir Monitoring Locations

Station	Reservoir	Location	Classification
GUN0142	Loch Raven	Gatehouse	Lower
GUN0156	Loch Raven	Loch Raven Drive bridge	Middle
GUN0171	Loch Raven	Between picnic area and golf course	Middle
GUN0174	Loch Raven	Dulaney Valley Road bridge	Upper
GUN0190	Loch Raven	At the power lines	Upper
GUN0399	Prettyboy	Gatehouse	Lower
GUN0401	Prettyboy	1000 ft. upstream of dam	Lower
GUN0437	Prettyboy	Beckleysville Road Bridge	Middle

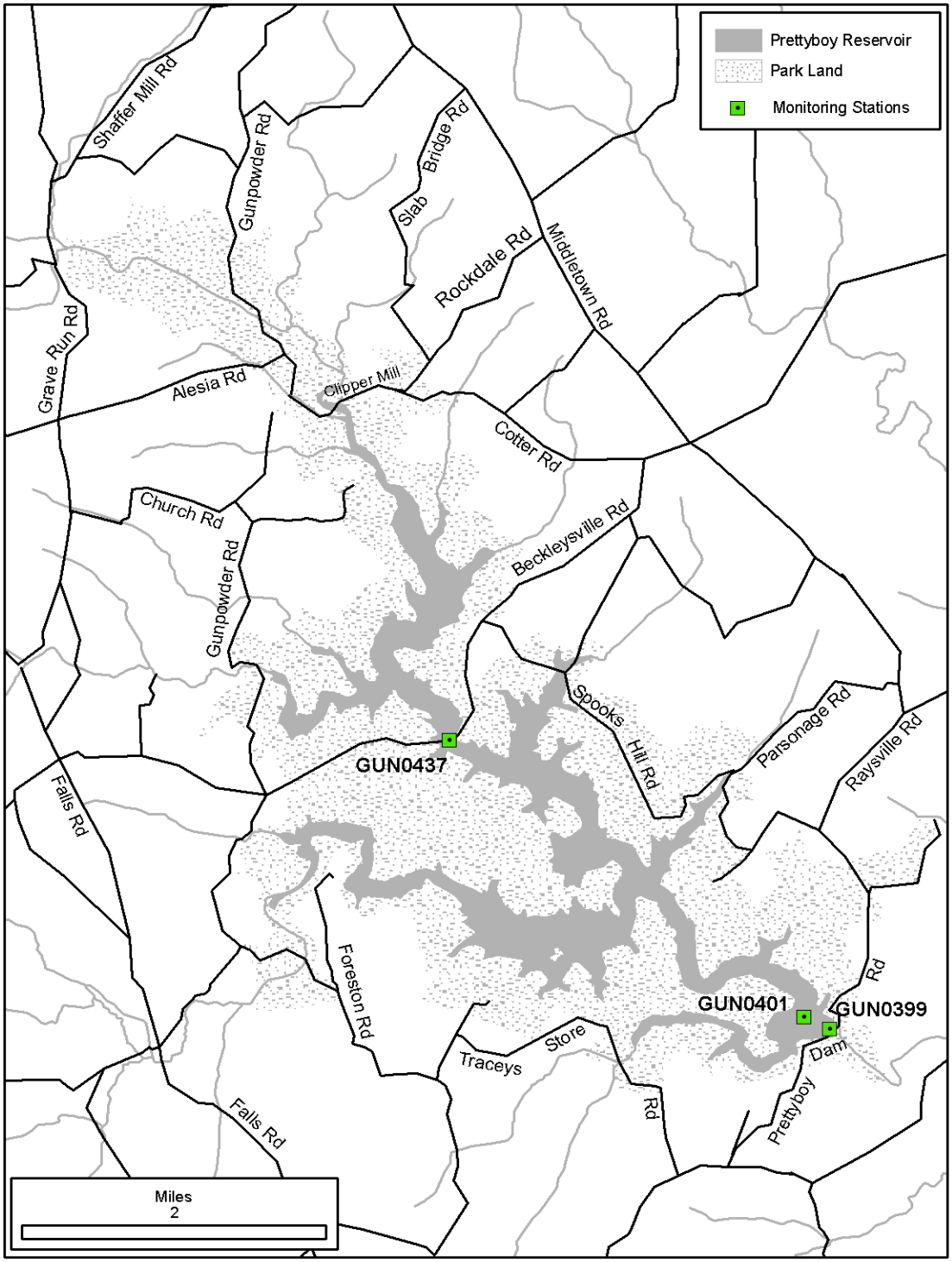

Figure 8: Sampling Locations in Prettyboy Reservoir (from DPW)

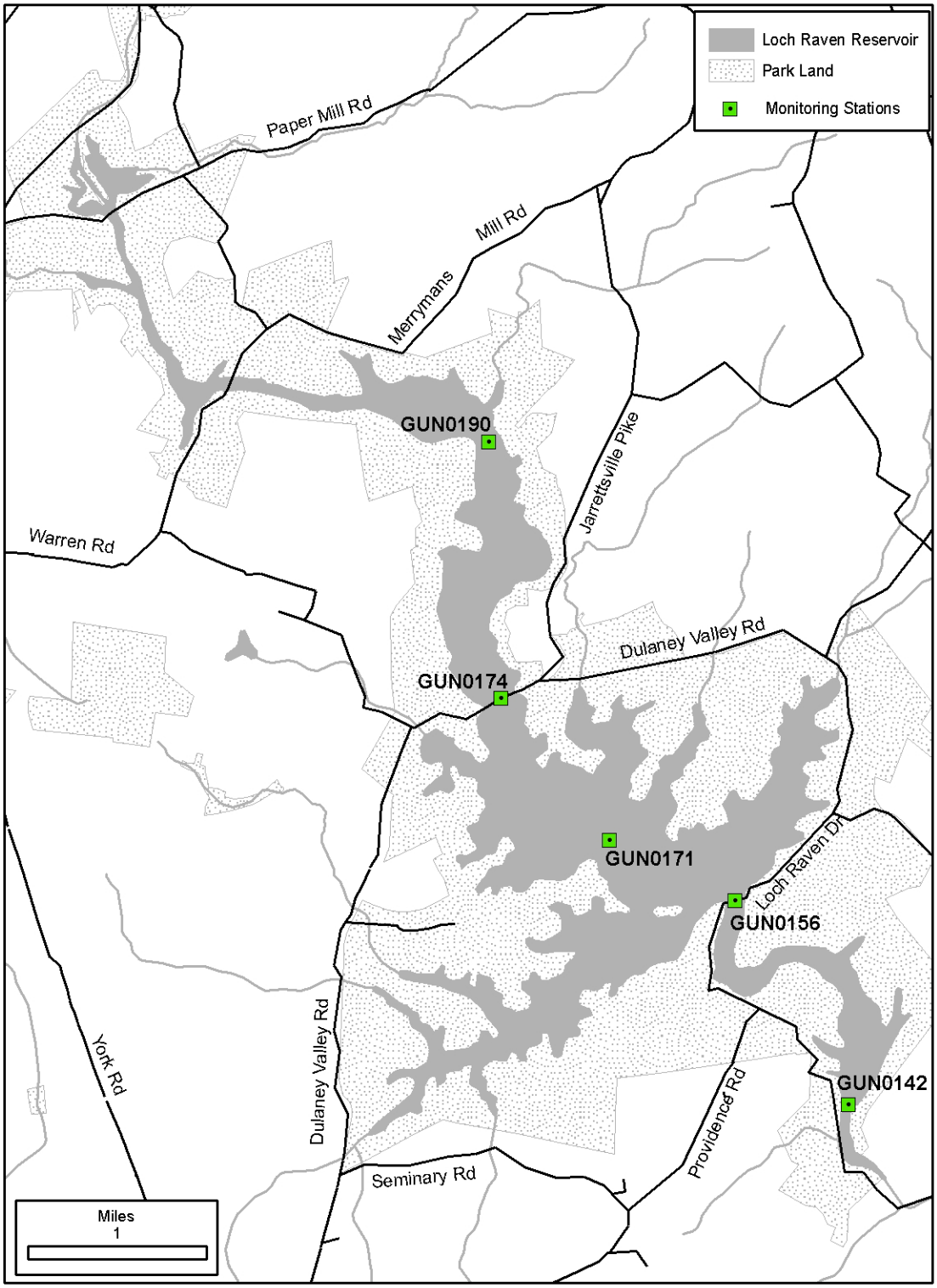

Figure 9: Sampling Locations in Loch Raven Reservoir (from DPW)

2.2.2 Temperature Stratification

Prettyboy and Loch Raven Reservoirs both regularly exhibit temperature stratification starting in April or May and lasting until November. Stratification sometimes occurs in winter but without significant consequences for water quality. Under stratified conditions during the summer and early fall, bottom waters in both reservoirs can become hypoxic, because stable density differences inhibit the turbulent mixing that transports oxygen from the surface. Under such conditions, the reservoirs can be divided vertically into a well-mixed surface layer, or epilimnion; a relatively homogeneous bottom layer or hypolimnion; and a transitional zone between them, the metalimnion, characterized by a sharp density gradient.

Contour plots of isotherms effectively illustrate seasonal position of the well-mixed surface layer or epilimnion. Figure 10 presents a contour plot of isothermals for GUN0142 in Loch Raven Reservoir for 1993, a representative year. Contours are shown only for the first 30 feet from the surface. In the winter, isothermal lines are vertical, showing that the reservoir has fairly uniform temperature over the first 30 feet of depth. In spring, isothermal lines begin to tilt away from the vertical, until by May, at depths greater than 15 to 20 feet, they are parallel to each other horizontally. At the surface, isothermal lines run vertically to a depth of 10 to 15 feet; this defines the epilimnion.

Figures A1 - A20 in Appendix A present contour plots for each monitoring location (lower, middle and upper) over the period 1992-2004. Generally, in both reservoirs, the epilimnion is limited to a depth of 10 to 15 feet in the summer. For the purposes of data analysis, the surface layer is considered to be 20 feet deep, with the understanding that in spring and fall the epilimnion can extend deeper than 20 feet, and in the summer it is likely to be shallower. For screening purposes, samples taken at depths of 40 feet or greater are considered in the bottom layer or hypolimnion.

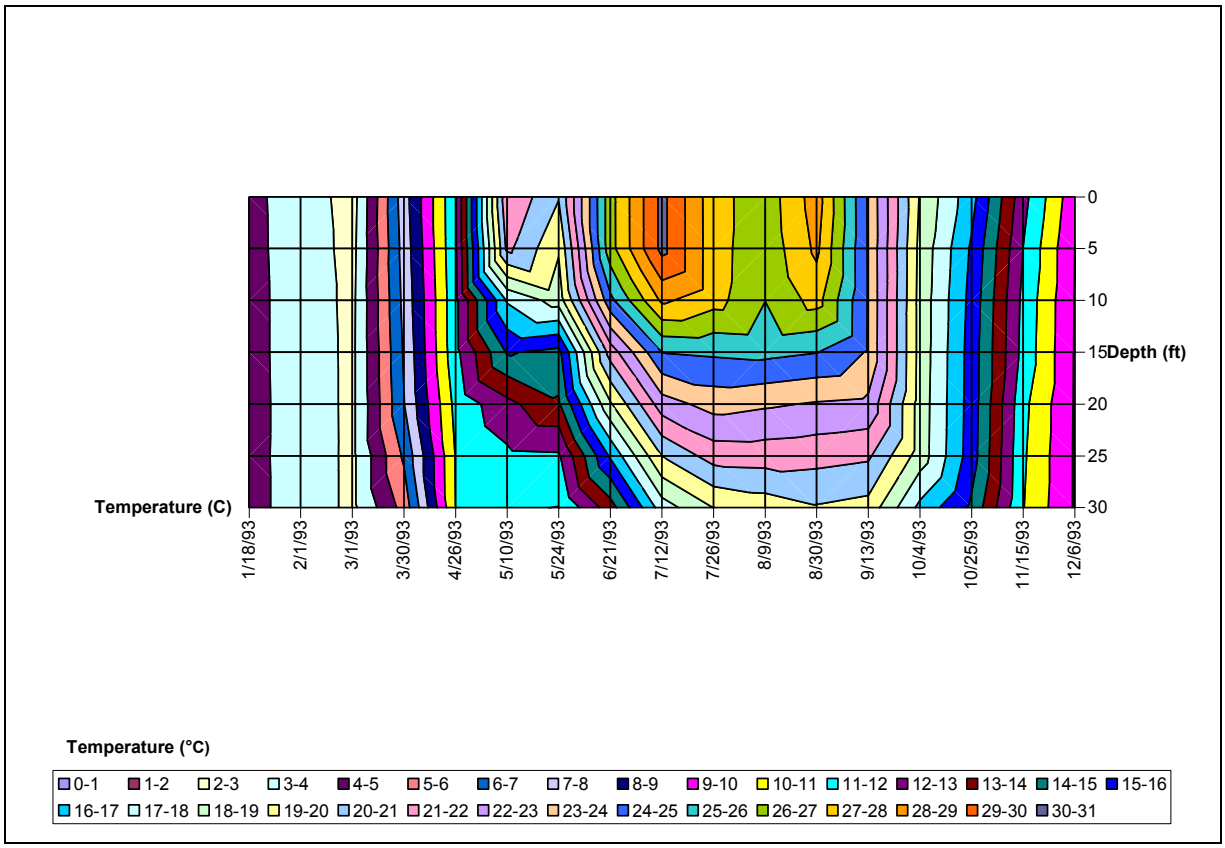

Figure 10: Isothermal Contours, Loch Raven Reservoir, Middle Stations, 1993

2.2.3 Dissolved Oxygen

Figures A21 - A25 in Appendix A show time series of average bottom DO concentrations at all monitoring locations in Prettyboy and Loch Raven Reservoirs. Quite clearly, hypoxia occurs in the hypolimnion of both Prettyboy and Loch Raven Reservoirs with regularity.

Figures A26-30 in Appendix A also show time series of DO at the surface and at five-foot intervals up to 20 feet, the screening-level definition of the epilimnion. For the most part, DO concentrations are above the 5.0 mg/l criterion, but there are periodic excursions below 5.0 mg/l at the 15- and 20-foot depths. In the majority of cases in which apparent hypoxia is observed in the epilimnion, the 20-foot screening depth has over-estimated the depth of the well-mixed layer, as shown by the temperature observations. As noted in the previous section, the depth of the epilimnion ranges between 10 and 15 feet in the summer months. See Tables B1 and B2 in Appendix B for a listing of all dates when DO concentrations were below 5.0 mg/l at either 15- or 20-foot sampling depth in Loch Raven and Prettyboy Reservoirs, respectively.

There are two related causes of these low DO concentrations. The first is temperature stratification, as explained above; the second is the entrainment of low DO waters into the epilimnion. Entrainment refers to the process by which turbulent layers spread into a non-turbulent region (Ford and Johnson, 1986). The onset of cool weather causes the epilimnion to increase in depth by entraining water from the metalimnion. This water can be low in oxygen and reduce the DO concentration in the well-mixed layer. This can occur any time under stratified conditions when the surface mixed-layer deepens, often well before the fall overturn typical of many lakes and reservoirs (including Prettyboy and Loch Raven), when the surface and bottom layers displace one another. All nineteen dates on which low DO occurred in Loch Raven without an approximately 2ºC difference in temperature between the 5- and 20-foot depths occurred in September, October or November, and all but five occurred in September alone.

This is illustrated by the low DO reading recorded on September 13, 1993, in GUN0171, the middle of Loch Raven Reservoir. Figure 11 shows the DO contour at this location. Figure 10 in the previous section, shows the temperature contour. A comparison of the figures indicates that at the end of August the reservoir at this location was highly stratified, with the well-mixed layer extending to about 15 feet. Throughout September, the surface waters cooled and the epilimnion deepened. The layers with low oxygen concentrations in the summer were drawn into the epilimnion. By October, the epilimnion once again had fairly uniform DO concentrations, although the reservoir had not completely overturned.

Entrainment and overturning account for the other low DO oxygen observations in Loch Raven and Prettyboy as well. In Prettyboy, another factor also can influence entrainment: drawdown. Withdrawals from a reservoir can induce currents that enhance mixing. Figure 12 shows the surface elevation of Prettyboy Reservoir from 1994 through 2004. In 1999 and 2002 (drought years), releases from Prettyboy to fill Loch Raven dropped the surface elevation by 30 feet or more. These drawdowns are probably a contributing factor in mixing low DO concentrations into the surface levels of the reservoir.

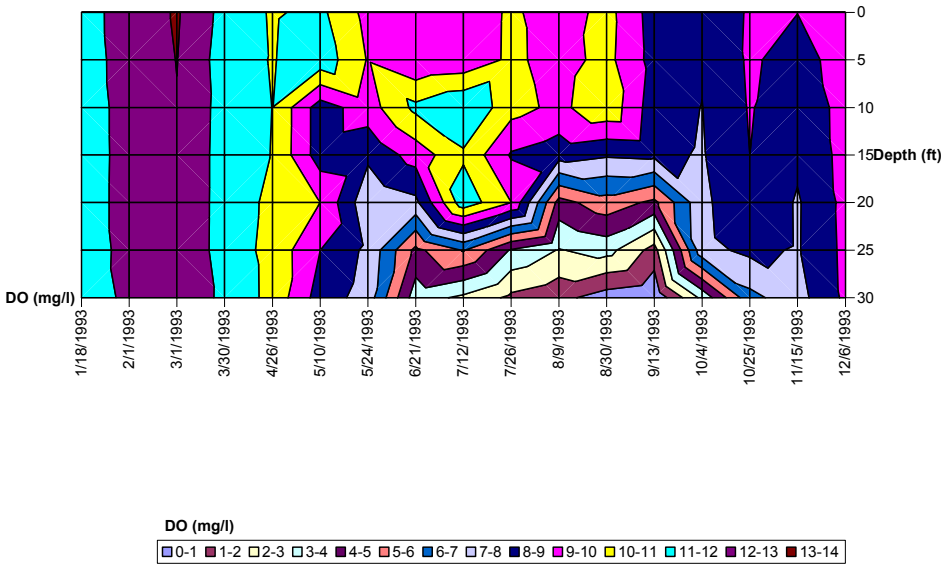

Figure 11: DO Contour, Loch Raven Reservoir, Middle Locations, 1993

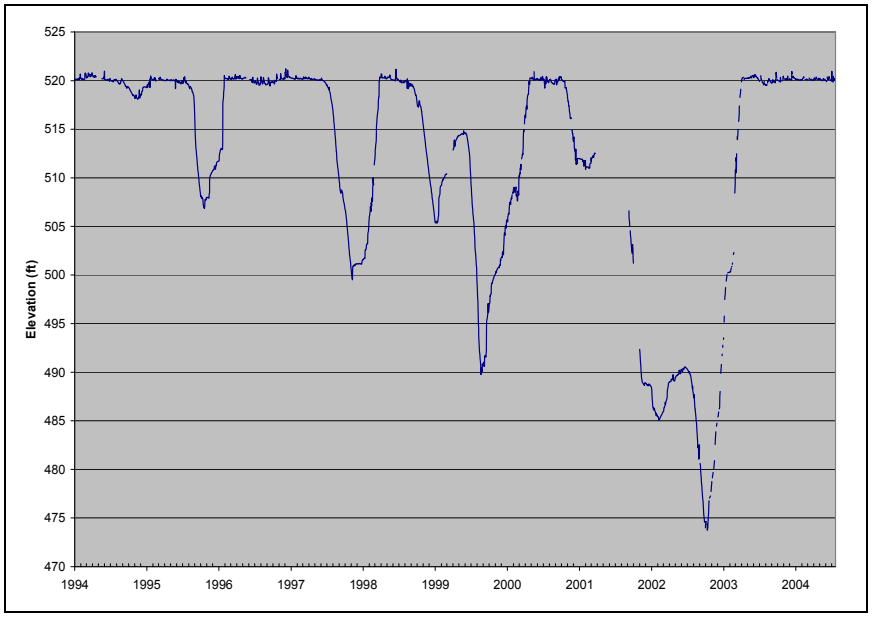

Figure 12: Surface Water Elevations in Prettyboy Reservoir, 1994-2004

2.2.4 Total Phosphorus

Figures A31 - A35 in Appendix A show average total phosphorus concentrations in the top and bottom sampling depths at each monitoring location in Prettyboy and Loch Raven Reservoirs. Surface layer concentrations are an average of the 10- and 20-foot depth samples. Bottom concentrations are averages of samples taken at 40-foot depths or greater. Tables 4 and 5 give summary statistics for TP concentrations in Prettyboy and Loch Raven Reservoirs, respectively. As the tables show, there is a longitudinal gradient to TP concentrations, with concentrations generally decreasing downstream. This is thought to reflect the fact that much of the phosphorus entering the reservoir is bound to sediment, and thus settles out before reaching the dams.

Table 4: Summary Statistics: TP Concentrations in Prettyboy Reservoir, 1992-2004

	Surface		Bottom	
Statistic	Middle	Lower	Middle	Lower
Mean	0.079	0.058	0.075	0.067
Standard deviation	0.112	0.082	0.106	0.110
Minimum	0.002	0.003	0.002	0.002
1st Quartile	0.021	0.019	0.025	0.018
Median	0.045	0.035	0.041	0.040
3rd Quartile	0.078	0.065	0.073	0.066
Maximum	0.675	0.552	0.825	0.970
Count	127	127	127	127

Table 5: Summary Statistics: TP Concentrations in Loch Raven Reservoir, 1992-2004

	Surface			Bottom		
Statistic	Upper	Middle	Lower	Upper	Middle	Lower
Mean	0.078	0.066	0.054	0.084	0.082	0.062
Standard Deviation	0.108	0.102	0.092	0.092	0.148	0.109
Minimum	0.005	0.003	0.002	0.005	0.003	0.003
1st Quartile	0.027	0.023	0.019	0.033	0.026	0.022
Median	0.053	0.042	0.036	0.058	0.045	0.033
3rd Quartile	0.085	0.071	0.060	0.100	0.081	0.078
Maximum	1.010	0.835	1.040	0.580	1.313	1.260
Count	136	139	205	90	138	205

The surface sample itself was excluded from the analysis because samples periodically have concentrations as high as 1.0 mg/l. Some of these high concentrations are confined to the surface layer and are suspected to be surface films. For this reason DPW also excludes surface layer concentrations (Baltimore City DPW, 1996).

2.2.5 Nutrient Limitation

Nitrogen and phosphorus are essential nutrients for algae growth. If one nutrient is available in great abundance relative to the other, then the nutrient that is less available limits the amount of plant matter that can be produced; this is known as the "limiting nutrient." The amount of the abundant nutrient does not matter because both nutrients are needed for algae growth. In general, a Nitrogen:Phosphorus (N:P) ratio in the range of 5:1 to 10:1 by mass is associated with plant growth being limited by neither phosphorus nor nitrogen. If the N:P ratio is greater than 10:1, phosphorus tends to be limiting; if the N:P ratio is less than 5:1, nitrogen tends to be limiting (Chiandani *et al*, 1974).

Since there are no data on organic nitrogen concentrations in the reservoir, nitrate is substituted for total nitrogen (TN) in the TN:TP ratio assessment, and the TN:TP ratio is underestimated. In both reservoirs, only about 7% of the samples taken at the 10- and 20-foot depths have nitrate:TP ratios less than 10:1, which can be taken as a cutoff for distinguishing nitrogen limitation from phosphorus limitation The median nitrate:TP ratio in Loch Raven is 38:1 and the median in Prettyboy is 47:1. About half the samples from Loch Raven with nitrate:TP ratios less than 10:1 occur on five dates, all of which appear to be associated with storm events. Storm events are likely to have high concentrations of particulate nitrogen and phosphorus, but while particulate phosphorus is accounted for in nitrate:TP ratios, particulate organic nitrogen is not. Storm events therefore inflate TP concentrations and exacerbate the underestimation of TN, so the resultant ratios are considered anomalous. Based on the available monitoring data and prevalent high N:P ratios, the evidence is conclusive that both Prettyboy and Loch Raven Reservoirs are strongly phosphorus limited.

2.2.6 Ammonia and Nitrogen

Figures A36 - A45 in Appendix A show the average surface and bottom concentrations of ammonia and nitrate in Prettyboy and Loch Raven Reservoirs. Since the surface layers of the reservoirs are not nitrogen limited, bottom concentrations of ammonia and nitrate are more important from the water quality standpoint for two reasons.

First, the time series graphs of ammonia show that, particularly for Loch Raven, there are significant releases of ammonia from the sediments. This contributes to oxygen demand. Although observed ammonia concentrations range as high as 4.0 mg/l, Maryland's ammonia water quality criteria (COMAR 26.08.02.03-2H(1)) were not exceeded. Second, nitrate concentrations for the most part remain above 0.5 mg/l. Nitrate is preferred to ferric iron (III) as an electron acceptor in diagenesis. Phosphate in the sediments is bound through ferric iron. It is less likely that phosphate will be released from sediments until ferric iron is reduced in diagenesis. Thus it can be anticipated that the phosphorus release rate from the sediments will remain low.

2.2.7 Algae and Chlorophyll *a*

Figures A46 – A50 in Appendix A show the time series of maximum Chla concentrations in the surface layer at the sampling locations in Prettyboy and Loch Raven Reservoirs. The same information is presented in a different format in Tables B3 and B4 in Appendix B, showing maximum Chla concentrations by month and year, 1992-2004. As these tables indicate, Chla concentrations above 10 µg/l occur frequently but not regularly. Concentrations above 30 µg/l are infrequent but not unusual.

In Loch Raven Reservoir, the largest concentrations tend to occur in early spring or in October. Concentrations are most consistently above 10 µg/l in the summer months, and most consistently below 10 µg/l in the winter months. In Prettyboy Reservoir, in contrast, surface Chla concentrations are most consistently above 10 µg/l in late winter and early spring. Concentrations above 30 µg/l are most frequently found in March or secondarily in September and October. Surface Chla concentrations tend to be below 10 µg/l from May through July, as well as in November and December.

2.2.8 Sedimentation

The Maryland Geological Survey (MGS) performed a new bathymetry survey of Loch Raven Reservoir in 1998 (Ortt *et al*, 2000). In conjunction with the survey, MGS also estimated sedimentation rates. Average annual sedimentation rates can be described in many ways: percent loss of capacity, inches of sediment accumulation per year, or tons/mi^2/yr. The latter measure was estimated by the Reservoir Technical Group (RTG) (2004), based on the new survey. Table 6 summarizes the average sediment accumulation rate for Loch Raven Reservoir.

The annual percent capacity loss (volumetric reduction) rate in Loch Raven Reservoir, 0.13%, compares favorably with the national averages. The mean average capacity loss rate for comparably sized reservoirs is 0.43%; the median is 0.27% *(*Ortt *et al, 2000)*. However, sediment accumulation varies spatially within the reservoir. MGS estimated that the Dulaney Branch of Loch Raven has lost 8% of its capacity, the Long Quarter Branch 13% of its capacity, and the upper reservoir 19% of its capacity. Sediment deposits in the former stream channel were greater than 10 feet thick and ran as high as 59 feet thick. The survey was not able to proceed above Warren and Merryman's Mill Road bridge because the reservoir became unnavigable.

Table 6: Sedimentation Rates in Loch Raven Reservoir

Sedimentation Rates	Loch Raven (built 1923)
Total Capacity Lost Since Construction	10.8%
Annual Average Capacity Lost	0.13%
Sediment Accumulation Rate (in/yr)	0.6
Sediment Deposition Rate (tons/mi^2/year)	0.49

2.3 Water Quality Impairments

The Maryland Water Quality Standards Stream Segment Designations for Prettyboy and Loch Raven Reservoirs are Use III-P: Nontidal Cold Water and Public Water Supply (COMAR 26.08.02.08J(4)). Designated Uses present in the Prettyboy and Loch Raven Reservoirs are: 1) growth and propagation of trout and 2) public water supply.

Maryland's General Water Quality Criteria prohibit pollution of waters of the State by any material in amounts sufficient to create a nuisance or interfere directly or indirectly with designated uses (COMAR 26.08.02.03B(2)). Excessive eutrophication, indicated by elevated levels of Chla, can produce nuisance levels of algae and interfere with designated uses such as fishing and swimming. The excess algal blooms eventually die off and decompose, consuming oxygen. Excessive eutrophication in Prettyboy and Loch Raven Reservoirs is ultimately caused by nutrient overenrichment. An analysis of the available water quality data presented in Section 2.2 has demonstrated that phosphorus is the limiting nutrient. In conjunction with excessive nutrients, Loch Raven Reservoir has experienced excessive sediment loads, resulting in a shortened projected lifespan of the reservoir.

Use III waters are subject to DO criteria of not less than 6.0 mg/l daily average and 5.0 mg/l at any time (COMAR 26.08.02.03-3E(2)) unless natural conditions result in lower levels of DO (COMAR 26.08.02.03A(2)). New standards for tidal waters of the Chesapeake Bay and its tributaries take into account stratification and its impact on deeper waters. MDE recognizes that stratified reservoirs and impoundments (there are no natural lakes in Maryland) present circumstances similar to stratified tidal waters, and is applying an interim interpretation of the existing standard to allow for the impact of stratification on DO concentrations. This interpretation recognizes that, given the morphology of the reservoir or impoundment, the resulting degree of stratification, and the naturally occurring sources of organic material in the watershed, hypoxia in the hypolimnion is a natural consequence. The interim interpretation of the non-tidal DO standard, as applied to reservoirs, is as follows:

- A minimum DO concentration of 5.0 mg/l (and 6.0 mg/ daily average for Use III) will be maintained throughout the water column during periods of complete and stable mixing;
- A minimum DO concentration of 5.0 mg/l (and 6.0 mg/ daily average for Use III) will be maintained in the mixed surface layer at all times, including during stratified conditions, except during periods of overturn or other naturally-occurring disruptions of stratification; and
- Hypolimnetic hypoxia will be addressed on a case-by-case basis, taking into account morphology, degree of stratification, sources of diagenic organic material in reservoir sediments, and other such factors.

The analysis of water quality data in Section 2.2 has shown that all observed DO concentrations below 5.0 mg/l in the surface layers of Prettyboy and Loch Raven Reservoirs are associated with stratification or the mixing of stratified waters into the surface layers during periods of reservoir overturn or drawdown. On the other hand, seasonal hypoxia occurs regularly in both reservoirs in the hypolimnion.

3.0 TARGETED WATER QUALITY GOALS

The overall objective of the TMDLs proposed in this document is to reduce phosphorus and sediment loads to levels that are expected to result in the attainment of the water quality criteria that support the Use III-P designation for Loch Raven and Prettyboy Reservoirs. The Chla endpoints selected for the reservoirs are (1) a maximum permissible instantaneous chlorophyll concentration of 30 µg/l in the surface layers and (2) a 30-day moving average concentration not to exceed 10 µg/l in the surface layers. A concentration of 10 µg/l corresponds to a score of approximately 53 on the Carlson Trophic State Index (TSI). This is the approximate boundary between mesotrophic and eutrophic conditions, which is an appropriate trophic state at which to manage these reservoirs. Mean Chla concentrations exceeding 10 ug/l are associated with peaks exceeding 30 ug/l, which in turn are associated with a shift to blue-green assemblages,

which present taste, odor and treatment problems (Walker 1984). These Chla endpoints should thus avoid nuisance algal blooms. Reduction of the phosphorus loads is predicted to reduce excessive algal growth and therefore prevent violations of narrative criteria associated with nuisances, such as taste and odor problems.

In summary, the TMDLs for phosphorus and sediment are intended to:

1. Resolve violations of narrative criteria associated with phosphorus enrichment of Prettyboy and Loch Raven Reservoirs, leading to excessive algal growth;
2. Resolve violations of narrative criteria associated with excess sedimentation of Loch Raven Reservoir; and
3. Assure both Prettyboy and Loch Raven Reservoirs meet the interim interpretation of the non-tidal DO criteria, as applied to reservoirs.

4.0 TOTAL MAXIMUM DAILY LOADS (TMDLs) AND ALLOCATIONS

4.1 Overview

Section 4.2 describes the modeling framework for simulating hydrodynamics, nutrient and sediment loads, and water quality responses in Prettyboy and Loch Raven Reservoirs. Section 4.3 describes the baseline scenario developed on the basis of modeling results. Section 4.4 explains how the nutrient TMDLs and load allocations for point sources and nonpoint sources were developed for the reservoirs, based on computer modeling of the water quality response to reduced nutrient and sediment loads. Section 4.5 presents the modeling results in the proper format for TMDLs and allocates the TMDLs between point sources and nonpoint sources. Section 4.6 explains the rationale for the margin of safety. Finally, the elements of the equations are combined in a summary of TMDLs for total phosphorus for both Prettyboy and Loch Raven Reservoirs, as well as a TMDL for sediments for Loch Raven Reservoir.

4.2 Computer Modeling Framework

To develop a TMDL, a linkage must be defined between the selected targets or goals and the identified sources. This linkage establishes the cause-and-effect relationship between the pollutant of concern and the pollutant sources. The relationship can vary seasonally, particularly for nonpoint sources, with factors such as precipitation. Once defined, the linkage yields the estimate of total loading capacity or TMDL (U.S. EPA, 1999).

CE-QUAL-W2 is a laterally averaged two-dimensional computer simulation model, capable in its most recent formulations of representing the hydrodynamics and water quality of rivers, lakes, and estuaries. It is particularly suited for representing temperature stratification that occurs in reservoirs like Prettyboy and Loch Raven. The W2 reservoir models were used to simulate not only hydrodynamics and temperature but dissolved oxygen and eutrophication dynamics as well. The reservoir models use version

3.2 of CE-QUAL-W2. Cole and Wells (2003) give a general description of the CE-QUAL-W2 model.

Prettyboy Reservoir was represented by eighteen active longitudinal segments in two branches. Each segment contains from four to thirty one-meter thick layers. Loch Raven Reservoir is represented by a single branch of sixteen segments, each with four to sixteen one-meter thick layers. The simulation period was set to 1992-1997 to coincide with the Gunpowder HSPF Model. These six years provide a range of hydrological conditions, including wet years (1993, 1996), dry years (1992, 1997), and average years (1994, 1995), thus fulfilling the requirement that TMDLs take into account a variety of hydrological conditions. Each year was simulated separately, and observed data, where available, were used to set the initial conditions for the simulation.

State variables in the CE-QUAL-W2 model include dissolved oxygen, ammonia, nitrate, dissolved inorganic phosphorus, and both dissolved and particulate organic matter (POM) in labile and refractory forms. In addition, any number of inorganic solids, carbonaceous biochemical oxygen demand (CBOD) variables or algal species can be represented in the model. Organic nitrogen and phosphorus, however, are only implicitly represented through CBOD, organic matter, and algal biomass state variables. In order to preserve a mass balance of all species of phosphorus, the state variables in the W2 models were configured as follows:

1. Inorganic phosphorus attached to silt and clay was modeled as distinct inorganic solids. Sorption between sediment and the water column was not simulated in the model.
2. Three biochemical oxygen demand (BOD) variables were used to represent allochthonous organic matter inputs to the reservoirs: (1) labile dissolved BOD, labile particulate CBOD, and refractory particulate CBOD. The concentration of these CBOD inputs were calculated based on the concentration of organic phosphorus determined by the HSPF model, using the stoichiometric ratio between phosphorus and oxygen demand in the reservoir models.
3. The organic matter state variables were reserved to represent the recycling of nutrients within the reservoir between algal biomass and reservoir nutrient pools. No organic matter, as represented by these variables, was input into the reservoirs. They were used to track nutrients released from algal decomposition.

To use the W2 model in this configuration, several minor changes had to be made to the W2 code. Inorganic solids contribute to light extinction but inorganic solids representing solid-phase phosphorus do not contribute to light extinction over and above the sediment to which they are attached. The W2 code was altered so solid-phase phosphorus would not contribute to light extinction. Second, in the W2 model, sediment oxygen demand (SOD) can be represented as a first-order reaction based on the quantity of labile organic matter that has settled to the bottom of a segment. In the original code the CBOD variables do not settle and do not contribute to the pool of organic material in the sediments. The code was altered so that (1) CBOD species could be assigned a settling

velocity and (2) labile particulate CBOD contributed to sediment organic matter. Each year's simulation was initialized with the final concentrations of sediment organic matter from the previous year's simulation, because no observations of sediment organic matter were available.

4.3 Scenario Descriptions and Results

4.3.1 Scenario Descriptions

TMDL development for the Gunpowder reservoirs involved the following four scenarios:

1. **Calibration Scenario**: The Calibration Scenario represents actual loads over the simulation period 1992-1997. As the name suggests, the loads in this scenario were used to calibrate the CE-QUAL-W2 models of Prettyboy and Loch Raven Reservoirs. Loads from wastewater treatment plants and other point source dischargers are based on reported flows and concentrations for the period. Loads from developed land falling under the National Pollutant Discharge Elimination System (NPDES) permit for stormwater facilities, as well as nonpoint source loads from forests and agricultural land, were determined through the calibration of the Gunpowder Falls HSPF Model.

2. **Baseline Scenario**: The Baseline Scenario differs from the Calibration Scenario only in that design flows and concentrations at the permitted limits are used to determine loads from wastewater treatment plants and other point source dischargers. Loads from developed land under Municipal Separate Storm Sewer System (MS4) permits and nonpoint source loads are the same as in the Calibration Scenario.

3. **TMDL Scenario**: The TMDL Scenario represents the maximum allowable loads from developed land falling under NPDES stormwater permits and the maximum allowable loads from nonpoint sources such that computer simulation predicts water quality standards will be met in Prettyboy and Loch Raven Reservoirs. Loads from permitted dischargers are calculated based on the design flow of the permit and the maximum permitted concentration.

4. **All-Forest Scenario**: The All-Forest Scenario simulates the response of the reservoirs to the phosphorus, sediment, nitrogen, and BOD loading rates that would occur if all of the land in the reservoirs' watersheds were forested. The All-Forest Scenario is used to determine to what extent hypoxic conditions in the hypolimnion are a function of external loading rates or reservoir morphology. The All-Forest Scenario constitutes an estimate of hypolimnetic DO concentrations under natural conditions. Flows and temperature were taken from the Calibration Scenario, while constituent loads were taken from the HSPF model simulation whereby all land in the watershed was forested.

4.3.2 Calibration Scenario Results

The primary function of the CE-QUAL-W2 models of Prettyboy and Loch Raven Reservoirs is to link algae biomass concentrations, as represented by Chla concentrations, to total phosphorus loads. The models were calibrated conservatively, to ensure that simulated Chla concentrations were at least as high as observed concentrations, even if maximum seasonal concentrations were shifted upstream or downstream in simulation, or occurred a month earlier or later than the corresponding observed concentrations.

Figures B1 and B2 in Appendix B compare simulated and observed maximum Chla concentrations in the surface layers of Prettyboy and Loch Raven Reservoirs, respectively, by sampling date. The models capture the observed peak seasonal average Chla concentrations, though sometimes shifted spatially or temporally. Similarly, Figures B3 and B4 show the cumulative distribution of simulated and observed maximum Chla concentrations. In both reservoirs, simulated concentrations are higher than observed concentrations above the 10 µg/l level, demonstrating further the conservative character of the calibration.

Figures B5 and B6 in Appendix B compare simulated and observed average surface DO concentrations at the lower sampling locations in Prettyboy and Loch Raven Reservoir, respectively. The models follow the seasonal trend in DO but tend to over-simulate DO in winter and under-simulate DO in summer. Figures B7 and B8 show the simulated and observed average bottom DO concentrations. The models capture the seasonal trend in bottom DO. The coefficients of determination between observed and simulated values are 0.80 and 0.81 for Prettyboy and Loch Raven Reservoirs, respectively.

Appendix C contains time series plots comparing simulated and observed concentrations at other locations. It also shows time series plots for total phosphorus, nitrate, and ammonia.

4.3.3 Baseline Scenario Results

Wastewater treatment plants and other permitted point sources contribute less than 1% of the total phosphorus load to Prettyboy and Loch Raven Reservoirs and an insignificant amount to the sediment load to Loch Raven Reservoir. The results of the Baseline Scenario are indistinguishable from the Calibration Scenario.

4.3.4 TMDL Scenario Results

The CE-QUAL-W2 models of Prettyboy and Loch Raven Reservoirs were used to determine the maximum total phosphorus loads compatible with water quality standards. Simulated loads were reduced until two conditions were met: (1) no simulated Chla concentration in any cell was above 30 µg/l, and (2) the 30-day moving average Chla concentration of each modeling cell within 15 meters of the surface was not greater than 10 µg/l. Figures B9 and B10 in Appendix B compare maximum Chla concentrations by

date under the Calibration and TMDL Scenarios to observed concentrations in the surface layer of Prettyboy and Loch Raven Reservoirs, respectively.

The TMDL Scenario was also analyzed to determine whether the reservoirs would meet the DO criteria for Use III-P waters under TMDL loading rates. Figures B11 and B12 show the average surface DO concentrations at the lower sampling locations in Prettyboy and Loch Raven Reservoirs, based on a screening depth of 20 feet. To more accurately screen for potential violations, the position of the well-mixed surface layer was more precisely determined on a daily basis. Instantaneous DO concentrations were output from all cells in the surface layer at 0.1-day intervals; the daily average DO concentration was also calculated for each cell in the surface layer. Under the TMDL scenario, there is no cell in the surface layer of either reservoir with an instantaneous DO concentration less than 5.0 mg/l, or a daily average DO concentration of less than 6.0 mg/l, except during periods such as the fall overturn when the surface layer deepens and entrains water with low DO concentrations from the metalimnion.

Seasonal hypoxia persists in the hypolimnion in both reservoirs even under the TMDL Scenario. Figures B13 and B14 in Appendix B show the average bottom DO concentrations at the lower sampling locations in Prettyboy and Loch Raven Reservoirs. As the figures indicate, although the average DO in the bottom layers improves under the TMDL Scenario, neither reservoir maintains a DO concentration of 5.0 mg/l in the hypolimnion throughout the simulation period.

4.3.5 All-Forest Scenario Results

As explained earlier, the purpose of the All-Forest Scenario is to help determine whether hypoxia in the bottom layers of Prettyboy and Loch Raven Reservoirs is primarily due to the stratification induced by reservoir morphology, or to input loads. If hypoxia occurs even under all-forested loading rates, then reservoir stratification is the primary cause of hypoxia and it can be concluded that the reservoir meets the water quality standards for DO as described in Section 2.3.

Average annual TP loads in the All-Forest Scenario are 20% of the load in the Calibration Scenario in Prettyboy Reservoir, and 28% of the load in the Calibration Scenario in Loch Raven Reservoir. The reduction in average annual loads of POM, the precursor to sediment oxygen demand, is not as large. Average annual POM loads in the All-Forest Scenario are 29% of the load in Calibration Scenario in Prettyboy and 41% of the load in Calibration Scenario in Loch Raven. The load decrease is less in the Loch Raven watershed because of the high percentage of forested and developed land.

Figures 13 and 14 below show the average bottom DO concentrations at lower sampling locations in the reservoirs under the All-Forest Scenario. Minimum concentrations at the sampling locations are also shown.

Average DO in the bottom layers of both reservoirs improves considerably under the All-Forest Scenario. The minimum DO concentration, however, frequently drops below 5.0 mg/l. Even under the All-Forest Scenario, the hypolimnion remains hypoxic in many (but not all) years of the simulation. The hypoxia tends to be worse in the lower stations of the reservoirs where the depths are greatest.

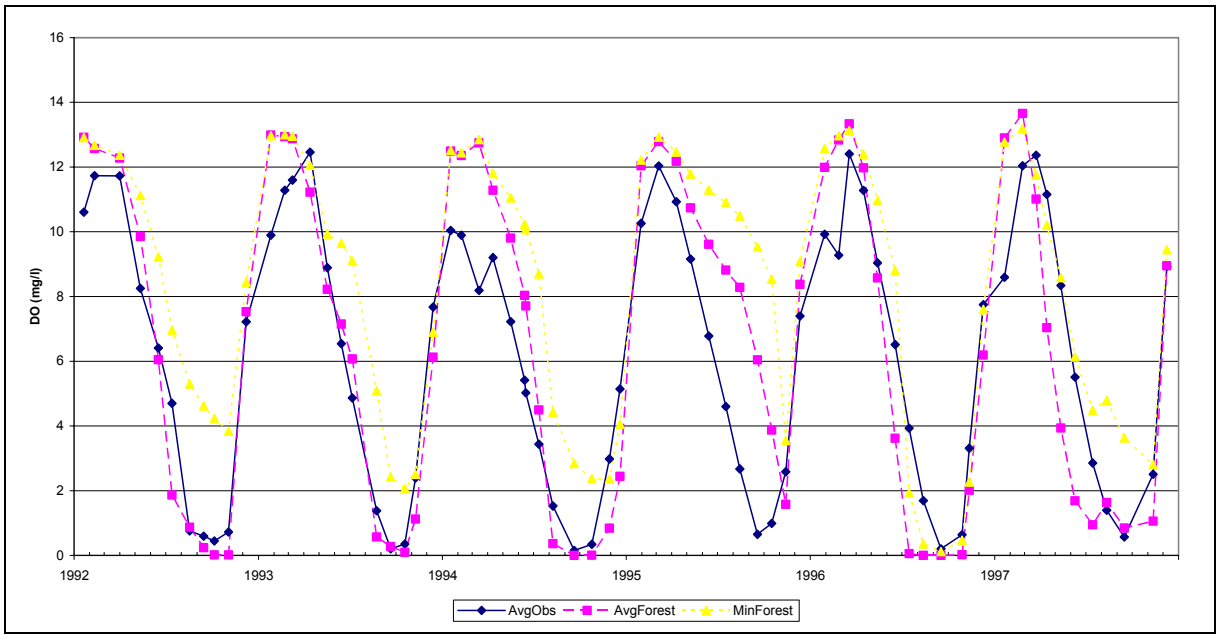

Figure 13: Observed and Simulated Average Bottom DO Concentrations, Lower Stations, All-Forest Scenario, Prettyboy Reservoir

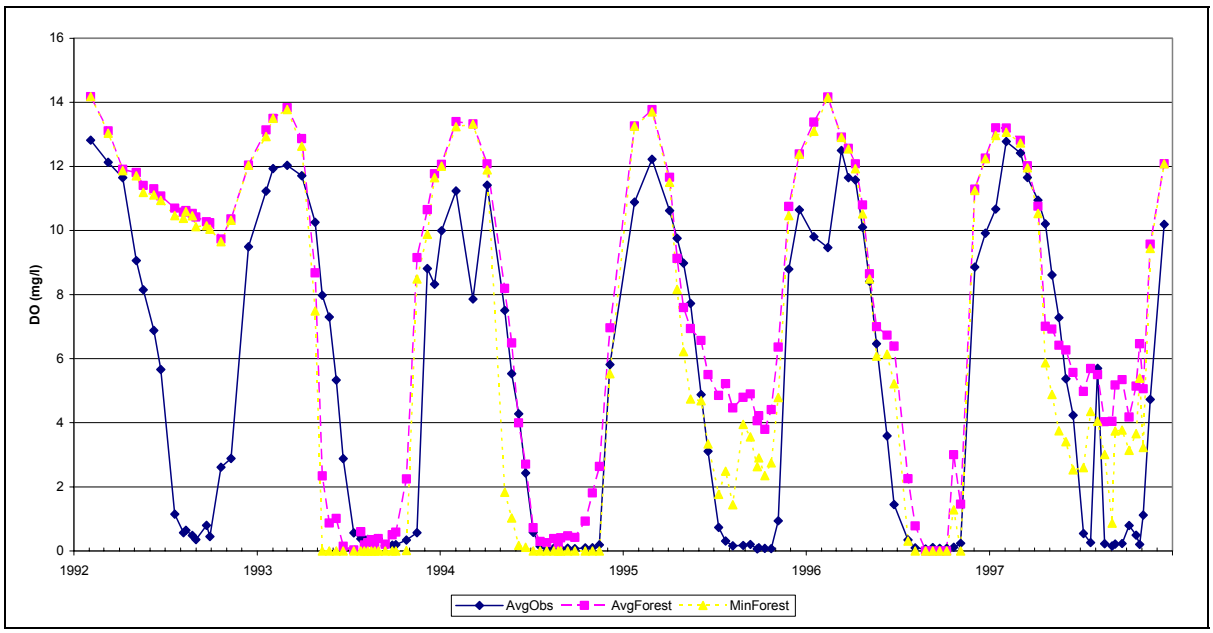

Figure 14: Observed and Simulated Average Bottom DO Concentrations, Lower Stations, All-Forest Scenario, Loch Raven Reservoir

A sensitivity analysis was performed to better determine how phosphorus and organic matter loading rates impact hypoxia in the hypolimnion. POM and TP loading rates were reduced to 50%, 20% and 10% of the loads of the All-Forest Scenario, and the percent of sampling dates where DO < 2.0 mg/l at the sampling locations was calculated. Figure 15 shows the results. Significant hypoxia persists even when loads are reduced to only 10% of the All-Forest Scenario, particularly in Prettyboy Reservoir, which is deeper than Loch Raven even though it has less volume. The sensitivity analysis shows that low DO in the bottom layers of the reservoirs is relatively insensitive to the particular assumptions used to determine organic matter loads in the models, and demonstrates that hypolimnetic hypoxia is primarily driven by stratification and reservoir morphology, rather than by external loads. The All-Forest Scenario demonstrates that current loads, and loads simulated under the TMDL Scenario, do not result in hypoxia that significantly exceeds that associated with natural conditions in the watershed. Low DO concentrations in the bottom layers of the reservoirs are therefore a naturally occurring condition, as described by the interim interpretation of Maryland's water quality standards. The TMDL Scenario thus meets water quality standards for DO under the interim interpretation.

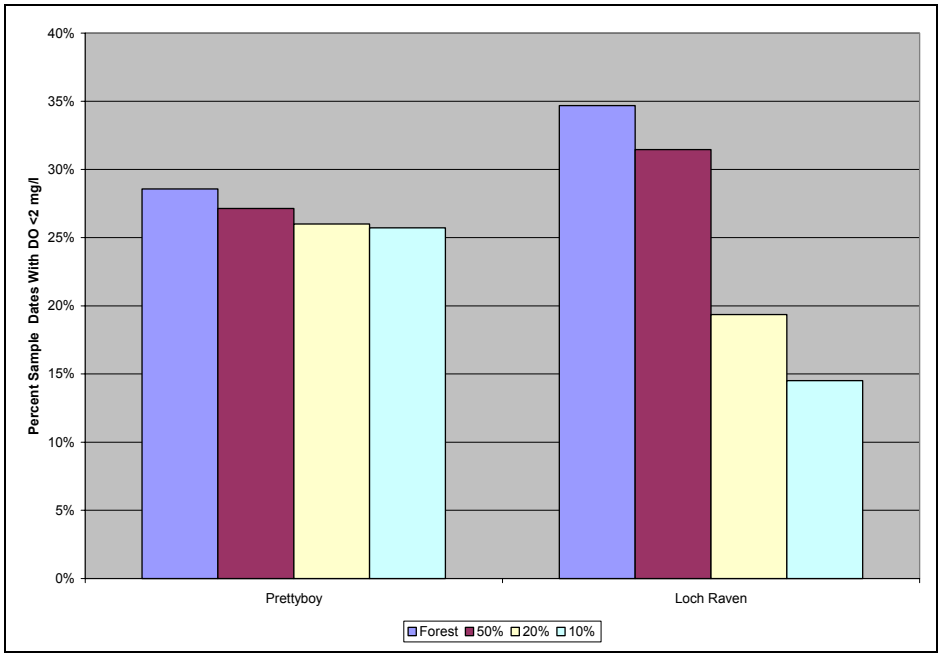

Figure 15: Percent of Sampling Dates on which DO < 2.0 mg/l as a function of proportion of All-Forest Scenario

4.4 TMDL Loading Caps

4.4.1 Phosphorus TMDL Loading Caps

This section presents the TMDLs for phosphorus for Prettyboy and Loch Raven Reservoirs. The TMDLs were estimated based on the phosphorus loadings as explained in Section 4.3 and the resulting water quality in the reservoirs for the simulated years 1992-1997. This period was selected to estimate the TMDLs because it covers a period that includes dry years as well as very wet years and thus takes into account a variety of hydrological conditions. Chla concentrations indicative of eutrophic conditions can occur at any time of year, and the simulation period encompasses the spectrum of observed seasonal concentrations (see Tables B3 and B4, Appendix B). Seasonal low DO concentrations in the hypolimnia that occur regularly each year are also represented in the simulation models.

TMDL loads were calculated on an average annual basis. The average residence time of Loch Raven Reservoir is approximately three to four months while the residence time of Prettyboy is approximately one year. Water quality conditions in both reservoirs are the cumulative result of loadings that span seasons, or even, in the case of hypolimnetic hypoxia, years. Average annual TP loads are therefore the appropriate measure in which to express nutrient TMDLs for Prettyboy and Loch Raven Reservoirs.

For Prettyboy Reservoir:

Total Phosphorus TMDL 23,192 lbs/year

For Loch Raven Reservoir:

Total Phosphorus TMDL 55,098 lbs/year

The TMDLs reflect a reduction of 54% from baseline TP loads in Prettyboy Reservoir and 50% from baseline loads in Loch Raven Reservoir.

Average Daily Loads:

In Prettyboy Reservoir, the average annual TMDL for TP will result in average daily TP loads of approximately 63.54 lbs/day. In Loch Raven Reservoir, the average annual TMDL for TP will result in average daily TP loads of approximately 150.95 lbs/day.

4.4.2 Sediment TMDL Loading Caps for Loch Raven Reservoir

Excessive sedimentation reduces a reservoir's storage capacity and therefore negatively impacts its ability to function as a water supply reservoir. Excessive sedimentation can also negatively impact a reservoir's fishery and interfere with its recreational uses. Although the maximum sedimentation rates occur during wet weather events, it is the cumulative effect of sedimentation that impacts the reservoir. No single critical period can be defined for the water quality impact of sedimentation. An excessive sedimentation rate negatively impacts a reservoir regardless of when it occurs.

Therefore, the efforts to reduce sediment loading to the lake should focus on achieving effective, long-term sediment control. Since some measures to control phosphorus from agriculture sources can also effectively reduce sedimentation, the expected sediment reduction can be estimated based on the degree of phosphorus control needed to improve the water quality of the reservoir.

To quantify the sediment reduction associated with this phosphorus reduction, the EPA Chesapeake Bay Program watershed modeling assumptions were consulted. For the agricultural best management practices (BMPs) that affect both phosphorus and sediments, EPA estimates a 1-to-1 reduction in sediments as a result of controlling phosphorus (EPA, Chesapeake Bay Program Office, 1998). However, this ratio does not account for phosphorus controls that do not remove sediments.

To estimate the applicable ratio, hence the sediment load reduction, it is necessary to estimate the proportion of the phosphorus reduction controls that remove sediments versus those that do not. In general, soil conservation and water quality plans (SCWQPs) remove sediments along with the phosphorus removal, while nutrient management plans (NMPs) do not. It has been assumed that 50% of the phosphorus reduction will come from SCWQPs and 50% from NMPs. This results in a 0.5-to-1 ratio of sediment reduction to phosphorus reduction. The net sediment reduction associated with a 50% NPS phosphorus reduction is about 25% (0.50 * 0.5 = 0.25).

It is assumed that this reduced sediment loading rate would result in a similar reduction in the sediment accumulation rate. The sediment accumulation rate predicted to result from this reduced loading rate would allow for the retention of 85% of the overall impoundment's original volume after 50 years. More important, it will reduce loss of volume in the upper reservoir, which otherwise would have less than 70% of its original capacity after 50 years. Under the TMDL loading cap, the upper reservoir may retain as much as 80% of its original capacity if the reduction in loading rates reduces volumetric loss at a rate proportionate to current capacity loss.

MDE believes that this volumetric retention will support the designated uses of Loch Raven Reservoir (Use III-P) for which it is protected: naturally-breeding trout and public water supply. This estimate is reasonably consistent with technical guidance provided by EPA Region III of a 0.7-to-1.0 reduction in sediment in relation to the reduction in phosphorus. (EPA, 1998) This rule-of-thumb would yield a 35% estimated reduction in sediment [100*(0.7 * 0.50) = 35%]

Assuming that a 50% reduction in total phosphorus load results in a 25% reduction in sediment load, the sediment loading cap for Loch Raven Reservoir is as follows:

For Loch Raven Reservoir:

Sediment TMDL	**28,925 tons/year**

Average Daily Loads:
In Loch Raven Reservoir, the average annual TMDL for sediment will result in average daily sediment loads of approximately 79.25 tons/day.

4.5 Total Load Allocations Between Point Sources and Nonpoint Sources

The allocations described in this section demonstrate how the TMDLs can be implemented to achieve water quality standards in Prettyboy and Loch Raven Reservoirs. Specifically, these allocations show that the sum of phosphorus loadings to the reservoirs from existing point and nonpoint sources can be maintained safely within the TMDLs established herein. The State reserves the right to revise these allocations provided such revisions are consistent with the achievement of water quality standards.

Phosphorus TMDL Allocations

- Nonpoint Source (NPS) Loads

  Nonpoint source loads including agricultural and forest loads are assigned to the TMDL as the Load Allocation (LA). The Calibration and Baseline Scenario loads were based on the HSPF model of the Gunpowder Falls Watershed. The modeling of the watershed accounted for both natural and human-induced components, including atmospheric deposition and septic loadings. Details on the HSPF model can be found in *Modeling Framework for Simulating Hydrodynamics and Water Quality in Prettyboy and Loch Raven Reservoirs* (ICPRB and MDE, 2006).

- Stormwater Loads

  In November 2002, EPA advised States that NPDES-regulated storm water discharges must be addressed by the wasteload allocation (WLA) component of a TMDL. See 40 C.F.R. § 130.2(h). NPDES-regulated storm water discharges may not be addressed by the load allocation (LA) component of a TMDL. EPA also provided guidance on ways to reflect the TMDL stormwater wasteload allocation (WLA). The stormwater phosphorus loads simulated in the TMDL scenario represent a 15% reduction in TP from baseline urban stormwater loads. Urban stormwater loads are now part of the WLA.

  Current stormwater Phase I individual permits and new stormwater Phase II permits are considered point sources subject to WLA assignment in the TMDL, instead of LA

assignment as in the past. EPA recognizes that limitations in the available data and information usually preclude stormwater allocations to specific outfalls. Therefore, the Agency guidance allows this stormwater WLA to be expressed as a gross allotment, rather than individual allocations for separate pipes, ditches, construction sites, etc. Available information for the Gunpowder Falls watershed allows the stormwater WLA for this analysis to be defined separately for Carroll and Baltimore Counties; however, these WLAs aggregate municipal and industrial stormwater, including the loads from construction activity.

Waste load allocations from point source dischargers are usually based on the relative contribution of pollutant load to the waterbody. Estimating a load contribution to a particular waterbody from the stormwater Phase I and II sources is imprecise, given the variability in sources, runoff volumes, and pollutant loads over time. Therefore, any stormwater WLA portion of the TMDL is based on a rough estimate.

- Wastewater Treatment Plant Loads

  In addition to nonpoint source loads and stormwater point sources, waste load allocations to the Hampstead and Manchester WWTP plus a 5% MOS, estimated as explained in the next section, make up the balance of the total allowable load. The Hampstead WWTP maximum allowable design flow of 0.9 MGD is used for this scenario. The total phosphorus limit at Hampstead is 0.3 mg/l year round. The Manchester WWTP maximum allowable current permit flow of 0.5 MGD is used for this scenario; discharges to surface water occur only from December through March. The total phosphorus limit at Manchester is 1.0 mg/l *when discharges occur*. All significant point sources are addressed by this allocation and are described further in the technical memorandum entitled "*Significant Nutrient and Sediment Point Sources in the Prettyboy and Loch Raven Reservoir Watersheds.*"

The TMDL, including loads from stormwater discharges, is now expressed as:

TMDL = WLA [non-stormwater point sources + regulated stormwater point source] + LA + MOS

The phosphorus allocations for Prettyboy and Loch Raven Reservoirs are presented in Table 7.

Table 7: Total Phosphorus Allocations (lbs/yr) for Prettyboy and Loch Raven Reservoirs

	Prettyboy Reservoir	Loch Raven Reservoir
Nonpoint Source[1]	19,092	30,184
Point Source[2]	2,940	22,010
Margin of Safety[3]	1,160	2,747
Total Maximum Daily Load	23,192	54,941

[1] Excludng urban stormwater loads.
[2]Including urban stormwater loads.
[3]Representing 5% of baseline nonpoint source and urban stormwater loads.

4.5.1 Sediment Load Allocations for Loch Raven Reservoir

- Nonpoint Source (NPS) Loads

  Nonpoint source loads including agricultural and forest loads are assigned to the TMDL as LA. The Calibration and Baseline Scenario loads were based on the HSPF model of the Gunpowder Falls Watershed. The modeling of the watershed accounted for both natural and human-induced components. The LA to nonpoint sources below the Prettyboy Dam represents a decrease of approximately 25% from baseline loads. Sediment loads from Prettyboy Reservoir are less than 2% of total sediment load. Details on the HSPF model can be found in *Modeling Framework for Simulating Hydrodynamics and Water Quality in Prettyboy and Loch Raven Reservoirs* (ICPRB and MDE, 2006).

- Stormwater PS Loads

  The reduction in total phosphorus loads from stormwater discharges will result in a reduction in sediment loads, but because of the uncertainty in BMP efficiencies for developed land, no reduction is assumed for sediment loads from stormwater discharges, and their share of the WLA is set equal to baseline conditions.

- Wastewater Treatment Plant Loads

  The waste load allocation to the Hampstead WWTP makes up the balance of the total allowable load. The Hampstead WWTP maximum allowable current permit flow of 0.9 MGD is used for this scenario. The total suspended solids limit is 30.0 mg/l year round. All significant point sources are addressed by this allocation and are described further in the technical memorandum entitled "*Significant Nutrient and Sediment Point Sources in the Prettyboy and Loch Raven Reservoir Watersheds*".

- Permitted Industrial Facilities

There are three industrial facilities with permits regulating the discharge of total suspended solids in the Loch Raven Reservoir watershed. Only one of them, the Lafarge Mid-Atlantic and Imerys facility, has even the potential to discharge significant sediment loads. The waste load allocation for the quarry was set as the product of maximum recorded average discharge at each of the two permitted outfalls and a suspended solids limit of 15 mg/l and 17 mg/l for the respective outfalls. The waste load allocation for the two other industrial facilities was also set as a product of the maximum recorded average flow and the permitted suspended solids concentration. All significant industrial point sources are addressed by this allocation and are described further in the technical memorandum entitled "*Significant Nutrient and Sediment Point Sources in the Prettyboy and Loch Raven Reservoir Watersheds*".

The TMDL for Suspended Sediment in Loch Raven Reservoir is as follows:

TMDL (tons/yr)	**=**	**LA**	**+**	**WLA**	**+**	**MOS**
28,925	**=**	**27,807**		**1,118**		**implicit**

4.6 Margins of Safety

A MOS is required as part of a TMDL in recognition of many uncertainties in the understanding and simulation of water quality in natural systems. For example, knowledge is incomplete regarding the exact nature and magnitude of pollutant loads from various sources and the specific impacts of those pollutants on the chemical and biological quality of complex, natural waterbodies. The MOS is intended to account for such uncertainties in a manner that is conservative from the standpoint of environmental protection.

Based on EPA guidance, the MOS can be achieved through two approaches (EPA, April 1991). One approach is to reserve a portion of the loading capacity as a separate term in the TMDL (*i.e.*, TMDL = Load Allocation (LA) + Waste Load Allocation (WLA) + MOS). The second approach is to incorporate the MOS as conservative assumptions used in the TMDL analysis. Maryland has adopted a MOS for nutrient TMDLs using the first approach. The reserved load allocated to the MOS was computed as 5% of the total loads for phosphorus. These explicit phosphorus margins of safety are **1,160 lbs/yr** for Prettyboy Reservoir, and **2,747 lbs/yr** for Loch Raven Reservoir.

In establishing a MOS for sediments, Maryland has adopted an implicit approach by incorporating conservative assumptions. First, because phosphorus binds to sediments, sediments will be controlled as a result of controlling phosphorus. This estimate of sediment reduction is based on the load allocation of phosphorus (4,150 lbs/yr), rather

than the entire phosphorus TMDL including the MOS. Thus, the explicit 5% MOS for phosphorus will result in an implicit MOS for sediments. This conservative assumption results in a difference of about 5,099 tons/yr (see Section 4.5 above for a discussion of the relationship between reductions in phosphorus and sediments). Secondly, as described in Section 4.4.2, MDE conservatively assumes a sediment-to-phosphorus reduction ratio of 0.5:1, rather than 0.7:1 sediment-to-phosphorus reduction ratio given in the technical guidance provided by EPA Region III. Table 8 compares the volumetric preservation under TMDL conditions in Loch Raven Reservoir with that of several other approved TMDLs.

Table 8: Volumetric Preservation of Various Impoundments Under Sediment TMDL Conditions

TMDL	VOLUMETRIC PRESERVATION (TMDL time-span)	VOLUMETRIC PRESERVATION (100 year time span)
Urieville Community Lake (MD)	76% after 40 years	40%
Tony Tank Lake (MD)	64% – 85% after 40 years	10% to 62.5%
Hurricane Lake (WV)	70% after 40 yrs	25%
Tomlinson Run Lake (WV)	30% after 40 yrs	Silted in
Clopper Lake (MD)	98% - 99% after 40 years	96% to 98%
Centennial Lake (MD)	68% - 87% after 40 years	20% to 69%
Lake Linganore (MD)	52% - 80% after 40 years	Silted in to 52%
Loch Raven Reservoir (MD)	85% after 50 years	80%

4.7 Summary of Total Maximum Daily Loads

The following equations summarize the nutrient TMDLs for Prettyboy and Loch Raven Reservoirs, and the sediment TMDL for Loch Raven Reservoir:

For Total Phosphorus in Prettyboy Reservoir:

TMDL (lbs/yr)	**=**	**LA**	**+**	**WLA**	**+**	**MOS**
23,192	**=**	**19,092**		**2,940**		**1,160**

For Total Phosphorus in Loch Raven Reservoir:

TMDL (lbs/yr)	**=**	**LA**	**+**	**WLA**	**+**	**MOS**
55,098	**=**	**30,184**		**22,010**		**2,747**

For Suspended Sediment in Loch Raven Reservoir:

TMDL (tons/yr)	=	LA +	WLA +	MOS
28,925	**=**	**27,774**	**1,151**	**implicit**

5.0 ASSURANCE OF IMPLEMENTATION

This section provides the basis for reasonable assurances that the phosphorus and sediment TMDLs will be achieved and maintained. For both TMDLs, Maryland has several well-established programs that may be drawn upon: the Water Quality Improvement Act of 1998 (WQIA), the Clean Water Action Plan (CWAP) framework, and the Chesapeake Bay Agreement's Tributary Strategies for Nutrient Reduction. Also, Maryland has adopted procedures to assure that future evaluations are conducted for all TMDLs that are established.

The Hampstead WWTP will continue to meet the requirements of its NPDES discharge permit, which since 1997 requires an effluent phosphorus concentration below 0.3 mg/l and a total suspended solids concentration less than 30 mg/l. The Manchester WWTP will continue to meet the requirements of its NPDES discharge permit, which requires it to use spray irrigation to dispose of its wastewater discharge April through November, and to meet an effluent concentration limit of 1.0 mg/l TP and 30 mg/l TSS when discharging to surface water December through March.

Maryland's WQIA requires that comprehensive and enforceable nutrient management plans be developed, approved and implemented for all agricultural lands throughout Maryland. This act specifically requires that nutrient management plans for nitrogen be developed and implemented by 2002, and plans for phosphorus be completed by 2005. Maryland's CWAP has been developed in a coordinated manner with the State's 303(d) process. All Category I watersheds identified in Maryland's Unified Watershed Assessment process are totally coincident with the impaired waters list for 2002 approved by EPA. The State is giving a high priority for funding assessment and restoration activities to these watersheds.

In 1983, the States of Maryland, Pennsylvania, and Virginia, the District of Columbia, the Chesapeake Bay Commission, and the U.S. EPA joined in a partnership to restore the Chesapeake Bay. In 1987, through the Chesapeake Bay Agreement, Maryland made a commitment to reduce nutrient loads to the Chesapeake Bay. In 1992, the Chesapeake Bay Agreement was amended to include the development and implementation of plans to achieve these nutrient reduction goals. Maryland's resultant Tributary Strategies for Nutrient Reduction provide a framework supporting the implementation of nonpoint source controls in the Upper Western Shore Tributary Strategy Basin, which includes the Gunpowder Falls watershed. Maryland is in the forefront of implementing quantifiable

nonpoint source controls through the Tributary Strategy efforts. This will help to ensure that nutrient control activities are targeted to areas in which nutrient TMDLs have been established.

In November 1990, EPA required jurisdictions with a population greater than 100,000 to apply for NPDES Permits for stormwater discharges. In 1983, the EPA Nationwide Urban Runoff Program found that stormwater runoff from urban areas contains the same general types of pollutants found in wastewater, and that 30% of identified cases of water quality impairment were attributable to stormwater discharges. The two Maryland jurisdictions where the majority of the Loch Raven and Prettyboy watersheds are located, Carroll County and Baltimore County, are required to participate in the stormwater NPDES program, and have to comply with the NPDES Permit regulations for stormwater discharges. Several management programs have been implemented in different areas served by the counties. These jurisdiction-wide programs are designed to control stormwater discharges to the maximum extent practicable.

Since 1979, Baltimore City, Baltimore County and Carroll County have had in place a formal agreement to manage the reservoir watersheds and, since 1984, these agreements have been accompanied by an action strategy with specific commitments from the signatories. A revised Reservoir Watershed Management Agreement was signed in 2005, accompanied by a revised Action Strategy. Table 9 lists the parties to the 2005 agreement and some of their major commitments made in the Action Strategy.

In June 2005, the Baltimore County Department of Environmental Protection and Resource Management, in cooperation with the Maryland Department of the Environment and other stakeholders in the region, began to develop a Watershed Restoration Action Strategy (WRAS) document for Prettyboy Reservoir. The purpose of the document is to present a strategy to reduce NPS pollution that contribute to impairments in the watershed, while at the same time conserving the unique, high quality natural resources. The strategy is developed through the combined efforts of the general public, watershed stakeholders, local and county governments, non-profit organizations and State and Federal agencies. The document outlines the conditions in the watershed, the potential sources of pollution and impairments, and actions that can be taken to address these issues. It is anticipated that this strategy, scheduled for completion in late 2006, will assure TMDL implementation for nonpoint sources.

Finally, Maryland uses a five-year watershed cycling strategy to manage its waters. Pursuant to this strategy, the State is divided into five regions and management activities will cycle through those regions over a five-year period. The cycle begins with intensive monitoring, followed by computer modeling, TMDL development, implementation activities, and follow-up evaluation. The choice of a five-year cycle is motivated by the five-year federal NPDES permit cycle. This continuing cycle ensures that every five years intensive follow-up monitoring will be performed. Thus, the watershed cycling strategy establishes a TMDL evaluation process that assures accountability.

Table 9: Signatories to the 2005 Reservoir Management Agreement and Their Major Commitments under the 2005 Action Strategy (RTG, 2005)

Maryland Department of the Environment	1. Use NPDES program to discourage significant phosphorus discharges in reservoir watersheds from package plants and new industrial dischargers.
Maryland Department of Agriculture	1. Enforce the provisions of Maryland Water Quality Improvement Act of 1998. 2. Offer assistance through the Maryland Agriculture Cost-Share Program. 3. Target assistance to farm operations having problems with the potential to cause water pollution.
Baltimore City	1. Continue water quality monitoring of reservoirs.
Baltimore County	1. Continued water quality monitoring of tributaries. 2. Maintain Resource Conservation zoning in the reservoir watersheds and maintain insofar as possible the Urban-Rural Demarcation Line. 3. Conduct programs of street-sweeping, storm drain-inlet cleaning, and storm pipe cleaning in urban areas.
Carroll County	1. Require enhanced stormwater management practices for all new development in reservoir watersheds. 2. Use master land-use plans to support Reservoir Management Agreement. 3. Limit insofar as possible additional urban development zoning with the reservoir watersheds.
Baltimore County Soil Conservation District Carroll County Soil Conservation District	1. Encourage farmers to participate in federal and state assistance programs that promote soil conservation and the protection of water quality. 2. Prepare Soil Conservation and Water Quality Plans for each farm in the reservoir watersheds, update plans where necessary, and assist operators in implementing them. 3. Encourage and assist operators to comply with nutrient management plans mandated under the Maryland Water Quality Improvement Act.
Baltimore Metropolitan Council	1. Provide staff for coordination and administration of the Reservoir Technical Program through the financial support of its member jurisdictions.

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Appendix A

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Appendix B

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Appendix C

APPENDIX G:

TMDL of Fecal Coliform for Loch Raven Reservoir

Total Maximum Daily Loads of Fecal Bacteria for the Loch Raven Reservoir Basin in Baltimore, Carroll, and Harford Counties, Maryland

FINAL

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List of Abbreviations

ARCC	Average rates of correct classification
ARA	Antibiotic Resistance Analysis
BMP	Best Management Practice
BST	Bacteria Source Tracking
cfs	Cubic Feet per Second
CFR	Code of Federal Regulations
CFU	Colony Forming Units
COMAR	Code of Maryland Regulations
CSO	Combined Sewer Overflow
CSS	Combined Sewer System
CWA	Clean Water Act
DNR	Department of Natural Resources
EPA	Environmental Protection Agency
GIS	Geographic Information System
LA	Load Allocation
MACS	Maryland Agricultural Cost Share Program
MDE	Maryland Department of the Environment
MDP	Maryland Department of Planning
MGD	Millions of Gallons per Day
ml	Milliliter(s)
MOS	Margin of Safety
MPN	Most Probable Number
MPR	Maximum Practicable Reduction
MS4	Municipal Separate Storm Sewer System
MST	Microbial Source Tracking
NPDES	National Pollutant Discharge Elimination System
NRCS	National Resources Conservation Service
RCC	Rates of Correct Classification
RESAC	Mid-Atlantic Regional Earth Science Applications Center
SSO	Sanitary Sewer Overflows
SW	Stormwater
STATSGO	State Soil Geographic Database
TMDL	Total Maximum Daily Load
USGS	United States Geological Survey
WQIA	Water Quality Improvement Act
WLA	Wasteload Allocation
WQLS	Water Quality Limited Segment
WWTP	Wastewater Treatment Plant

EXECUTIVE SUMMARY

This document, upon approval by the U.S. Environmental Protection Agency (EPA), establishes a Total Maximum Daily Load (TMDL) for fecal bacteria in the Loch Raven Reservoir watershed (Maryland 8-digit assessment unit MD-02130805). Section 303(d) of the federal Clean Water Act (CWA) and the EPA's implementing regulations direct each state to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. For each WQLS, states are required to either establish a Total Maximum Daily Load (TMDL) of the specified substance that the waterbody can receive without violating water quality standards or demonstrate that water quality standards are being met.

The Maryland Department of the Environment (MDE) has identified the tributaries of Loch Raven Reservoir on the State's 303(d) List [Category 5 of the *Integrated Report of Surface Water Quality in Maryland* (Integrated Report)] as impaired by fecal bacteria (listed in 2008) and impacts to biological communities (listed in 2002, 2004 and 2008). The reservoir itself is not listed as impaired by fecal bacteria. The Loch Raven Reservoir and all its tributaries have been designated as Use III-P (Nontidal Cold Water and Public Water Supply). See Code of Maryland Regulations (COMAR) 26.08.02.08J. This document proposes to establish a TMDL for fecal bacteria in the Loch Raven Reservoir watershed that will allow for attainment of the beneficial use designation of water contact recreation. The listings for impacts to biological communities will be addressed in a separate TMDL document. Listings for the impoundment have already been addressed by TMDLs for phosphorus, sediments and mercury, and a WQA for heavy metals. MDE monitored the Loch Raven Reservoir watershed from 2003-2004 for fecal bacteria. A data solicitation for fecal bacteria was conducted by MDE in 2003, and all readily available data from the past five years were considered. To account for portions of subwatersheds located in Pennsylvania (PA), an upstream load allocation (LA_{PA}), determined to be necessary in order to meet MD water quality standards in the MD portion of the watershed, is also included in this TMDL.

For this TMDL analysis, the Loch Raven Reservoir watershed has been divided into eight subwatersheds. For convenience, seven of these will be referenced by the downstream bacteria monitoring station's name and location: GUN0387 (Gunpowder Falls at Falls Road), LIT0002 (Little Falls), GUN0284 (Gunpowder Falls at Corbett Road), GUN0233 (Gunpowder Falls at Phoenix Road), WGP0050 (Western Run), BEV0005 (Beaverdam Run), and SBH0002 (Spring Branch). The eighth subwatershed encompasses all unmonitored areas downstream of the seven stations, excepting the impoundment, and will be referred to as the Downstream Subwatershed. The pollutant loads set forth in this document are for these eight subwatersheds. To establish baseline and allowable pollutant loads for this TMDL, a flow duration curve approach was employed, using bacteria data from MDE and flow strata estimated from United States Geological Survey (USGS) daily flow monitoring. The sources of fecal bacteria are estimated at seven representative stations in the Loch Raven Reservoir watershed where samples were collected for one year. Multiple antibiotic resistance analysis (ARA) source tracking was used to determine the relative proportion of domestic (pets and human associated animals), human (human waste), livestock (agriculture-related animals), and wildlife (mammals and waterfowl) source categories.

The baseline load is estimated from current monitoring data using a long-term geometric mean and weighting factors from the flow duration curve. The TMDL for fecal bacteria entering the Loch Raven Reservoir watershed is established after considering two different hydrological conditions: an average annual condition and an average seasonal dry weather condition (the period between May 1st and September 30th when water contact recreation is more prevalent). The allowable load quantified by the TMDL is reported in units of Most Probable Number (MPN)/day and represents a long-term load estimated over a variety of hydrological conditions.

Two scenarios were developed, with the first assessing if attainment of current water quality standards could be achieved by applying maximum practicable reductions (MPRs), and the second applying higher reductions than MPRs. Scenario solutions were based on an optimization method where the objective was to minimize the overall risk to human health, assuming that the risk varies across the four bacteria source categories. In six of the eight subwatersheds, it was estimated that water quality standards could not be attained with MPRs; thus, higher maximum reductions were applied.

The MD 8-digit Loch Raven Reservoir Total Baseline Load consists of upstream loads generated outside the MD 8-digit watershed assessment unit: a Pennsylvania Upstream Baseline Load (BL_{PA}), plus loads generated within the assessment unit: a MD 8-digit Loch Raven Reservoir Baseline Load (BL_{LR}) Contribution. The baseline loads are summarized in the following table:

MD 8-Digit Loch Raven Reservoir Fecal Bacteria Baseline Loads (Billion MPN *E. coli*/year)								
Total Baseline Load	**=**	**Upstream Baseline Load[1]**	**+**	**MD 8-digit Loch Raven Reservoir Baseline Load Contribution**				
		BL_{PA}		**Nonpoint Source BL_{LR}**	**+**	**NPDES Stormwater BL_{LR}**	**+**	**WWTP BL_{LR}**
2,194,308	=	7,106	+	2,033,052	+	152,583	+	1,567

[1]Although the upstream baseline load is reported here as a single value, it could include point and nonpoint sources.

The MD 8-digit Loch Raven Reservoir TMDL of fecal bacteria consists of an annual average allocation attributed to loads generated outside the assessment unit: a Pennsylvania Upstream Load Allocation (LA_{PA}), plus allocations attributed to loads generated within the assessment unit: a MD 8-digit Loch Raven Reservoir TMDL Contribution.

The MD 8-digit Loch Raven Reservoir TMDL Contribution, representing the sum of individual TMDLs for the eight subwatersheds or portions thereof within MD, is distributed between a load allocation (LA_{LR}) for nonpoint sources and waste load allocations (WLA_{LR}) for point sources. Point sources include any National Pollutant Discharge Elimination System (NPDES) wastewater treatment plants (WWTPs) and NPDES regulated stormwater (SW) discharges, including county and municipal separate storm sewer systems (MS4s). The margin of safety (MOS) has been incorporated using a conservative assumption by estimating the loading capacity of the stream based on a water quality endpoint concentration more stringent than the applicable MD water quality standard criterion. The *E. coli* water quality criterion concentration was reduced by 5%, from 126 MPN/100ml to 119.7 MPN/100ml.

The MD 8-digit Loch Raven Reservoir TMDL of fecal bacteria is presented in the following table:

MD 8-Digit Loch Raven Reservoir Fecal Bacteria TMDL (Billion MPN *E. coli*/year)										
TMDL	=	**LA**			+	**WLA**			+	**MOS**
		LA_{PA}[1]	+	**LA_{LR}**		**SW WLA_{LR}**	+	**WWTP WLA_{LR}**		
513,894	=	6,200	+	487,750	+	18,377	+	1,567	+	Incorpo-rated

Upstream Load Allocation — MD 8-digit Loch Raven Reservoir TMDL Contribution (507,694)

[1]Although the upstream load is reported here as a single value, it could include point and nonpoint sources.

The LA_{PA}, accounting for portions of subwatersheds located in Pennsylvania, is determined to be necessary in order to meet MD water quality standards in the MD 8-digit Loch Raven Reservoir watershed. The LA_{PA} represents a reduction of approximately 13% from the PA baseline load of 7,106 billion MPN *E. coli*/year. The MD 8-digit TMDL Contribution (507,694 billion MPN *E. coli*/year) represents a reduction of approximately 77% from the MD 8-digit Baseline Load Contribution of 2,187,202 billion MPN *E. coli*/year.

Pursuant to recent EPA guidance (US EPA 2006a), maximum daily load (MDL) expressions of the long-term annual average TMDLs are also provided, as shown in the following table:

MD 8-Digit Loch Raven Reservoir Fecal Bacteria MDL Summary (Billion MPN *E. coli*/day)										
MDL	=	**LA**			+	**WLA**			+	**MOS**
		LA_{PA}	+	**LA_{LR}**		**SW WLA_{LR}**	+	**WWTP WLA_{LR}**		
17,951	=	243	+	16,876	+	819	+	13	+	Incorpo-rated

Upstream MDL — MD 8-digit Loch Raven Reservoir MDL Contribution (17,708)

Once EPA has approved a TMDL, MDE intends for the required reductions to be implemented in an iterative process that first addresses those sources with the largest impacts to water quality and creating the greatest risks to human health, with consideration given to ease and cost of implementation. In addition, follow-up monitoring plans will be established to track progress and to assess the implementation efforts. As previously stated, water quality standards cannot be attained in six of the eight subwatersheds using the MPR scenario. MPRs may not be sufficient in subwatersheds where wildlife is a significant component or where very high reductions of fecal bacteria loads are required to meet water quality standards. In these cases, it is expected that the MPR scenario will be the first stage of TMDL implementation. Progress will be made through the iterative implementation process described above, and the situation will be reevaluated in the future..

1.0 INTRODUCTION

This document, upon approval by the U.S. Environmental Protection Agency (EPA), establishes a Total Maximum Daily Load (TMDL) for fecal bacteria in the Loch Raven Reservoir watershed (Maryland 8-digit assessment unit MD-02130805). Section 303(d)(1)(C) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (EPA) implementing regulations direct each state to develop a TMDL for each impaired water quality limited segment (WQLS) on the Section 303(d) List, taking into account seasonal variations and a protective margin of safety (MOS) to account for uncertainty. A TMDL reflects the total pollutant loading of the impairing substance a waterbody can receive and still meet water quality standards.

TMDLs are established to achieve and maintain water quality standards. A water quality standard is the combination of a designated use for a particular body of water and the water quality criteria designed to protect that use. Designated uses include activities such as swimming, drinking water supply, and shellfish propagation and harvest. Water quality criteria consist of narrative statements and numeric values designed to protect the designated uses. Criteria may differ among waters with different designated uses.

The Maryland Department of the Environment (MDE) has identified the tributaries of Loch Raven Reservoir on the State's 303(d) List [Category 5 of the *Integrated Report of Surface Water Quality in Maryland* (Integrated Report)] as impaired by fecal bacteria (listed in 2008) and impacts to biological communities (listed in 2002, 2004 and 2008). The reservoir itself is not listed as impaired by fecal bacteria. The Loch Raven Reservoir and all its tributaries have been designated as Use III-P (Nontidal Cold Water and Public Water Supply). See Code of Maryland Regulations (COMAR) 26.08.02.08J. This document proposes to establish a TMDL for fecal bacteria in the Loch Raven Reservoir watershed that will allow for attainment of the beneficial use designation of water contact recreation. The listings for impacts to biological communities will be addressed in a separate TMDL document. Listings for the impoundment have already been addressed by TMDLs for phosphorus, sediments and mercury, and a WQA for heavy metals. MDE monitored the Loch Raven Reservoir watershed from 2003-2004 for fecal bacteria. A data solicitation for fecal bacteria was conducted by MDE in 2003, and all readily available data from the past five years were considered. To account for portions of subwatersheds located in Pennsylvania (PA), an upstream load allocation (LA_{PA}), determined to be necessary in order to meet MD water quality standards in the MD portion of the watershed, is also included in this TMDL.

Fecal bacteria are microscopic single-celled organisms (primarily fecal coliform and fecal streptococci) found in the wastes of warm-blooded animals. Their presence in water is used to assess the sanitary quality of water for body-contact recreation, for consumption of molluscan bivalves (shellfish), and for drinking water. Excessive amounts of fecal bacteria in surface water used for recreation are known to indicate an increased risk of pathogen-induced illness to humans. Infections due to pathogen-contaminated recreation waters include gastrointestinal, respiratory, eye, ear, nose, throat, and skin diseases (US EPA 1986).

In 1986, EPA published "Ambient Water Quality Criteria for Bacteria," in which three indicator organisms were assessed to determine their correlation with swimming-associated illnesses. Fecal coliform, *E. coli* and enterococci were the indicators used in the analysis. Fecal coliform bacteria are a subgroup of total coliform bacteria and *E. coli* bacteria are a subgroup of fecal coliform bacteria. Most *E. coli* are harmless and are found in great quantities in the intestines of people and warm-blooded animals. However, certain pathogenic strains may cause illness. Enterococci are a subgroup of bacteria in the fecal streptococcus group. Fecal coliform, *E. coli* and enterococci can all be classified as fecal bacteria. The results of the EPA study demonstrated that fecal coliform showed less correlation to swimming-associated gastroenteritis than did either *E. coli* or enterococci.

Based on EPA's guidance (US EPA 1986), adopted by Maryland in 2004, the State has revised the bacteria water quality criteria and it is now based on water column limits for either *E. coli* or enterococci. Because multiple monitoring datasets are available within this watershed for various pathogen indicators, the general term "fecal bacteria" will be used to refer to the impairing substance throughout this document. The TMDL will be based on the pathogen indicator organisms specified in MD's current bacteria water quality criteria, either *E. coli* or enterococci. The indicator organism used in the Loch Raven Reservoir TMDL analysis was *E. coli*.

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting

Location

The Loch Raven Reservoir watershed is located in both Maryland (MD) and Pennsylvania (PA), with a drainage area of 224.4 square miles (143,617 acres). The majority of the watershed is in MD with a portion in York County, PA (see Figure 2.1.1). The MD portion is largely in Baltimore County, with small areas in Carroll and Harford counties.

The watershed includes the towns of Lutherville, Timonium, Cockeysville, Phoenix, Parkton, and Hampstead. The tributaries to the reservoir include Gunpowder Falls, Greene Branch, Beaverdam Run, Royston Branch, Overshot Run, Merryman Branch, Fitzhugh Run, Jenkins Run, Dulaney Branch, Kelly Branch, Spring Branch, Long Quarter Branch and Rush Brook. Gunpowder Falls begins at the outlet of the Prettyboy Reservoir. A major tributary to Gunpowder Falls is Little Falls, which begins near the PA border. See Figure 2.1.1.

Antidegradation Policy and Tier II Waters

Antidegradation is one of three key components required by the Clean Water Act. These three components are: designated uses, water quality criteria, and antidegradation policy. The Clean Water Act's (CWA) Tier II antidegradation policy is found in section 303(d) and its goals are to 1) ensure that no activity will lower water quality to support existing uses, and 2) maintain and protect high quality waters.

Waters of the Loch Raven Reservoir watershed designated as Tier II are listed in Table 2.1.1.

Table 2.1.1: High Quality (Tier II) Waters in the Loch Raven Reservoir Watershed

Tier II Segment	County	Segment Length (miles)	Subwatershed
Beetree Run 1	Baltimore	1.59	LIT0002
First Mine Branch 1	Baltimore, Harford	3.15	LIT0002
Little Falls 1	Baltimore	0.96	LIT0002
Blackrock Run 1	Baltimore	1.41	WGP0050
Delaware Run 1	Baltimore	0.73	WGP0050
Indian Run 1	Baltimore	0.85	WGP0050
Western Run 1	Baltimore	1.64	WGP0050

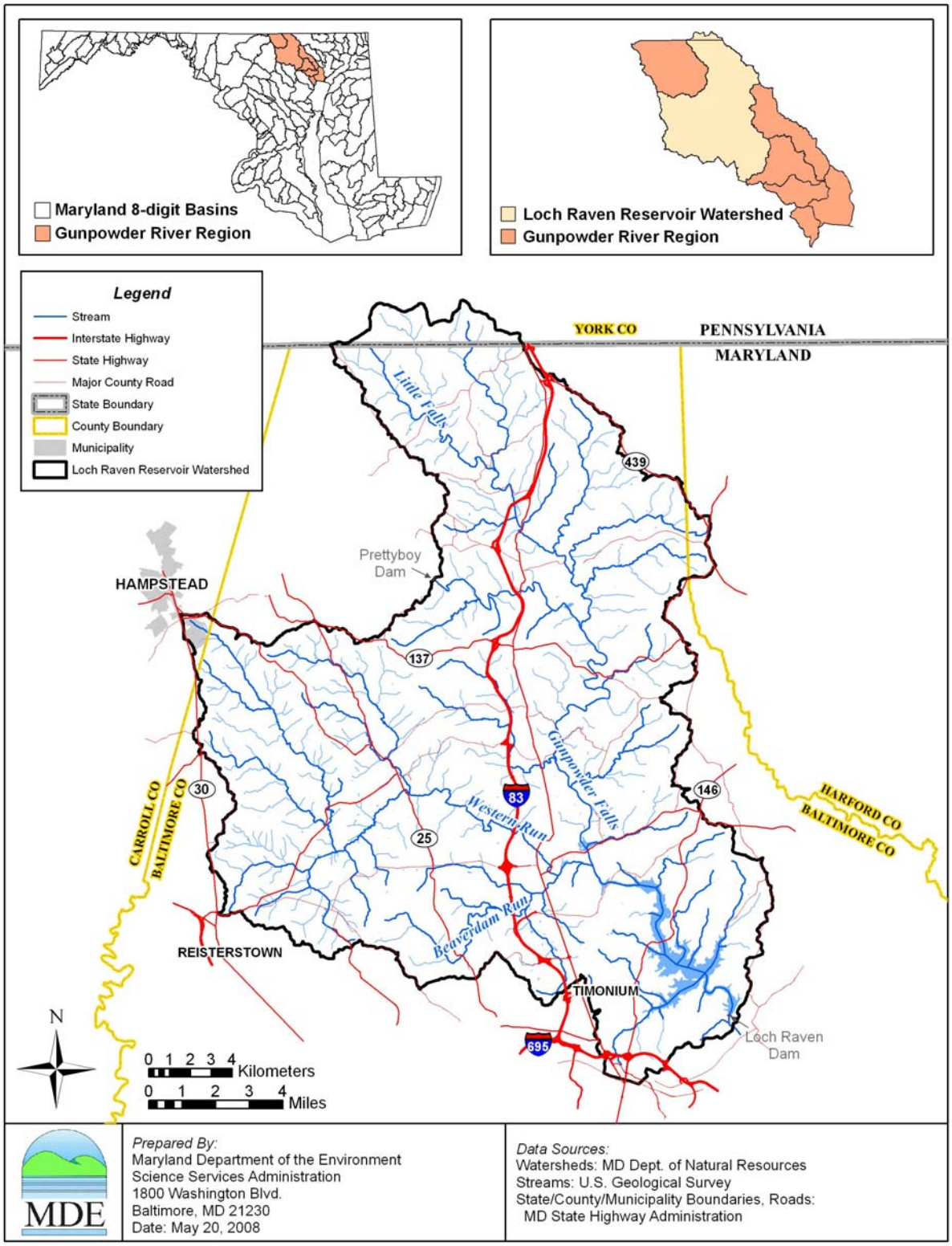

Figure 2.1.1: Location Map of the Loch Raven Reservoir Watershed

Land Use

The Loch Raven Reservoir watershed covers an area of 143,617 acres in MD and PA. Based on the 2002 Maryland Department of Planning (MDP) land use/land cover data, MD's portion of the watershed can be characterized as primarily forest and agricultural land, but with significant urban area as well. The forested areas are mainly along Gunpowder Falls and surrounding the reservoir. The urban areas are mostly in the southern part of the watershed. Regional Earth Science Application Center (RESAC) land use/land cover was used to estimate the land use for the PA portion of the watershed. RESAC shows that the PA portion is largely pasture and agricultural.

The land use acreage and percentage distribution is shown in Table 2.1.1, and spatial distributions for each land use are shown in Figure 2.1.2. Table 2.1.2 shows the land use percentage distribution for each of the eight subwatersheds considered in the analysis. Note that seven of the subwatersheds are identified by the MDE monitoring stations located in the mainstem of the river and its main tributaries, and are listed by flow from upstream to downstream. The eighth subwatershed encompasses all unmonitored areas downstream of the monitoring stations, excepting the impoundment, and is identified as the Downstream Subwatershed.

Table 2.1.2: Land Use Percentage Distribution for the Loch Raven Reservoir Watershed

Land Type	Maryland Area		Pennsylvania Area		*Total*	
	Acres	%	Acres	%	Acres	%
Forest	52,000	36.9	515	19.0	52,515	36.6
Agricultural	42,410	30.1	826	30.5	43,236	30.1
Urban	34,201	24.3	333	12.3	34,534	24.0
Pasture	10,201	7.2	1,037	38.3	11,238	7.8
Water	2,093	1.5	1	0.02	2,094	1.5
Total	**140,905**	**100**	**2,712**	**100**	**143,617**	**100**

Table 2.1.3: Land Use Percentage Distribution for the Loch Raven Reservoir Watershed

Station / Subwatershed	Land Use Area (%)				
	Agricultural	Forest	Pasture	Urban	Water
GUN0387 / Gunpowder Falls at Falls Rd.	5.1	78.5	3.0	13.3	0.04
LIT0002 / Little Falls	34.7	38.1	12.9	14.3	0.01
GUN0284 / Gunpowder Falls at Corbett Rd.	23.4	53.1	8.6	14.7	0.1
GUN0233 / Gunpowder Falls at Phoenix Rd.	36.0	35.2	10.8	18.0	0
WGP0050 / Western Run	48.8	32.7	6.7	11.8	0
BEV0005 / Beaverdam Run	12.1	23.7	1.2	62.9	0.1
SBH0002 / Spring Branch	0	2.7	0	97.3	0
Downstream Subwatershed	7.1	39.5	4.4	41.0	7.9

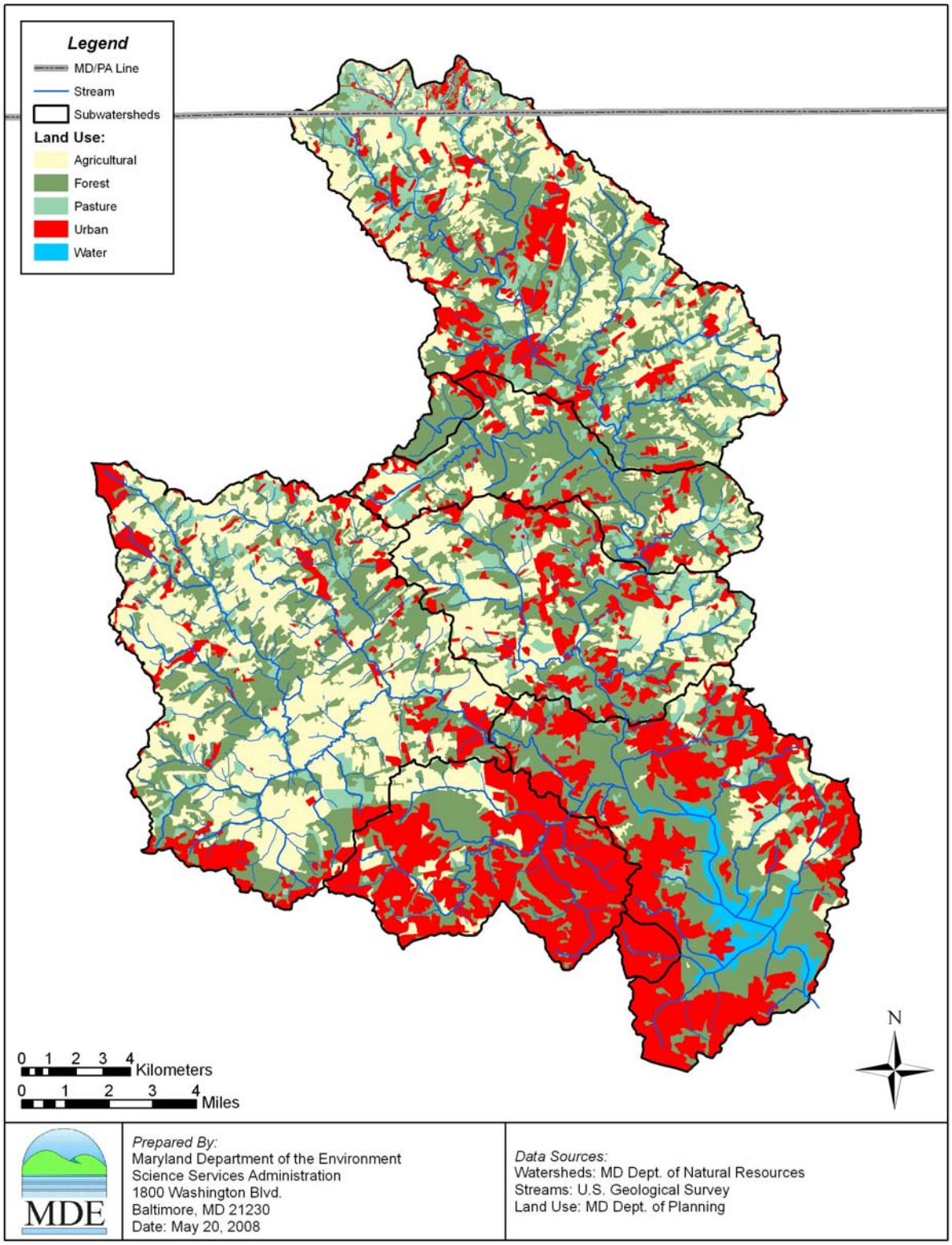

Figure 2.1.2: Land Use of the Loch Raven Reservoir Watershed

Population

The total population in the Loch Raven Reservoir watershed is estimated to be 90,345 people. Figure 2.1.3 illustrates the population density in the watershed. The human population in the Pennsylvania portion of the watershed was estimated based on a weighted average from the 2000 Census GIS Block Groups and the RESAC land cover mapping. Since the boundaries of the watershed differ from the boundaries of the block groups, residential land use data were used to extract the necessary areas of the Census block groups. The residential density designations used for this estimation are shown in Table 2.1.3. The population in the Maryland portion of the watershed was estimated based on a weighted average from the Census block groups and the 2007 MDP Property View. The population for each subwatershed was estimated and is presented in Table 2.1.4.

Table 2.1.4: Number of Dwellings Per Acre

Land Use Code	Dwellings Per Acre
Low Density Residential	1
Medium Density Residential	5
High Density Residential	8

Table 2.1.5: Total Population Per Subwatershed in the Loch Raven Reservoir Watershed

Station / Subwatershed	Population
GUN0387 / Gunpowder Falls at Falls Rd.	219
LIT0002 / Little Falls	8,346
GUN0284 / Gunpowder Falls at Corbett Rd.	2,938
GUN0233 / Gunpowder Falls at Phoenix Rd.	4,854
WGP0050 / Western Run	9,580
BEV0005 / Beaverdam Run	24,541
SBH0002 / Spring Branch	4,940
Downstream Subwatershed	34,927
Total	**90,345**

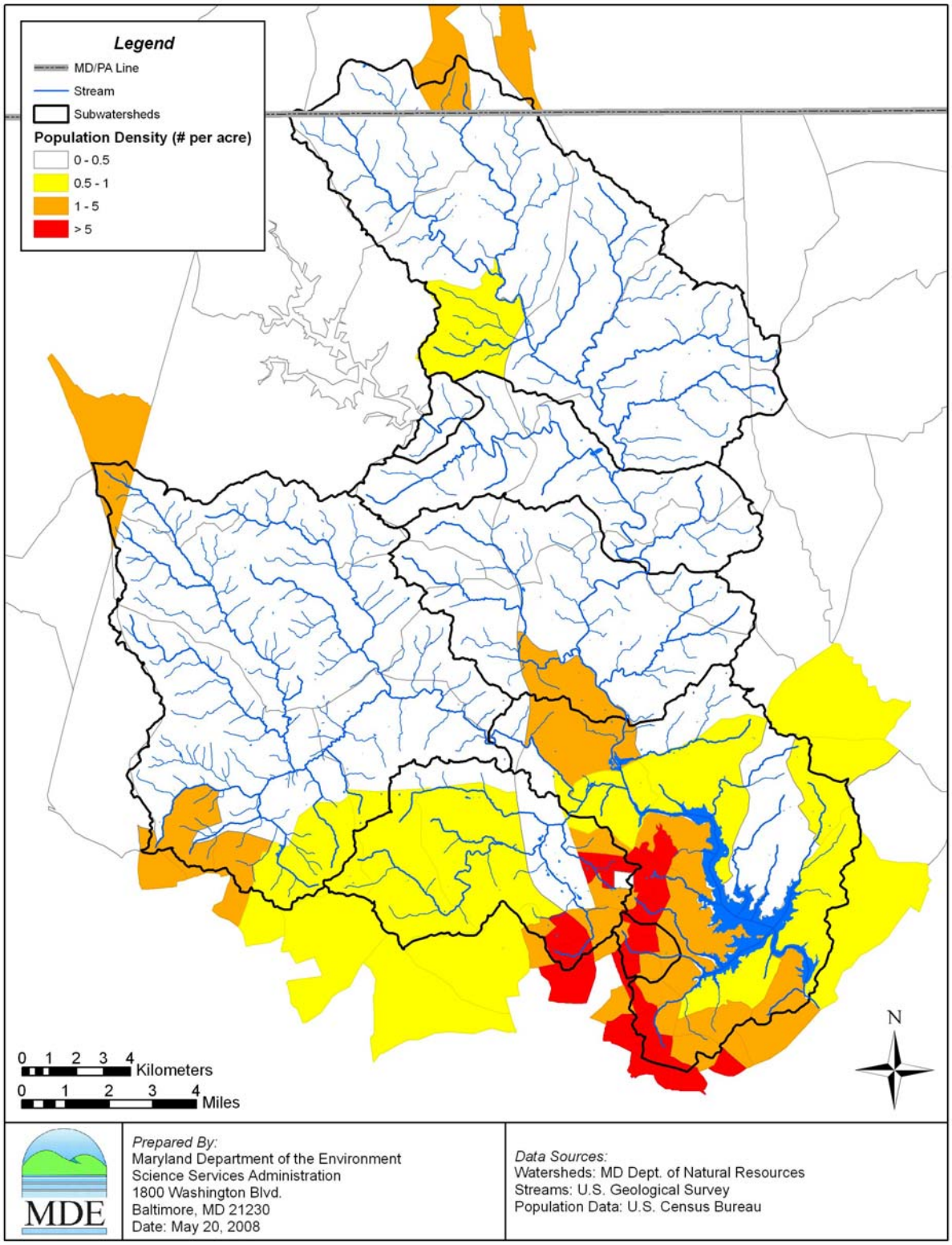

Figure 2.1.3: Population Density in the Loch Raven Reservoir Watershed

2.2 Water Quality Characterization

EPA's guidance document, "Ambient Water Quality Criteria for Bacteria" (1986), recommended that states use *E. coli* (for fresh water) or enterococci (for fresh or salt water) as pathogen indicators. Fecal bacteria, *E. coli*, and enterococci were assessed as indicator organisms for predicting human health impacts. A statistical analysis found that the highest correlation to gastrointestinal illness was linked to elevated levels of *E. coli* and enterococci in fresh water (enterococci in salt water).

As per EPA's guidance, Maryland has adopted the new indicator organisms, *E. coli* and enterococci, for the protection of public health in Use I, II, III and IV waters. These bacteria listings were originally assessed using fecal coliform bacteria. The analysis was based on a geometric mean of the monitoring data, where the result had to be less than or equal to 200 MPN/100ml. From EPA's analysis (US EPA 1986), this fecal coliform geometric mean target equates to an approximate risk of 8 illnesses per 1,000 swimmers at fresh water beaches and 19 illnesses per 1,000 swimmers at marine beaches (enterococci only), which is consistent with MDE's revised Use I bacteria criteria. Therefore, the original 303(d) List fecal coliform listings can be addressed using the refined bacteria indicator organisms to ensure that risk levels are acceptable.

Bacteria Monitoring

Table 2.2.1 lists the historical monitoring data for the Loch Raven Reservoir watershed. MDE conducted monitoring sampling at seven stations in the Loch Raven Reservoir watershed from November 2003 through October 2004. Four United States Geological Survey (USGS) gage stations were used in deriving the surface water flow. The locations of these stations are shown in Tables 2.2.2 to 2.2.4 and in Figure 2.2.1. Observations recorded from the seven MDE monitoring stations are provided in Appendix A.

Bacteria counts are highly variable, which is typical due to the nature of bacteria and their relationship to flow. The E. coli counts for the seven stations ranged between 1 and 14,140 MPN/100 ml.

Table 2.2.1: Historical Monitoring Data in the Loch Raven Reservoir Watershed

Organization	Date	Design	Summary
DNR	01/1986 through 12/2003	Fecal Coliform*	1 station 1 sample per month
MDE	11/2003 through 10/2004	*E. coli*	7 stations 2 samples per month
MDE	11/2003 through 10/2004	BST (*Enterococcus)*	7 stations 1 sample per month

*Only *E. coli* was used for this analysis.

Table 2.2.2: Location of DNR Core Station in the Loch Raven Reservoir Watershed

Station	Tributary	Latitude (Decimal Degrees)	Longitude (Decimal Degrees)
GUN0258	Gunpowder Falls	39.550	-76.636

Table 2.2.3: Location of MDE Monitoring Stations in Loch Raven Reservoir Watershed

Tributary	Station	Observation Period	Total Observations	Latitude (Decimal Degrees)	Longitude (Decimal Degrees)
Gunpowder Falls	GUN0387	2003 – 2004	24	39.619	-76.690
Little Falls	LIT0002	2003 – 2004	24	39.602	-76.622
Gunpowder Falls	GUN0284	2003 – 2004	24	39.568	-76.611
Gunpowder Falls	GUN0233	2003 – 2004	23	39.519	-76.620
Western Run	WGP0050	2003 – 2004	24	39.511	-76.677
Beaverdam Run	BEV0005	2003 – 2004	24	39.487	-76.645
Spring Branch	SBH0002	2003 – 2004	24	39.440	-76.597

Table 2.2.4: Location of USGS Gauging Stations in Loch Raven Reservoir Watershed

Site Number	Observation Period Used	Total Observations	Latitude	Longitude
01582000	1982-2007	9,131	39.604	-76.620
01582500	1982-2007	9,061	39.550	-76.636
01583500	1982-2007	9,131	39.511	-76.677
01583600	1982-2007	9,131	39.486	-76.646

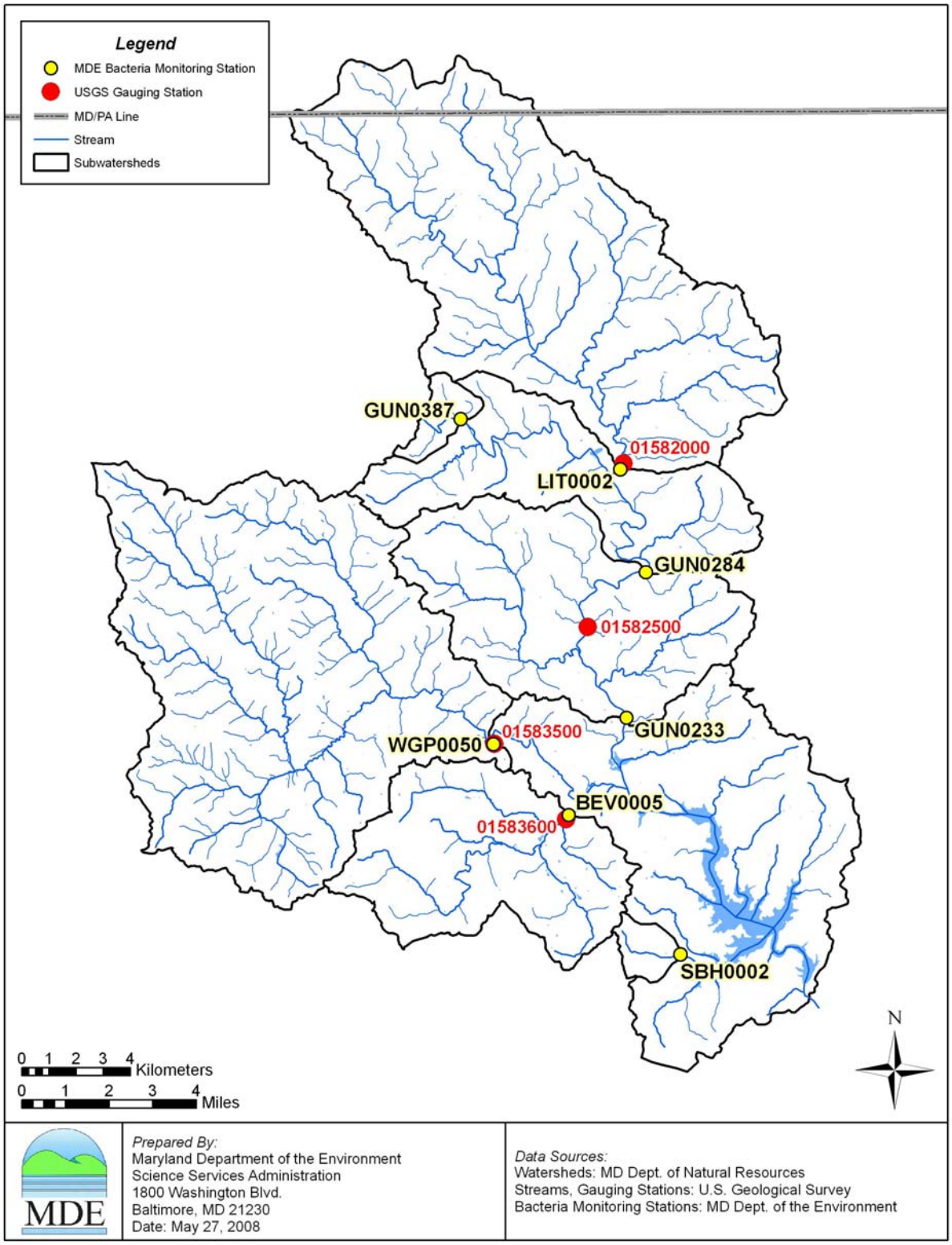

Figure 2.2.1: Monitoring Stations and Subwatersheds in the Loch Raven Reservoir Watershed

2.3 Water Quality Impairment

Designated Uses and Water Quality Standard

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for the waters of the MD 8-digit Loch Raven Reservoir watershed is Use III-P (Nontidal Cold Water and Public Water Supply). (COMAR 26.08.02.08J) The waters of the MD 8-digit Loch Raven Reservoir watershed were listed on Maryland's 303(d) List [Category 5 of the *Integrated Report of Surface Water Quality in Maryland* (Integrated Report)] as impaired by fecal bacteria in 2008.

Water Quality Criteria

The State water quality standard for bacteria applicable to freshwater and used in this study is as follows:

Table 2.3.1: Bacteria Criteria Values
(Source: COMAR 26.08.02.03-3 Water Quality Criteria Specific to Designated Uses; Table 1)

Indicator	Steady-State Geometric Mean Indicator Density
Freshwater	
E. coli	126 MPN/100ml

Water Quality Assessment

Interpretation of Bacteria Data for General Recreational Use

Pursuant to the 2008 Integrated Report, the requirements to confirm a Category 5 listing for fecal bacteria impairment in all Use Waters (Water Contact Recreation and Protection of Aquatic Life) are as follows:

A steady-state geometric mean will be calculated with available data from the previous two to five years. The data shall be from samples collected during steady-state, dry weather conditions and during the beach season (Memorial Day through Labor Day), to be representative of the critical condition (highest water contact recreation use). If the resulting steady-state geometric mean is greater than 35 cfu/100 ml enterococci in marine/estuarine waters, 33 cfu/100 ml enterococci in freshwater, or 126 cfu/100 ml *E. coli* in freshwater, the waterbody is confirmed as impaired and a TMDL should be established.

Bacteria water quality impairment in the MD 8-digit Loch Raven Reservoir watershed was assessed as explained above, by comparing the dry weather steady-state geometric means of *E.*

coli concentrations for each subwatershed of the Loch Raven Reservoir with the water quality criterion. The 1986 EPA criteria guidance document assumed steady-state conditions in determining the risk at various bacterial concentrations, and therefore the chosen criterion value of 126 cfu/100 ml *E. coli* also reflects steady-state conditions (EPA 1986).

The dry weather steady-state geometric means are calculated using samples taken during non-rainy days and from May 1st to September 30th, capturing the beach season. Results of these calculations are presented in Table 2.3.2. As shown in the table below, all but one of the seven monitored subwatersheds of the Loch Raven Reservoir had steady-state geometric mean concentrations of *E. coli* above the water quality criterion, supporting the 2008 listing for fecal bacteria and it is therefore concluded that a TMDL is required.

Table 2.3.2: Loch Raven Reservoir Watershed Dry Weather Period Steady-State Geometric Means

Station / Tributary	Number of Samples	Seasonal Steady-State Geometric Mean (MPN/100ml)	Water Quality Criterion (MPN/100ml)
GUN0387 Gunpowder Falls at Falls Rd.	10	18	126
LIT0002 Little Falls	10	139	126
GUN0284 Gunpowder Falls at Corbett Rd.	10	168	126
GUN0233 Gunpowder Falls at Phoenix Rd.	10	224	126
WGP0050 Western Run	10	491	126
BEV0005 Beaverdam Run	9	611	126
SBH0002 Spring Branch	10	1,080	126

2.4 Source Assessment

Nonpoint Source Assessment

Nonpoint sources of fecal bacteria do not have one discharge point but occur over the entire length of a stream or waterbody. During rain events, surface runoff transports water and fecal bacteria over the land surface and discharges to the stream system. This transport is dictated by rainfall, soil type, land use, and topography of the watershed. Many types of nonpoint sources introduce fecal bacteria to the land surface, including the manure spreading process, direct deposition from livestock during the grazing season, and excretions from pets and wildlife. The deposition of non-human fecal bacteria directly to the stream occurs when livestock, domestic animals, or wildlife have direct access to the waterbody. Nonpoint source contributions from human sources generally arise from failing septic systems and their associated drain fields or leaking infrastructure (i.e., sewer systems).

Sewer Systems

The MD Loch Raven Reservoir watershed is serviced by both sewer systems and septic systems. Sewer systems are present in the towns of Timonium, Cockeysville, and Hampstead. Wastewater collected by the Hampstead WWTP is treated and discharged into Piney Run, a tributary of Western Run.

Septic Systems

On-site disposal (septic) systems are located throughout the Loch Raven Reservoir watershed. Table 2.4.1 presents the number of septic systems per subwatershed in MD. Figure 2.4.1 displays the areas that are serviced by sewers and the locations of the septic systems in MD.

Table 2.4.1: Septic Systems Per Subwatershed in the Loch Raven Reservoir Watershed in MD

Station / Subwatershed	Septic Systems
GUN0387 / Gunpowder Falls at Falls Rd.	79
LIT0002 / Little Falls	2,407
GUN0284 / Gunpowder Falls at Corbett Rd.	997
GUN0233 / Gunpowder Falls at Phoenix Rd.	1,483
WGP0050 / Western Run	2,379
BEV0005 / Beaverdam Run	3,961
SBH0002 / Spring Branch	6
Downstream Subwatershed	4,331
Total	**15,643**

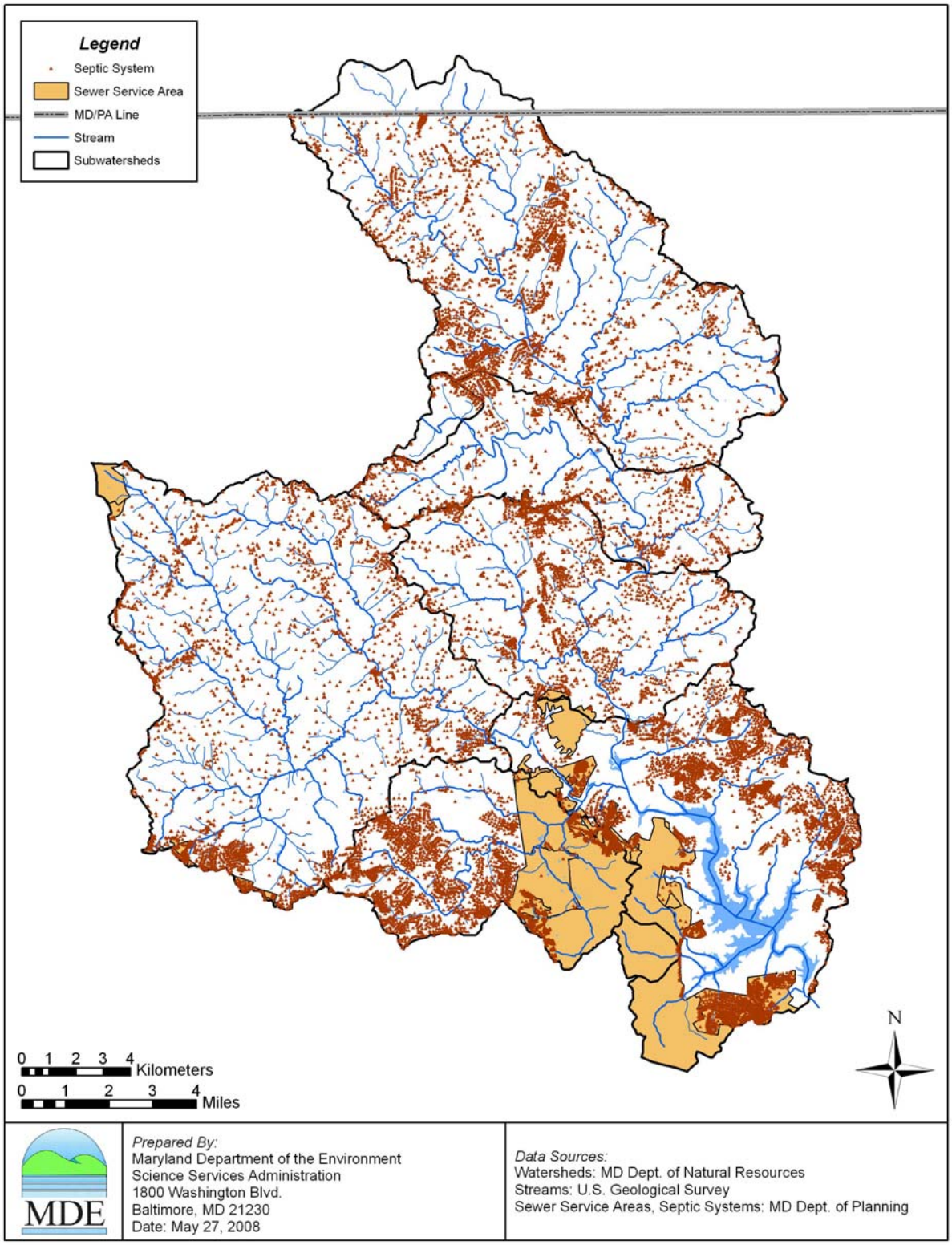

Figure 2.4.1: Sanitary Sewer Service Areas and Septic Locations in MD's Portion of the Loch Raven Reservoir Watershed

Point Source Assessment

There are two broad types of National Pollutant Discharge Elimination System (NPDES) permits considered in this analysis; individual and general. Both types of permits include industrial and municipal categories. Individual permits are issued for industrial and municipal WWTPs and Phase I municipal separate storm sewer systems (MS4s). MDE general permits have been established for surface water discharges from: Phase II and other MS4 entities; surface coal mines; mineral mines; quarries; borrow pits; ready-mix concrete; asphalt plants; seafood processors; hydrostatic testing of tanks and pipelines; marinas; concentrated animal feeding operations; and stormwater associated with industrial activities.

NPDES Regulated Stormwater

NPDES regulated stormwater discharges are considered point sources subject to assignment to the waste load allocation (WLA). Stormwater runoff is an important source of water pollution, including bacterial pollution. For example, domestic animal and wildlife waste may be transported through an MS4 conveyance or system of conveyances. MS4s may include roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, storm drains, best management practices (BMPs), and environmental site design (ESD), designed or used for collecting and conveying, or treating and reducing, stormwater before delivering it to a waterbody. MS4 stormwater management programs are designed to reduce the amount of pollution that enters a waterbody from storm sewer systems to the maximum extent practicable.

MD's portion of the Loch Raven Reservoir watershed is located in Baltimore, Carroll, and Harford Counties, which all have individual Phase I NPDES MS4 permits. The municipality of Hampstead is covered separately by a general Phase II NPDES MS4 permit. Nonpoint source bacteria loads attributable to these MS4s, and any other Phase I and Phase II NPDES-regulated stormwater entities in the watershed, including the MD State Highway Administration (SHA) Phase I MS4, Phase II State and federal MS4s, and industrial stormwater permittees, are combined in aggregate stormwater waste load allocations (SW-WLAs) in this TMDL.

Sanitary Sewer Overflows

Sanitary Sewer Overflows (SSOs) occur when the capacity of a separate sanitary sewer is exceeded. There are several factors that may contribute to SSOs from a sewerage system, including pipe capacity, operations and maintenance effectiveness, sewer design, age of system, pipe materials, geology and building codes. SSOs are prohibited by the facilities' permits, and must be reported to MDE's Water Management Administration in accordance with COMAR 26.08.10 to be addressed under the State's enforcement program.

There were a total of 8 SSOs reported to MDE between November 2003 and October 2004 in the Loch Raven Reservoir watershed. Approximately 14,000 gallons of SSOs were discharged through various waterways (surface water, groundwater, sanitary sewers, etc.). Figure 2.4.2 shows the locations where SSOs occurred in the MD portion of the watershed between November 2003 and October 2004.

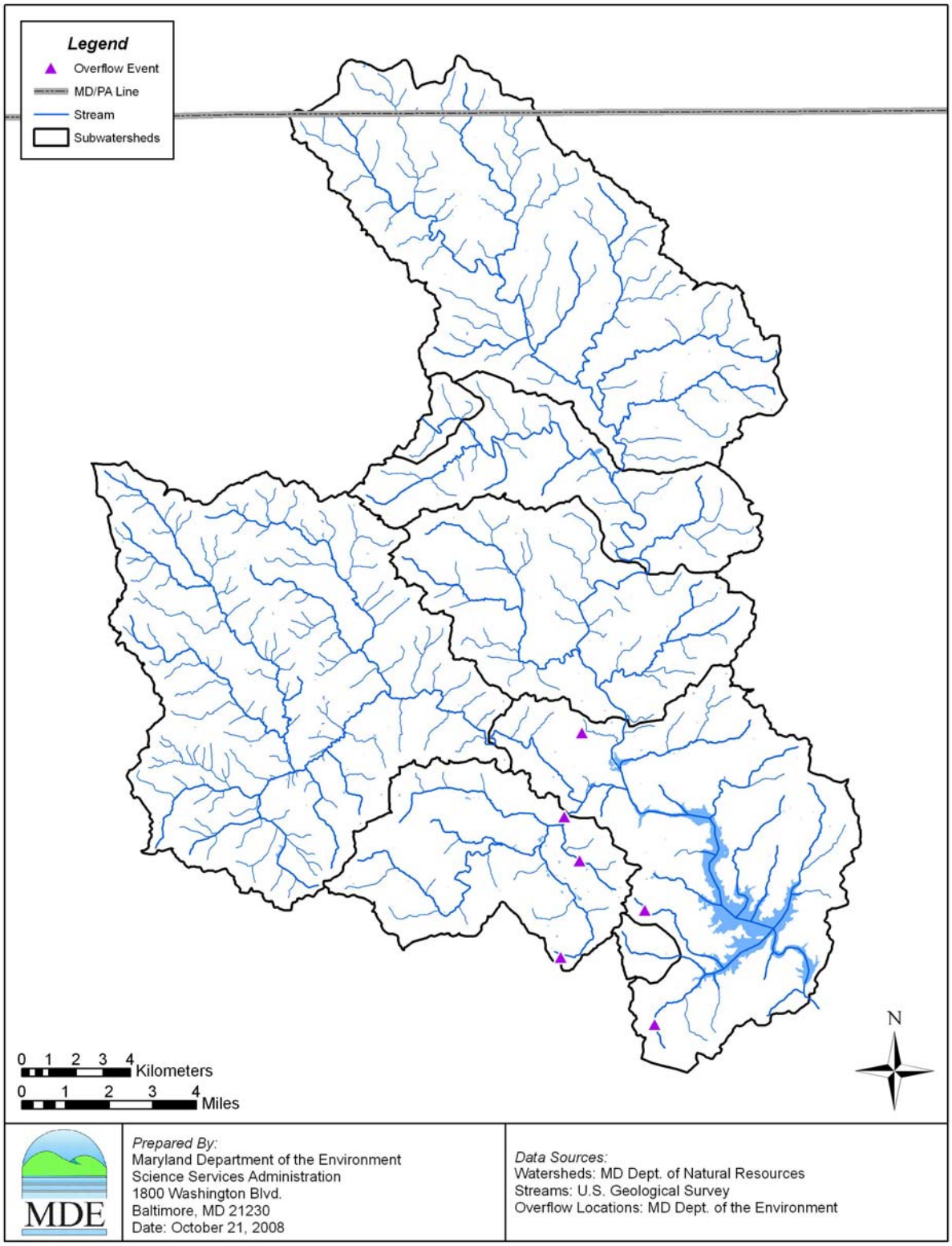

Figure 2.4.2: Sanitary Sewer Overflow Areas in the Loch Raven Reservoir Watershed

Municipal and Industrial Wastewater Treatment Plants (WWTPs)

WWTPs are designed to treat wastewater before it is discharged to a stream or river. The goals of wastewater treatment are to protect the public health, protect aquatic life, and to prevent harmful substances from entering the environment.

Based on MDE's point source permitting information, there is one active municipal NPDES permitted point source facility with a permit regulating the discharge of fecal bacteria in the Loch Raven Reservoir watershed. This facility, Hampstead WWTP, treats approximately 0.94 MGD (million gallons per day). There are no industrial facilities in the Loch Raven Reservoir watershed with NPDES permits regulating the discharge of fecal bacteria. Table 2.4.2 lists the Hampstead facility and Figure 2.4.3 shows its location in the watershed.

Table 2.4.2: NPDES Permit Holders Regulated for Fecal Bacteria Discharge in the Loch Raven Reservoir Watershed

Facility	NPDES Permit No.	County	Average Flow (MGD)	Fecal Coliform Concentration Annual AVG (MPN/100ml)	Fecal Coliform Load (Billion MPN/day)
Hampstead WWTP	MD0022446	Carroll	0.944	7.9	0.28

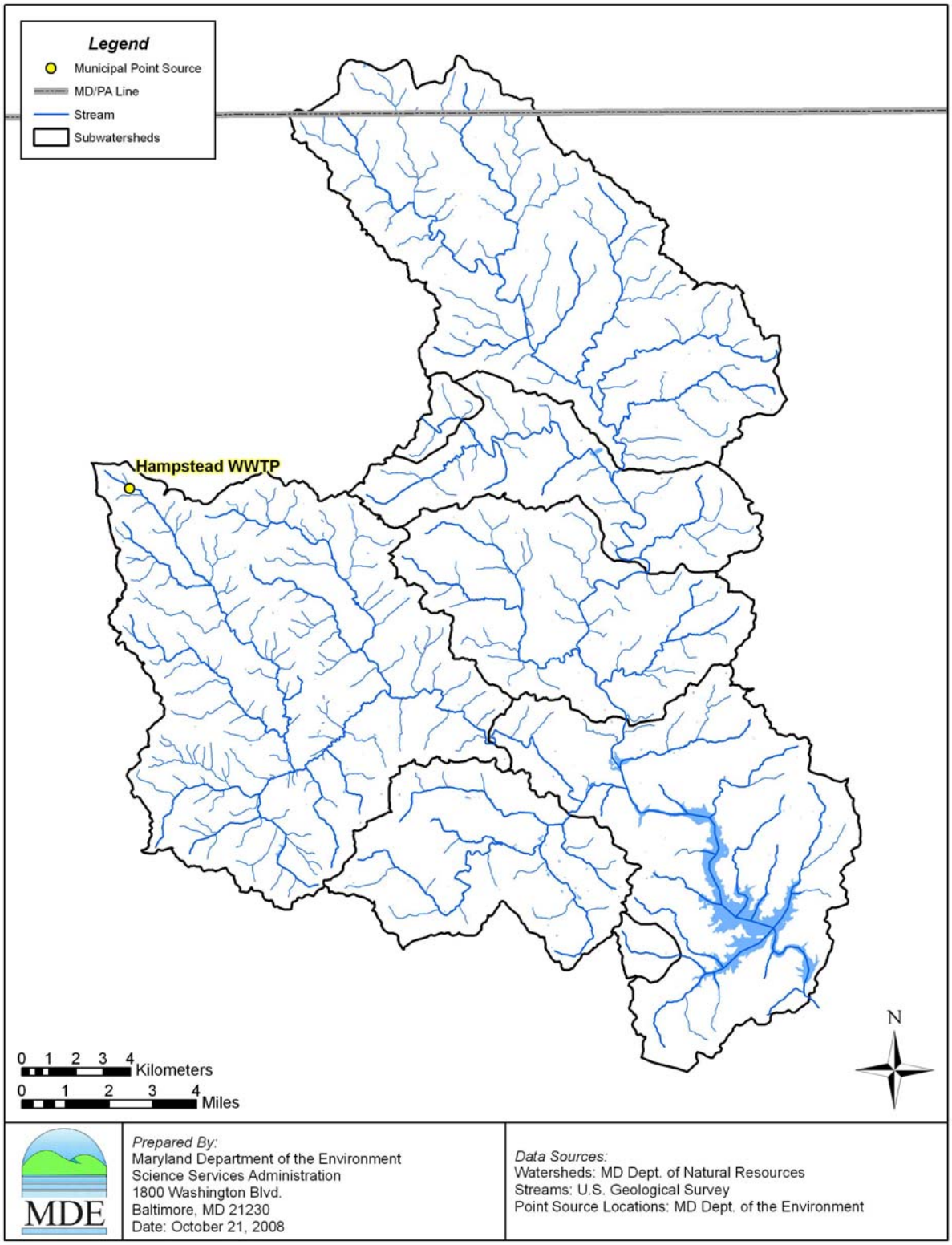

Figure 2.4.3: Permitted Point Sources Discharging Fecal Bacteria in the Loch Raven Reservoir Watershed

Bacteria Source Tracking

Bacteria source tracking (BST) was used to identify the relative contributions of different sources of bacteria to in-stream water samples. BST monitoring was conducted at five stations in the Loch Raven Reservoir watershed, where samples were collected once per month for a one-year duration. Sources are defined as domestic (pets and human associated animals), human (human waste), livestock (agricultural animals), and wildlife (mammals and waterfowl). Samples are collected within the watershed from known fecal sources, and a BST technique known as antibiotic resistance analysis (ARA) was used to identify the patterns of antibiotic resistance of these known sources. To identify probable sources, these antibiotic resistance patterns are then compared to isolates of unknown bacteria from ambient water samples. Figure 2.4.4 presents the relative contributions by probable sources of bacteria for the Loch Raven Reservoir Watershed. Details of the BST methodology and data can be found in Appendix C.

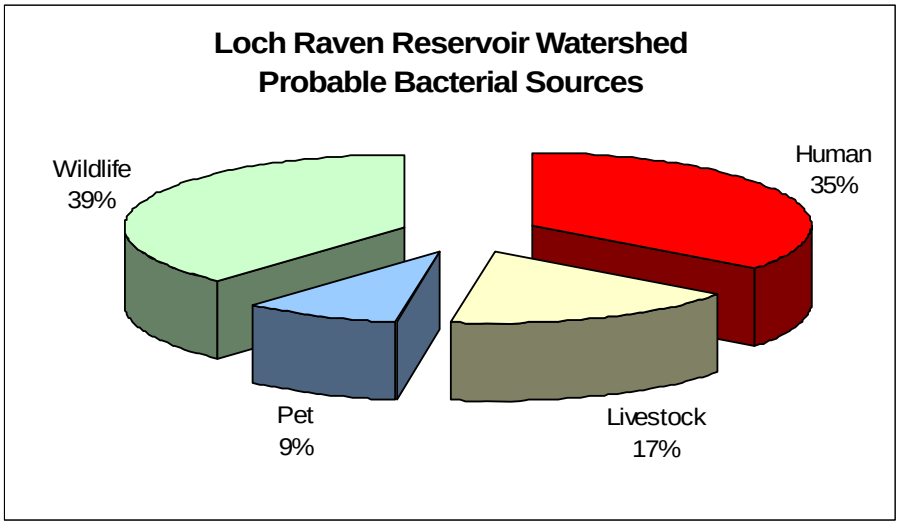

Figure 2.4.4: Loch Raven Reservoir Watershed Relative Contributions by Probable Sources of Fecal Bacteria Contamination

3.0 TARGETED WATER QUALITY GOAL

The overall objective of the fecal bacteria TMDL set forth in this document is to establish the loading caps needed to assure attainment of water quality standards in the Loch Raven Reservoir watershed. These standards are described fully in Section 2.3, "Water Quality Impairment."

4.0 TOTAL MAXIMUM DAILY LOADS AND SOURCE ALLOCATION

4.1 Overview

This section provides an overview of the non-tidal fecal bacteria TMDL development, with a discussion of the many complexities involved in estimating bacteria concentrations, loads, and sources. Section 4.2 presents the analysis framework and how the hydrological, water quality, and BST data are linked together in the TMDL process. Section 4.3 describes the analysis for estimating a representative geometric mean fecal bacteria concentration and baseline loads. This analysis methodology is based on available monitoring data and is specific to a free-flowing stream system. Section 4.4 shows how the BST analysis results are used to estimate the relative contributions of the different sources of bacteria for each subwatershed of the Loch Raven Reservoir watershed. Section 4.5 addresses the critical condition and seasonality. Section 4.6 presents the margin of safety. Section 4.7 discusses annual average TMDL loading caps and how maximum daily loads are estimated. Section 4.8 presents TMDL scenario descriptions. Section 4.9 presents the load allocations. Finally, in Section 4.10, the TMDL equation is summarized.

To be most effective, the TMDL provides a basis for allocating loads among the known pollutant sources in the watershed so that appropriate control measures can be implemented and water quality standards achieved. By definition, the TMDL is the sum of the individual waste load allocations (WLAs) for point sources and load allocations (LAs) for non point sources and natural background sources. A margin of safety (MOS) is also included and accounts for the uncertainty in the analytical procedures used for water quality modeling, as well as the limits in scientific and technical understanding of water quality in natural systems. Although this formulation suggests that the TMDL be expressed as a load, the Code of Federal Regulations (40 CFR 130.2(i)) states that the TMDL can be expressed in terms of "mass per time, toxicity or other appropriate measure."

For many reasons, bacteria are difficult to simulate in water quality models. They reproduce and die off in a non-linear fashion as a function of many environmental factors, including temperature, pH, turbidity (UV light penetration) and settling. They occur in concentrations that vary widely (i.e., over orders of magnitude) and an accurate estimation of source inputs is difficult to develop. Finally, limited data are available to characterize the effectiveness of any program or practice at reducing bacteria loads (Schueler 1999).

Bacteria concentrations, determined through laboratory analysis of in-stream water samples for bacteria indicators (e.g., enterococci), are expressed in either colony forming units (CFU) or most probable number (MPN) of colonies. The first method (US EPA 1985) is a direct estimate of the bacteria colonies (Method 1600). The second method is a statistical estimate of the number of colonies (ONPG MUG Standard Method 9223B, AOAC 991.15). Sample results indicate the extreme variability in the total bacteria counts (see Appendix A). The distribution of the sample results tends to be lognormal, with a strong positive skew of the data. Estimating loads of constituents that vary by orders of magnitude can introduce much uncertainty and result in large confidence intervals around the final results.

Estimating bacteria sources can also be problematic due to the many assumptions required and limited available data. Lack of specific numeric and spatial location data for several source categories, from failing septic systems to domestic animals, livestock, and wildlife populations, can create many potential uncertainties in traditional water quality modeling. For this reason, MDE applies an analytical method combined with the bacteria source tracking described above for the calculation of this TMDL.

4.2 Analytical Framework

The TMDL analysis uses flow duration curves to identify flow intervals that are used as indicators of hydrological conditions (i.e., annual average and critical conditions). This analytical method, combined with water quality monitoring data and BST, provides reasonable results (Cleland 2003), a better description of water quality than traditional water quality modeling, and also meets TMDL requirements.

In brief, baseline loads are estimated first for each subwatershed by using bacteria monitoring data and long-term flow data. These baseline loads are divided into four bacteria source categories, using the results of BST analysis. Next, the percent reduction required to meet the water quality criterion in each subwatershed is estimated from the observed bacteria concentrations after accounting for critical condition and seasonality. Critical condition and seasonality are determined by assessing annual and dry weather seasonal hydrological conditions. Finally, TMDLs for each subwatershed are estimated by applying these percent reductions.

Figure 4.2.1 illustrates how the hydrological (flow duration curve), water quality, and BST data are linked together for the TMDL development.

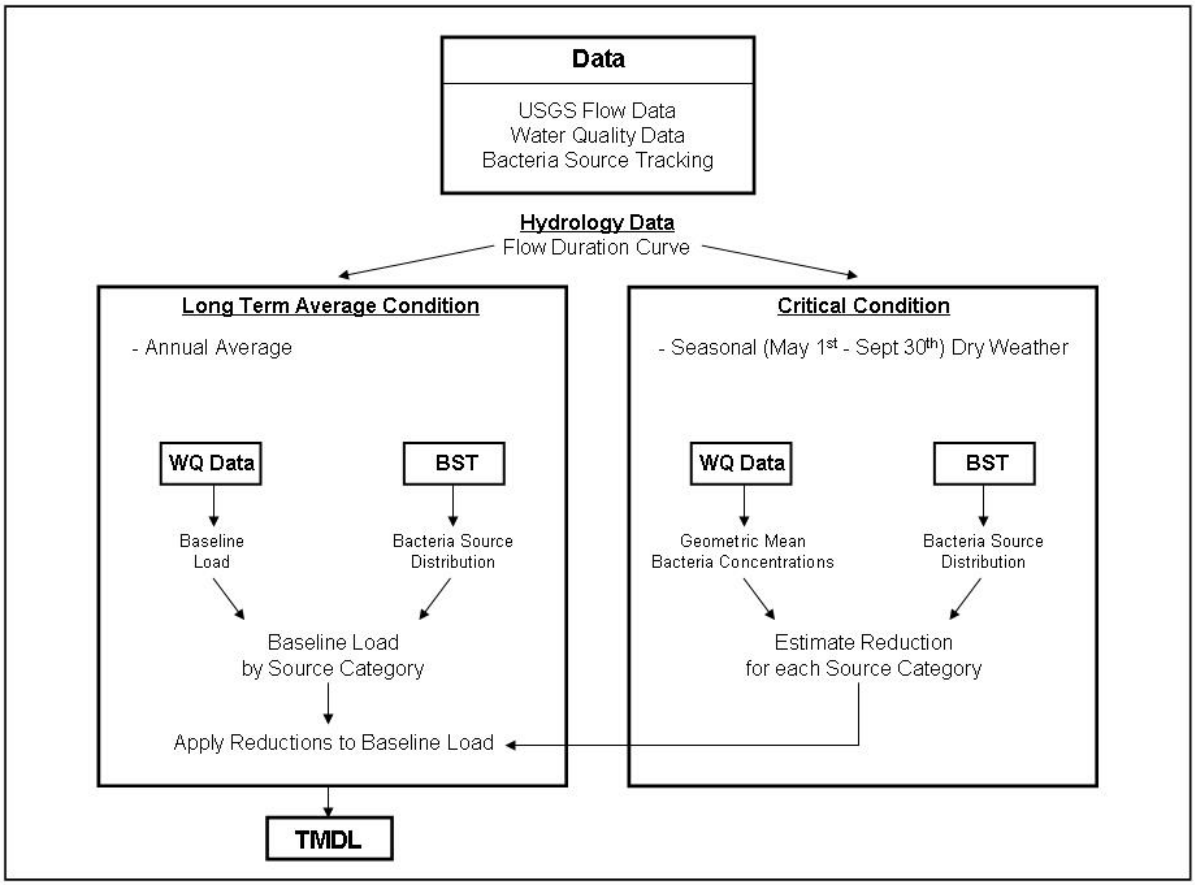

Figure 4.2.1: Diagram of the Non-tidal Bacteria TMDL Analysis Framework

4.3 Estimating Baseline Loads

Baseline loads are estimated for all subwatersheds of the Loch Raven Reservoir watershed. Baseline loads estimated in this TMDL analysis are reported as long-term average annual loads. These loads are estimated using geometric mean concentrations and bias correction factors (calculated from bacteria monitoring data) and daily average flows (estimated from long-term flow data).

Estimating Weighted Annual Average Geometric Mean Concentrations

The weighted annual average geometric mean used in the calculation of baseline loads can be estimated either by monitoring design or by statistical analysis as follows:

1. A stratified monitoring design is used where the number of samples collected is proportional to the duration of high flows, mid flows, and low flows within the watershed. This sample design allows a geometric mean to be calculated directly from the monitoring data without bias.

2. Routine monitoring typically results in samples from varying hydrologic conditions (i.e., high flows, mid flows, and low flows) where the numbers of samples are not proportional to the duration of those conditions. Averaging these data without consideration of the sampling conditions results in a biased estimate of geometric means. The potential bias of these geometric means can be reduced by weighting the sampling results collected during high flow, mid flow, and low flow regimes by the proportion of time each flow regime is expected to occur. This ensures that the high flow and low flow conditions are proportionally balanced.

3. If (1) the monitoring design was not stratified based on flow regime or (2) flow information is not available to weight the samples accordingly, then a geometric mean of sequential monitoring data can be used as an estimate of the geometric mean for the specified period.

A routine monitoring design was used to collect bacteria data in the Loch Raven Reservoir watershed. To estimate the weighted geometric mean, the monitoring data were first reviewed by plotting the sample results versus their corresponding daily flow duration percentile.

To calculate the weighted geometric mean with routine monitoring data, a conceptual model was developed by dividing the daily flow frequency for the stream segment into strata that are representative of hydrologic conditions. A conceptual continuum of flows is illustrated in Figure 4.3.1.

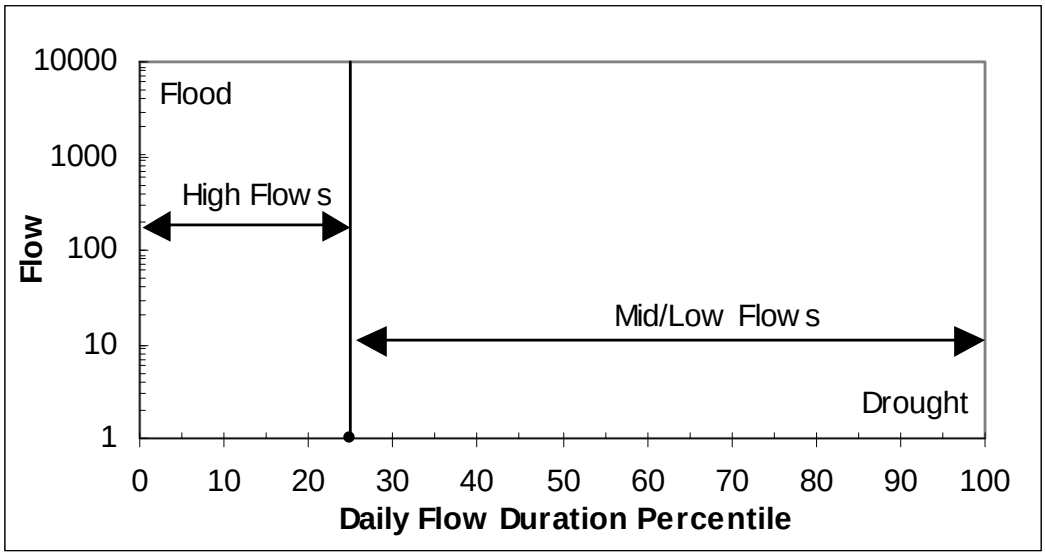

Figure 4.3.1: Conceptual Diagram of Flow Duration Zones

During high flows, a significant portion of the total stream flow is from surface flow contributions. Low flow conditions represent periods with minimal rainfall and surface runoff. There is typically a transitional mid flow period between the high and low flow durations, representative of varying contributions of surface flow inputs that result from differing rainfall volumes and antecedent soil moisture conditions. Because the bacteria samples were taken during a routine monitoring design and not a stratified monitoring design, the division of the entire flow regime into strata enables the estimation of a less flow-biased geometric mean.

Based on flow data of USGS gages 01582000, 01582500, 01583500 and 01583600 it was determined that the long-term average daily flow corresponds to a daily flow duration of 34.3%. Hence for this analysis it is defined that flows greater than the 34.3 percentile flow represent high flows, and flows lesser than the 34.3 percentile flow represent mid/low flows. A detailed method of how the flow strata were defined is presented in Appendix B.

Factors for estimating a weighted geometric mean are based on the frequency of each flow stratum. The weighting factor accounts for the proportion of time that each flow stratum represents. The weighting factors for an average hydrological year used in the Loch Raven Reservoir watershed TMDL analysis are presented in Table 4.3.1.

Table 4.3.1: Weighting Factors for Average Hydrology Year Used for Estimation of Geometric Means in the Loch Raven Reservoir Watershed

Flow Duration Zone	Duration Interval	Weighting Factor
High Flows	0 – 34.3%	0.343
Mid/Low Flows	34.3 – 100%	0.657

Bacteria enumeration results for samples within a specified stratum will receive their corresponding weighting factor. The geometric mean is calculated as follows:

$$M = \sum_{i=1}^{2} M_i * W_i \qquad (1)$$

where,

$$M_i = \frac{\sum_{j=1}^{n_i} \log_{10}(C_{i,j})}{n_i} \qquad (2)$$

M = log weighted mean
M_i = log mean concentration for stratum i
W_i = proportion of stratum i
$C_{i,j}$ = concentration for sample j in stratum i
n_i = number of samples in stratum

Finally, the weighted geometric mean concentration is estimated using the following equation:

$$C_{gm} = 10^M \qquad (3)$$

where,

C_{gm} = Steady-state geometric mean concentration

For both the annual and seasonal analysis only the overall geometric mean for the period was applied due to an insufficient number of samples in both hydrological conditions. Table 4.3.2 presents the annual maximum and minimum concentrations and the overall annual geometric means for each subwatershed of the Loch Raven Reservoir. Table 4.3.3 presents the seasonal dry weather steady-state (May 1st –September 30th) maximum and minimum concentrations and the overall geometric mean concentrations for each subwatershed. Graphs illustration these results can be found in Appendix B. For the downstream subwatershed the average geometric mean concentrations of the three upstream watersheds, GUN0233, WGP0050 and BEV0005, were applied to account for the unmonitored streams. The watershed of SBH0002 was not used in this calculation due to its unique land use (highly urbanized) conditions and extreme concentrations.

Table 4.3.2: Loch Raven Reservoir Watershed Annual Geometric Means

Station / Tributary	**Number of Samples**	***E. coli* Minimum Concentration** (MPN/100ml)	***E. coli* Maximum Concentration** (MPN/100ml)	**Annual* Average Geometric Mean** (MPN/100ml)
GUN0387 Gunpowder Falls at Falls Rd.	24	1	120	14
LIT0002 Little Falls	24	10	770	96
GUN0284 Gunpowder Falls at Corbett Rd.	24	10	770	75
GUN0233 Gunpowder Falls at Phoenix Rd.	23	10	14,140	142
WGP0050 Western Run	24	10	2,910	233
BEV0005 Beaverdam Run	24	20	2,500	213
SBH0002 Spring Branch	24	30	9,210	300
Downstream Subwatershed	N/A			196

*** Used for estimating average annual baseline loads**

Table 4.3.3: Loch Raven Reservoir Watershed Seasonal (May 1 - September 30) Dry Weather Steady-State Geometric Means

Station / Tributary	Number of Samples	*E. coli* Minimum Concentration (MPN/100ml)	*E. coli* Maximum Concentration (MPN/100ml)	Dry Weather* Steady-State Geometric Mean (MPN/100ml)
GUN0387 Gunpowder Falls at Falls Rd.	10	10	120	18
LIT0002 Little Falls	10	10	770	139
GUN0284 Gunpowder Falls at Corbett Rd.	10	50	770	168
GUN0233 Gunpowder Falls at Phoenix Rd.	10	60	3,800	224
WGP0050 Western Run	10	190	1,400	491
BEV0005 Beaverdam Run	9	140	2,500	611
SBH0002 Spring Branch	10	260	9,210	1,080
Downstream Subwatershed	N/A			442

***Used for estimating reductions needed to meet water quality standards**

As stated previously, for both the annual and seasonal analysis an overall geometric mean was calculated, rather than by flow stratum, due to an insufficient number of samples in the two flow conditions. The geometric mean concentration is calculated from the log transformation of the raw data. Statistical theory tells us that when back-transformed values are used to calculate average daily loads or total annual loads, the loads will be biased low (Richards 1998). To avoid this bias, a factor should be added to the log-concentration before it is back-transformed. There are several methods of determining this bias correction factor, ranging from parametric estimates resulting from the theory of the log-normal distribution to non-parametric estimates using a bias correction factor [Ferguson 1986; Cohn et al. 1989; Duan 1983]. There is much literature on the applicability and results from these various methods with a summary provided in Richards (1998). Each has advantages and conditions of applicability. A non-parametric estimate of the bias correction factor (Duan 1983) was used in this TMDL analysis.

With calculated geometric means and arithmetic means for each subwatershed, the bias correction factors are estimated as follows:

$$F_1 = A/C \qquad (6)$$

where,

F_1 = bias correction factor
A = long term annual arithmetic mean
C = long term annual geometric mean

Daily average flows are estimated for each subwatershed using the watershed area ratio approach, since nearby long-term monitoring data are available.

For each subwatershed, the baseline loads are then estimated as follows:

$$L = Q * C * F_1 * F_2 \qquad (7)$$

where,

L = daily average load (Billion MPN/day) at monitoring station
Q = daily average flow (cfs)
C = geometric mean (MPN/100ml)
F_1 = bias correction factor
F_2 = unit conversion factor (0.0245)

Estimating Subwatershed Loads

Subwatersheds with more than one monitoring station are subdivided into unique watershed segments, thus allowing individual load and reduction targets to be determined for each. In the Loch Raven Reservoir watershed two stations have upstream monitoring stations, as listed in Table 4.3.4. In these two cases the subwatershed is differentiated by adding the extension "sub" to the name of the downstream monitoring station. For example, GUN0233sub signifies only the area and load between stations GUN0233 and GUN0284 while GUN0233 refers to the cumulative area draining to that station. The portion of the watershed downstream of stations, GUN0233, WGP0050, BEV0005 and SBH0002, is referred to as the Downstream Subwatershed. This identification represents only the area and load downstream of those four stations. There are a total of eight subwatersheds considered in this analysis, corresponding to the seven monitoring stations and the unmonitored downstream portion.

Table 4.3.4: Subdivided Watersheds in the Loch Raven Reservoir Watershed

Subwatershed	Upstream Station(s)
GUN0284sub	GUN0387, LIT0002
GUN0233sub	GUN0284
Downstream Subwatershed	GUN0233, WGP0050, BEV0005, SBH0002

Bacteria loads from these subwatersheds are joined by loads from their upstream subwatersheds to result in the concentration measured at the downstream monitoring station. The total baseline loads from the upstream watersheds, estimated from the monitoring data, were multiplied by a transport factor derived from first order decay. The decay factor for *E. coli* used in the analysis was obtained from the study "Pathogen Decay in Urban Waters" by Easton et al. (2001), and was estimated by linear regression of counts of microorganisms versus time (die-off plots). The estimated transported loads were then subtracted from the downstream cumulative load to estimate the adjacent subwatershed load. The general equation for the flow mass balance is:

$$\sum Q_{us} + Q_{sub} = Q_{ds} \qquad (8)$$

where,

Q_{us} = upstream flow (cfs)
Q_{sub} = subwatershed flow (cfs)
Q_{ds} = downstream flow (cfs)

And the general equation for the bacteria loading mass balance is:

$$\sum (e^{-kt} Q_{us} C_{us}) + Q_{sub} C_{sub} = Q_{ds} C_{ds} \qquad (9)$$

where,

C_{us} = upstream bacteria concentration (MPN/100ml)
k = bacteria (*E. coli*) decay coefficient (1/day) = 0.762 day^{-1}
t = travel time from upstream watershed to outlet (days)
C_{sub} = subwatershed bacteria concentration (MPN/100ml)
C_{ds} = downstream bacteria concentration (MPN/100ml)

The subwatershed load, expressed as $Q_{sub}C_{sub}$ in equation (9), and the average flow are used to estimate the geometric mean concentration of the subwatershed.

As explained above, to estimate the load from subwatershed GUN0284sub, the transported load from stations GUN0387 and LIT0002 is subtracted from the load measured at station GUN0284. The difference is assigned to subwatershed GUN0284sub. To estimate the load from subwatershed GUN0233sub, the transported load from stations GUN0284 is subtracted from the load measured at station GUN0233. The difference is assigned to subwatershed GUN0233sub.

Source estimates from the BST analysis are completed for each station and are based on the contribution from the upstream watershed. Given the uncertainty of in-stream bacteria processes and the complexity involved in back-calculating an accurate source transport factor, the sources for GUN0284sub and GUN0233sub were assigned from the analysis for GUN0284 and GUN0233, respectively.

The bacteria concentration for the watershed referred to as the Downstream Subwatershed, is assigned as the average of the concentrations at the three upstream stations, GUN0233, WGP0050 and BEV0005, and is assumed to be representative of that subwatershed. The bacteria source distribution for the downstream subwatershed is also assigned as the average of the BST analysis results of the three specified upstream stations.

Results of the baseline load calculations, including subwatersheds partially located in PA, are presented in Table 4.3.5.

Table 4.3.5: Baseline Loads Calculations

Subwatershed	Area (mi^2)	Daily Average Flow (cfs)	*E. coli* Concentration (MPN/100ml)	Baseline *E. coli* Load (Billion MPN/year)
GUN0387	1.8	2.3	14	460
LIT0002[1]	53.8	70.3	96	97,368
GUN0284sub	18.6	24.3	343	142,466
GUN0233sub	26.9	35.2	572	1,177,287
WGP0050	60.1	69.7	233	307,744
BEV0005	20.9	30.3	213	115,900
SBH0002	1.5	2.2	300	21,893
Downstream Subwatershed	40.7	53.2	196	331,190

[1]Subwatershed partially located in Pennsylvania

Baseline loads for subwatersheds located in both MD and PA were estimated using the ratios of the areas of the MD and PA portions to the total area of the subwatershed. The total baseline

load for all subwatersheds or portions thereof located in MD is estimated as 2,187,202 billion MPN *E.coli*/year. The total baseline load for the portions of subwatersheds located in PA is 7,106 billion MPN E. coli/year. A summary of the baseline loads is given in Table 4.3.6.

Table 4.3.6: Baseline Loads Summary

MD 8-Digit Loch Raven Reservoir Fecal Bacteria Baseline Loads (Billion MPN *E. coli*/year)								
Total Baseline Load	**=**	**Upstream Baseline Load[1]**	**+**	**MD 8-digit Loch Raven Reservoir Baseline Load Contribution**				
		BL_{PA}		**Nonpoint Source BL_{LR}**	**+**	**NPDES Stormwater BL_{LR}**	**+**	**WWTP BL_{LR}**
2,194,308	=	7,106	+	2,033,052	+	152,583	+	1,567

[1]Although the upstream baseline load is reported here as a single value, it could include point and nonpoint sources.

4.4 Bacteria Source Tracking

As explained above in the Source Assessment Section, ARA was used to identify probable bacterial sources in the Loch Raven watershed. An accurate representation of the expected contribution of each source (human, pets, livestock and wildlife) at each station is estimated by using a weighted mean of the identified sample results. The weighting factors are based on the $\log_{10}$ of the bacteria concentration. The procedure for calculating the weighted mean of the sources per monitoring station is as follows:

1. Calculate the percentage of isolates per source per each sample date (S).
2. Calculate an initial weighted percentage (IMS) of each source. The weighting is based on the $\log_{10}$ bacteria concentration for the water sample.
3. Adjust the weighted percentage based on the classification of known sources.

The weighted mean for each source category is calculated using the following equations:

$$MS_l = \sum_{k=1}^{5} \frac{A_{l,k} * IMS_k}{P_k} \qquad (4)$$

where,

$$IMS_k = \frac{\sum_{j=1}^{n} \log_{10}(C_j) * S_{j,k}}{\sum_{j=1}^{n} \log_{10}(C_j)} \qquad (5)$$

and where,

MS_l = weighted mean proportion of isolates of source l
IMS_k = initial weighted mean proportion of isolates for source k

$A_{l,k}$ = number of known source l isolates initially predicted as source k
P_k = number of total known isolates initially predicted as source k
j = sample
k = source category (1=human, 2=domestic, 3=livestock, 4=wildlife, 5=unknown)
l = final source category (1=human, 2=domestic, 3=livestock, 4=wildlife)
C_j = concentration for sample j
$S_{j,k}$ = proportion of isolates for sample j, of source k
n = number of samples

The complete distributions of the annual and seasonal period source loads are listed in Tables 4.4.1 and 4.4.2. Details of the BST data and tables with the BST analysis results can be found in Appendix C. For the downstream subwatershed, averages of the three upstream (GUN0233, WGP0050 and BEV0005) source percentages were used.

Table 4.4.1: Distribution of Fecal Bacteria Source Loads in the Loch Raven Reservoir Watershed for the Average Annual Period

Station	% Domestic Animals	% Human	% Livestock	% Wildlife
GUN0387	7.9	41.4	4.7	46.0
LIT0002	5.0	53.8	10.6	30.7
GUN0284	15.1	26.0	13.4	45.5
GUN0233	6.4	26.2	13.7	53.7
WGP0050	5.4	28.1	14.3	52.2
BEV0005	7.6	37.4	12.4	42.6
SBH0002	5.4	33.1	13.9	47.6
Downstream Subwatershed	6.5	30.6	13.5	49.5

Table 4.4.2: Distribution of Fecal Bacteria Source Loads in the Loch Raven Reservoir Watershed for the Seasonal (May 1 – September 30) Dry Weather Period

Station	% Domestic Animals	% Human	% Livestock	% Wildlife
GUN0387	15.8	46.7	4.4	33.2
LIT0002	9.6	58.7	6.7	25.0
GUN0284	23.8	28.6	8.2	39.4
GUN0233	11.2	30.2	9.3	49.2
WGP0050	8.3	33.0	10.1	48.6
BEV0005	7.9	38.0	12.0	42.1
SBH0002	4.6	29.0	14.0	52.4
Downstream Subwatershed	9.2	33.7	10.5	46.6

4.5 Critical Condition and Seasonality

Federal regulations (40 CFR 130.7(c)(1)) require TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters. The intent of this requirement is to ensure that the water quality of the waterbody is protected during times when it is most vulnerable.

For this TMDL the critical condition is determined by assessing both the annual and dry weather seasonal conditions. Seasonality is assessed as the time period when water contact recreation is expected, specifically dry weather days during May 1st through September 30th. The critical condition requirement is met by determining the maximum reduction per bacteria source that satisfies both conditions and meets the water quality standard, thereby minimizing the risk to water contact recreation. It is assumed that the reduction applied to a bacteria source category will be constant through both conditions.

The reductions of fecal bacteria required to meet water quality standards in each subwatershed of the Loch Raven Reservoir watershed are shown in Table 4.4.1. For computational purposes, the calculations include those subwatersheds partially located in PA.

Table 4.5.1: Required Fecal Bacteria Reductions (by Condition) to Meet Water Quality Standards

Station	Condition	Domestic Animals %	Human %	Livestock %	Wildlife %
GUN0387	Annual	0.0	0.0	0.0	0.0
	Seasonal	0.0	0.0	0.0	0.0
	Maximum Source Reduction	**0.0**	**0.0**	**0.0**	**0.0**
LIT0002[1]	Annual	0.0	0.0	0.0	0.0
	Seasonal	0.0	23.7	0.0	0.0
	Maximum Source Reduction	**0.0**	**23.7**	**0.0**	**0.0**
GUN0284sub	Annual	98.0	98.0	98.0	25.7
	Seasonal	98.0	98.0	98.0	76.1
	Maximum Source Reduction	**98.0**	**98.0**	**98.0**	**76.1**
GUN0233sub	Annual	98.0	98.0	98.0	62.8
	Seasonal	98.0	98.0	98.0	68.3
	Maximum Source Reduction	**98.0**	**98.0**	**98.0**	**68.3**
WGP0050	Annual	98.0	98.0	98.0	3.4
	Seasonal	98.0	98.0	98.0	51.9
	Maximum Source Reduction	**98.0**	**98.0**	**98.0**	**51.9**
BEV0005	Annual	29.8	95.0	48.9	0.0
	Seasonal	98.0	98.0	98.0	56.2
	Maximum Source Reduction	**98.0**	**98.0**	**98.0**	**56.2**
SBH0002	Annual	98.0	98.0	98.0	18.3
	Seasonal	98.0	98.0	98.0	80.7
	Maximum Source Reduction	**98.0**	**98.0**	**98.0**	**80.7**
Downstream Subwatershed	Annual	28.8	95.0	59.9	0.0
	Seasonal	98.0	98.0	98.0	44.2
	Maximum Source Reduction	**98.0**	**98.0**	**98.0**	**44.2**

[1]Subwatersheds partially located in Pennsylvania

4.6 Margin of Safety

A margin of safety (MOS) is required as part of this TMDL in recognition of the many uncertainties in the understanding and simulation of bacteriological water quality in natural systems and in statistical estimates of indicators. As mentioned in Section 4.1, it is difficult to estimate stream loadings for fecal bacteria due to the variation in loadings across sample locations and time. Load estimation methods should be both precise and accurate to obtain the true estimate of the mean load.

Based on EPA guidance, the MOS can be achieved through two approaches (EPA 1991). One approach is to reserve a portion of the loading capacity as a separate term in the TMDL (i.e., TMDL = LA + WLA + MOS). The second approach is to incorporate the MOS as conservative assumptions used in the TMDL analysis. The second approach was used for this TMDL by estimating the loading capacity of the stream based on a reduced (more stringent) water quality criterion concentration. The *E. coli* water quality criterion concentration was reduced by 5%, from 126 *E. coli* MPN/100ml to 119.7 *E. coli* MPN/100ml.

4.7 Scenario Descriptions

Source Distribution

The final bacteria source distribution and corresponding baseline loads are derived from the source proportions listed in Table 4.4.1. The source distribution and baseline loads used in the TMDL scenarios are presented in Table 4.67.1. As stated in Section 4.3, the source distributions for subwatersheds GUN0284sub and GUN0233sub were based on the sources identified at stations GUN0284 and GUN0233 respectively.

Table 4.7.1: Bacteria Source Distributions and Corresponding Baseline Loads Used in the Annual Average TMDL Analysis

Subwatershed	Domestic		Human		Livestock		Wildlife		Total Load (Billion *E. coli* MPN/year)
	%	Load (Billion *E. coli* MPN/year)	%	Load (Billion *E. coli* MPN/year)	%	Load (Billion *E. coli* MPN/year)	%	Load (Billion *E. coli* MPN/year)	
GUN0387	7.9	36	41.4	190	4.7	22	46.0	212	460
LIT0002[1]	5.0	4,835	53.8	52,396	10.6	10,275	30.7	29,862	97,368
GUN0284sub	15.1	21,497	26.0	37,092	13.4	19,028	45.5	64,849	142,466
GUN0233sub	6.4	75,552	26.2	308,913	13.7	160,834	53.7	631,988	1,177,287
WGP0050	5.4	16,654	28.1	86,556	14.3	43,975	52.2	160,559	307,744
BEV0005	7.6	8,765	37.4	43,373	12.4	14,377	42.6	49,385	115,900
SBH0002	5.4	1,184	33.1	7,254	13.9	3,032	47.6	10,423	21,893
Downstream Subwatershed	6.5	21,408	30.6	101,331	13.5	44,551	49.5	163,900	331,190

[1]Subwatersheds partially located in Pennsylvania

First Scenario: Fecal Bacteria Practicable Reduction Targets

The maximum practicable reduction (MPR) for each of the four source categories is listed in Table 4.7.2. These values are based on review of the available literature and best professional judgment. It is assumed that human sources would potentially have the highest risk of causing gastrointestinal illness and therefore should have the highest reduction. If a domestic WWTP is located in the upstream watershed, this is considered in the MPR so as to not violate the permitted loads. The domestic animal category includes sources from pets (e.g., dogs) and the MPR is based on an estimated success of education and outreach programs.

Table 4.7.2: Maximum Practicable Reduction Targets

Max Practicable Reduction per Source	Human	Domestic	Livestock	Wildlife
	95%	75%	75%	0%
Rationale	(a) Direct source inputs. (b) Human pathogens more prevalent in humans than animals. (c) Enteric viral diseases spread from human to human.[1]	Target goal reflects uncertainty in effectiveness of urban BMPs[2] and is also based on best professional judgment	Target goal based on sediment reductions from BMPs[3] and best professional judgment	No programmatic approaches for wildlife reduction to meet water quality standards. Waters contaminated by wild animal wastes offer a public health risk that is orders of magnitude less than that associated with human waste.[4]

[1]Health Effects Criteria for Fresh Recreational Waters. EPA-600/1-84-004. U.S. Environmental Protection Agency, Washington, DC. EPA. 1984.
[2]Preliminary Data Summary of Urban Storm Water Best Management Practices. EPA-821-R-99-012. U.S. Environmental Protection Agency, Washington, DC. EPA. 1999.
[3]Agricultural BMP Descriptions as Defined for The Chesapeake Bay Program Watershed Model. Nutrient Subcommittee Agricultural Nutrient Reduction Workshop. EPA. 2004.
[4]Environmental Indicators and Shellfish Safety. 1994. Edited by Cameron, R., Mackeney and Merle D. Pierson, Chapman & Hall.

As previously stated, these maximum practicable reduction targets are based on the available literature and best professional judgment. There is much uncertainty with estimated reductions from best management practices (BMP). The BMP efficiency for bacteria reduction ranged from –6% to +99% based on a total of 10 observations (US EPA 1999). The MPR to agricultural lands was based on sediment reductions identified by EPA (US EPA 2004).

The practicable reduction scenario was developed based on an optimization analysis whereby a subjective estimate of risk was minimized and constraints were set on maximum reduction and allowable background conditions. Risk was defined on a scale of one to five, where it was assumed that human sources had the highest risk (5), domestic animals and livestock next (3), and wildlife the lowest (1) (See Table 4.7.2). The model was defined as follows:

$$\text{Risk Score} = \text{Min} \sum_{i=1}^{4} P_j * W_j \qquad (10)$$

where,

$$P_j = \frac{(1 - R_i) * Pb_j}{1 - TR} \qquad (11)$$

and,

$$TR = \frac{C - C_{cr}}{C} \qquad (12)$$

Therefore the risk score can be represented as:

$$Risk\ Score = Min\sum_{i=1}^{4}\left[\frac{(1-R_j)*Pb_j}{(1-\frac{C-Ccr}{C})}*W_j\right] \qquad (13)$$

where,

i	= hydrological condition
j	= bacteria source category =human, domestic animal, livestock and wildlife
P_j	= % of each source category (human, domestic animals, livestock and wildlife) in final allocation
W_j	= weight of risk per source category = 5, 3 or 1
R_j	= percent reduction applied by source category (human, domestic animals, livestock and wildlife) for the specified hydrological condition (variable)
Pb_j	= original (baseline) percent distribution by source category (variable)
TR	= total reduction (constant within each hydrological condition) = Target reduction
C	= in-stream concentration
Ccr	= water quality criterion

The model is subject to the following constraints:

$$\begin{aligned} C &= Ccr \\ 0 \le R_{human} &\le 95\% \\ 0 \le R_{pets} &\le 75\% \\ 0 \le R_{livestock} &\le 75\% \\ R_{wildlife} &= 0 \\ P_j &\ge 1\% \end{aligned}$$

In six of the eight subwatersheds, the constraints of this scenario could not be satisfied, indicating there was not a practicable solution. A summary of the first scenario analysis results is presented in Table 4.7.3.

Table 4.7.3: Practicable Reduction Scenario Results

Subwatershed	Applied Reductions				Total Reduction %	Target Reduction %
	Domestic %	Human %	Livestock %	Wildlife %		
GUN0387	0.0	0.0	0.0	0.0	0.0	0.0
LIT0002[1]	0.0	23.7	0.0	0.0	12.7	12.7
GUN0284sub	75.0	95.0	75.0	0.0	46.1	88.0
GUN0233sub	75.0	95.0	75.0	0.0	40.0	82.1
WGP0050	75.0	95.0	75.0	0.0	41.5	73.9
BEV0005	75.0	95.0	75.0	0.0	50.5	80.2
SBH0002	75.0	95.0	75.0	0.0	45.9	89.8
Downstream Subwatershed	75.0	95.0	75.0	0.0	44.0	71.4

[1]Subwatersheds partially located in Pennsylvania

Second Scenario: Fecal Bacteria Reductions Higher than MPRs

The TMDL must specify load allocations that will meet the water quality standards. In the practicable reduction targets scenario, six of the eight subwatersheds could not meet water quality standards based on MPRs.

To further develop the TMDL, a second scenario was analyzed in which the constraints on the MPRs were relaxed. In these subwatersheds, the maximum allowable reduction was increased to 98% for all sources, including wildlife. A similar optimization procedure as before was used to minimize risk. Again, the objective is to minimize the sum of the risk for all conditions while meeting the scenario reduction constraints. The model was defined in the same manner as considered in the practicable reduction scenario but subject to the following constraints:

$$C = Ccr$$
$$0 \leq R_{human} \leq 98\%$$
$$0 \leq R_{pets} \leq 98\%$$
$$0 \leq R_{livestock} \leq 98\%$$
$$0 \leq R_{wildlife} \leq 98\%$$
$$P_j \geq 1\%$$

A summary of the results of this second scenario analysis is presented in Table 4.7.4.

Table 4.7.4: Reduction Results Based on Optimization Model Allowing Up to 98% Reduction

Subwatershed	Applied Reductions				Total Reduction %	Target Reduction %
	Domestic %	Human %	Livestock %	Wildlife %		
GUN0387	0.0	0.0	0.0	0.0	0.0	0.0
LIT0002[1]	0.0	23.7	0.0	0.0	12.7	12.7
GUN0284sub	98.0	98.0	98.0	76.1	88.0	88.0
GUN0233sub	98.0	98.0	98.0	68.3	82.1	82.1
WGP0050	98.0	98.0	98.0	51.9	73.9	73.9
BEV0005	98.0	98.0	98.0	56.2	80.2	80.2
SBH0002	98.0	98.0	98.0	80.7	89.8	89.8
Downstream Subwatershed	98.0	98.0	98.0	44.2	71.4	71.4

[1]Subwatersheds partially located in Pennsylvania

4.8 TMDL Loading Caps

The TMDL loading cap is an estimate of the assimilative capacity of the monitored watershed. The TMDL loading caps are provided in billion MPN *E. coli*/day. These loading caps are for the seven subwatersheds located upstream of their respective monitoring stations as well as the one downstream watershed. Loading caps for subwatersheds of Loch Raven Reservoir partially located in PA were included in the TMDL scenario. A TMDL summary for the entire Loch Raven Reservoir watershed will include an upstream load allocation for the portion of the watershed located in PA to indicate estimated loads necessary to meet MD water quality standards in the MD 8-digit assessment unit for the Loch Raven Reservoir watershed.

Annual Average TMDL

As explained in the sections above, the annual average TMDL loading caps are estimated by first determining the baseline or current condition loads for each subwatershed and the associated geometric mean from the available monitoring data. This annual average baseline load is estimated using the geometric mean concentration and the long-term annual average daily flow.

Next, the percent reduction required to meet the water quality criterion is estimated from the observed bacteria concentrations accounting for the critical conditions (See Section 4.5). A reduction in concentration is proportional to a reduction in load; thus the TMDL is equal to the current baseline load multiplied by one minus the required reduction. This reduction, estimated as explained in Section 4.5, represents the maximum reduction per source that satisfies the two

hydrological conditions in each subwatershed, and that is required to meet water quality standards.

$$\text{TMDL Loading Cap} = L_b * (1 - R) \qquad (14)$$

where,

L_b = current or baseline load estimated from monitoring data
R = reduction required from baseline to meet water quality criterion.

The annual average bacteria TMDL loading caps for the subwatersheds, including those partially located in PA, are shown in Tables 4.8.1 and 4.8.2.

Table 4.8.1: Annual Average TMDL Loading Caps

Subwatershed	*E. coli* Baseline Load (Billion MPN/year)	Long-Term Average *E. coli* TMDL Load (Billion MPN/year)	% Target Reduction
GUN0387	460	460	0.0
LIT0002[1]	97,368	84,958	12.7
GUN0284sub	142,466	17,029	88.0
GUN0233sub	1,177,287	211,228	82.1
WGP0050	307,744	80,168	73.9
BEV0005	115,900	22,967	80.2
SBH0002	21,893	2,244	89.8
Downstream Subwatershed	331,190	94,840	71.4
Total	**2,194,308**	**513,894**	**76.6**

[1]Subwatersheds partially located in Pennsylvania

Table 4.8.2: Annual Average TMDL Loading Caps by Source Category

Subwatershed	Domestic		Human		Livestock		Wildlife		Total Load (Billion *E. coli* MPN/year)
	%	Load (Billion *E. coli* MPN/year)	%	Load (Billion *E. coli* MPN/year)	%	Load (Billion *E. coli* MPN/year)	%	Load (Billion *E. coli* MPN/year)	
GUN0387	7.9	36	41.4	190	4.7	22	46.0	212	460
LIT0002[1]	5.7	4,835	47.1	39,986	12.1	10,275	35.1	29,862	84,958
GUN0284sub	2.5	430	4.4	742	2.2	381	90.9	15,476	17,029
GUN0233sub	0.7	1,511	2.9	6,178	1.5	3,217	94.8	200,322	211,228
WGP0050	0.4	333	2.2	1,731	1.1	879	96.3	77,225	80,168
BEV0005	0.8	175	3.8	868	1.3	288	94.2	21,636	22,967
SBH0002	1.1	24	6.5	145	2.7	61	89.8	2,014	2,244
Downstream Subwatershed	0.5	428	2.1	2,027	0.9	891	96.5	91,494	94,840

[1]Subwatersheds partially located in Pennsylvania

Maximum Daily Loads

Recent EPA guidance (US EPA 2006a) recommends that maximum daily load (MDL) expressions of long-term annual average TMDLs should also be provided as part of the TMDL analysis and report. Selection of an appropriate method for translating a TMDL based on a longer time period into one using a daily time period requires decisions regarding 1) the level of resolution, and 2) the level of protection. The level of resolution pertains to the amount of detail used in specifying the maximum daily load. The level of protection represents how often the maximum daily load (MDL) is expected to be exceeded. Draft EPA/TetraTech guidance on daily loads (Limno-Tech 2007) provides three categories of options for both level of resolution and level of protection, and discusses these categories in detail.

For the Loch Raven Reservoir watershed MDLs, a "representative daily load" option was selected as the level of resolution, and a value "that will be exceeded with a pre-defined probability" was selected as the level of protection. In these options, the MDLs have an upper bound percentile that accounts for the variability of daily loads. The upper bound percentile and the MDLs were estimated following EPA's "*Technical Support Document for Water Quality-Based Toxics Control*" (1991 TSD) (EPA 1991); and "*Approaches For Developing a Daily Load Expression for TMDLs Computed for Longer Term Averages*" (EPA 2006).

There are three steps to the overall process of estimating these MDLs. First, all the data available from each monitoring station are examined and the percentile rank of the highest observed concentration (at each station) is computed. The highest computed percentile rank is the upper bound percentile to be used in estimating the MDLs.

Secondly, the long-term annual average TMDL (see Table 4.8.1) concentrations are estimated. This is conducted for each station using a statistical methodology (the "Statistical Theory of Rollback," or "STR," described more fully in Appendix D).

Third, based on the estimated long-term average (LTA) TMDL concentrations, the MDL at each station is estimated using the upper boundary percentile computed in the first step above. Finally, MDLs are computed from these MDL concentrations and their corresponding flows.

Results of the fecal bacteria MDL analysis for the Loch Raven Reservoir subwatersheds, including for computational purposes those partially located in PA, are shown in Table 4.8.3. The downstream subwatershed is assigned the average MDL of the upstream subwatersheds (GUN0233, WGP0050 and BEV0005).

Table 4.8.3: Loch Raven Reservoir Watershed Maximum Daily Loads Summary

Subwatershed	Maximum Daily Load (Billion *E. coli* MPN/day)
GUN0387	11
LIT0002[1]	3,327
GUN0284sub	157
GUN0233sub	2,186
WGP0050	5,251
BEV0005	1,194
SBH0002	212
Downstream Subwatershed	5,613

[1]Subwatersheds partially located in Pennsylvania

See Appendix D for a more detailed explanation of the procedure for obtaining these daily loads.

4.9 TMDL Allocations

The Loch Raven Reservoir watershed fecal bacteria TMDL is composed of the following components:

$$TMDL = LA_{LR} + WLA_{LR} + LA_{PA} + MOS \qquad (15)$$

where,

LA_{LR} = MD Loch Raven Reservoir Watershed Load Allocation
WLA_{LR} = MD Loch Raven Reservoir Watershed Waste Load Allocation
LA_{PA} = Pennsylvania Load Allocation
MOS = Margin of Safety

The TMDL allocation for the Loch Raven Reservoir MD 8-digit basin includes load allocations (LA_{LR}) for nonpoint sources and waste load allocations (WLA_{LR}) for point sources including WWTPs and NPDES-regulated stormwater discharges. The Stormwater (SW) WLA_{LR} includes any nonpoint source loads determined to be transported and discharged by regulated stormwater systems. An explanation of the distribution of nonpoint source loads and point source loads to the LA_{LR} and to the SW-WLA_{LR} and WWTP-WLA_{LR} is provided in the subsections that follow.

In addition to these allocation categories for the MD 8-digit watershed, the Loch Raven Reservoir watershed TMDL includes an upstream load allocation for the portion of the watershed located in PA (LA_{PA}). The LA_{PA} was calculated using the ratios of the areas of the watershed in MD and in PA to the total area of the watershed, and is presented as a "lump-sum" upstream load comprising all bacteria source categories. The LA_{PA}, determined to be necessary in order to meet MD water quality standards in the Loch Raven Reservoir MD 8-digit basin, will not be distributed between nonpoint sources (LA) and point sources (WLA).

The margin of safety (MOS) is explicit and is incorporated in the analysis using a conservative assumption; it is not specified as a separate term. The assumption is that a 5% reduction of the criterion concentration established by MD to meet the applicable water quality standard will result in more conservative allowable loads of fecal bacteria, and thus provide the MOS. The final loads are based on average hydrological conditions, with reductions estimated based on critical hydrological conditions. The load reduction scenario results in load allocations that will achieve water quality standards. The State reserves the right to revise these allocations provided such revisions are consistent with the achievement of water quality standards.

<u>Bacteria Source Categories and Allocation Distributions</u>

The bacteria sources are grouped into four categories that are also consistent with divisions for various management strategies. The categories are human, domestic animal, livestock and wildlife. TMDL allocation rules are presented in Table 4.8.1. This table identifies how the TMDL will be allocated among the LA_{LR} (those nonpoint sources or portions thereof not transported and discharged by stormwater systems) and the WLA_{LR} (point sources including WWTPs, and NPDES regulated stormwater discharges). Only the final LA_{LR} or WLA_{LR} is

reported in this TMDL. Note that the assignment of an allowable human load to the LA_{LR} is in consideration of the possible presence of such loads in the watershed beyond the reach of the sanitary sewer systems. The term "allowable load" means the load that the waterbody can assimilate and still meet water quality standards.

Table 4.9.1: Potential Source Contributions for TMDL Allocation Categories in the Loch Raven Reservoir Watershed in MD

Source Category	TMDL Allocation Categories		
	LA_{LR}	WLA_{LR}	
		WWTP	Stormwater
Human	X	X	
Domestic	X		X
Livestock	X		
Wildlife	X		X

* These allocations apply only to the portion of the watershed in MD. The TMDL allocation scenario load attributed to PA includes all four bacteria source categories in one single load.

LA_{LR}

All four bacteria source categories could potentially contribute to nonpoint source loads. For human sources, the nonpoint source contribution is estimated by subtracting any WWTP loads from the TMDL human load, and is then assigned to the LA_{LR}. Livestock loads are also assigned to the LA_{LR}. Since the entire Loch Raven Reservoir watershed is covered by NPDES MS4 permits, bacteria loads from domestic animal and wildlife sources are distributed between the SW-WLA_{LR} and LA_{LR}.

WLA_{LR}

NPDES Regulated Stormwater

EPA's guidance document, "Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs" (November 2002), advises that all individual and general NPDES Phase I and Phase II stormwater permits are point sources subject to WLA assignment in the TMDL. The document acknowledges that quantification of rainfall-driven nonpoint source loads is uncertain, stating that available data and information usually are not detailed enough to determine WLAs for NPDES-regulated stormwater discharges on an outfall-specific basis; therefore, the EPA guidance allows the stormwater WLA to be expressed as an aggregate allotment.

Bacteria loads from domestic animal sources are distributed between the SW-WLA_{LR} and the LA_{LR} based on a ratio of the population in urban land use areas to the population in non-urban areas. The bacteria load from wildlife sources is distributed between the SW-WLA_{LR} and LA_{LR} based on a ratio of the per capita acreage in urban areas to the per capita acreage in non-urban areas. This weighting allows for a greater domestic animal source allocation in urban areas, and a greater wildlife source allocation to non-urban areas. In watersheds with no existing NPDES-regulated stormwater permits, these loads will be included entirely in the LA.

Within the MD portion of the Loch Raven Reservoir watershed, the jurisdictions of Baltimore County, Carroll County, and Harford County have individual Phase I MS4 permits. The municipality of Hampstead is also covered by a general Phase II MS4 permit. Based on EPA's guidance, the SW-WLA is presented as one combined load for the entire land area of each jurisdiction in each subwatershed. In addition to the county and municipal MS4s, the SW-WLA category includes any other Phase I and Phase II NPDES regulated stormwater entities in the watershed, including the MD SHA Phase I MS4, Phase II State and federal MS4s, and industrial stormwater permittees. In the future, when more detailed data and information become available, it is anticipated that the SW-WLA may be disaggregated into more specific allocations by permit type.

The NPDES regulated stormwater baseline loads of fecal bacteria for the MD portion of the Loch Raven Reservoir watershed are presented by jurisdiction and subwatershed in Table 4.9.2. The corresponding SW-WLA_{LR} distribution is presented in Table 4.9.3. It is important to note that these apportioned loads are still aggregate SW-WLAs within each jurisdiction. The average annual allocations represent overall reductions in fecal bacteria loads from regulated stormwater sources of 88% from Baltimore County, 95% from Carroll County, 98% from the municipality of Hampstead, and 0% from Harford County. Upon approval of the TMDL, "NPDES-regulated municipal stormwater and small construction storm water discharges effluent limits should be expressed as BMPs or other similar requirements, rather than as numeric effluent limits" (US EPA 2002a).

Table 4.9.2: Stormwater Baseline Loads in MD

Subwatershed	Baltimore County $SW\text{-}BL_{LR}$	Carroll County $SW\text{-}BL_{LR}$	Hampstead $SW\text{-}BL_{LR}$	Harford County $SW\text{-}BL_{LR}$
	(Billion MPN *E. coli*/year)			
GUN0387	33	N/A	N/A	N/A
LIT0002[1]	3,234	N/A	N/A	35
GUN0284sub	15,284	N/A	N/A	N/A
GUN0233sub	66,357	N/A	N/A	N/A
WGP0050	10,332	426	4,714	N/A
BEV0005	17,961	N/A	N/A	N/A
SBH0002	10,750	N/A	N/A	N/A
Downstream Subwatershed	23,457	N/A	N/A	N/A

[1]MD portion of the subwatershed only.

Table 4.9.3: Annual Average Stormwater Allocations in MD

Subwatershed	Baltimore County $SW\text{-}WLA_{LR}$	Carroll County $SW\text{-}WLA_{LR}$	Hampstead $SW\text{-}WLA_{LR}$	Harford County $SW\text{-}WLA_{LR}$
	(Billion MPN *E. coli*/year)			
GUN0387	33	N/A	N/A	N/A
LIT0002[1]	3,234	N/A	N/A	35
GUN0284sub	512	N/A	N/A	N/A
GUN0233sub	4,538	N/A	N/A	N/A
WGP0050	1,556	21	104	N/A
BEV0005	4,498	N/A	N/A	N/A
SBH0002	1,874	N/A	N/A	N/A
Downstream Subwatershed	1,972	N/A	N/A	N/A

[1]MD portion of the subwatershed only.

Municipal and Industrial WWTPs

As explained in the source assessment section above, there is one NPDES permitted point source facility with a permit regulating the discharge of fecal bacteria in the Loch Raven Reservoir watershed. This facility discharges into the subwatershed of WGP0050 (Western Run). The WLA for the WWTP is estimated using the design flow of the plant stated in the facility's

NPDES permit and the *E. coli* criterion concentration of 126 MPN/100ml. Bacteria loads assigned to the WWTP are allocated as the WWTP-WLA_{LR}.

4.10 Summary

The long-term annual average TMDL and TMDL allocations are presented in Table 4.10.1. Table 4.10.2 presents the maximum daily loads for the subwatersheds or portions thereof within the Loch Raven Reservoir MD 8-digit basin.

Table 4.10.1: Loch Reservoir Watershed Annual Average TMDL

Subwatershed	Total Allocation	LA_{LR}	SW-WLA_{LR}	WWTP-WLA_{LR}
	(Billion MPN *E. coli* /year)			
GUN0387	460	427	33	0
LIT0002[1]	78,758	75,490	3,268	0
GUN0284sub	17,029	16,517	512	0
GUN0233sub	211,228	206,690	4,538	0
WGP0050	80,168	76,920	1,681	1,567
BEV0005	22,967	18,469	4,498	0
SBH0002	2,244	369	1,875	0
Downstream Subwatershed	94,840	92,868	1,972	0
MD Total	507,694	487,750	18,377	1,567
PA Upstream Load	6,200			
***TMDL*[2]**	**513,894**			

[1]MD portion of the subwatershed only.
[2]The MOS is incorporated.

Table 4.10.2: Loch Raven Reservoir Watershed Maximum Daily Loads

Subwatershed	Total Allocation	LA_{LR}	$SW\text{-}WLA_{LR}$	$WWTP\text{-}WLA_{LR}$
	(Billion MPN *E. coli* /day)			
GUN0387	11	10	1	0
LIT0002[1]	3,084	2,956	128	0
GUN0284sub	157	152	5	0
GUN0233sub	2,186	2,139	47	0
WGP0050	5,251	5,128	110	13
BEV0005	1,194	960	234	0
SBH0002	212	35	177	0
Downstream Subwatershed	5,613	5,496	117	0
MD Total	17,708	16,876	819	13
PA Upstream Load	243			
***TMDL*[2]**	**17,951**			

[1]MD portion of the subwatershed only.
[2]The MOS is incorporated.

The long-term annual average fecal bacteria TMDL summary for the entire Loch Raven Reservoir watershed is presented in Table 4.10.3.

Table 4.10.3: MD 8-Digit Loch Raven Reservoir Watershed Annual Average TMDL Summary

(Billion MPN *E. coli*/year)										
TMDL	=	**LA**			+	**WLA**			+	**MOS**
		LA_{PA}[1]	+	**LA_{LR}**		**SW WLA_{LR}**	+	**WWTP WLA_{LR}**		
513,894	=	6,200	+	487,750	+	18,377	+	1,567	+	Incorpo-rated
		Upstream Load Allocation		MD 8-digit Loch Raven Reservoir TMDL Contribution (507,694)						

[1]This upstream PA load allocation is determined to be necessary in order to meet MD water quality standards in the MD portion of the Loch Raven Reservoir watershed. Although the upstream load is reported here as a single value, it could include point and nonpoint sources.

The maximum daily loads of fecal bacteria for the MD 8-digit Loch Raven Reservoir watershed, including the PA upstream load, are summarized in Table 4.10.4.

Table 4.10.4: MD 8-Digit Loch Raven Reservoir Watershed MDL Summary

(Billion MPN *E. coli*/day)										
MDL	=	**LA**			+	**WLA**			+	**MOS**
		LA_{PA}	+	**LA_{LR}**		**SW WLA_{LR}**	+	**WWTP WLA_{LR}**		
17,951	=	243	+	16,876	+	819	+	13	+	Incorpo-rated
		Upstream MDL		MD 8-digit Loch Raven Reservoir MDL Contribution (17,708)						

In certain watersheds, the goal of meeting water quality standards may require very high reductions that are not achievable with current technologies and management practices. In this situation, where there is no feasible TMDL scenario, MPRs are increased to provide estimates of the reductions required to meet water quality standards. In six of the eight Loch Raven Reservoir subwatersheds, water quality standards cannot be achieved with the maximum practicable reduction rates specified in Table 4.7.3. For these six subwatersheds the TMDLs shown in Tables 4.10.1 and 4.10.2 represent reductions from current bacteria loadings that are beyond practical reductions. In cases where such high reductions are required to meet standards, it is expected that the first stage of implementation will be to carry out the MPR scenario.

5.0 ASSURANCE OF IMPLEMENTATION

Section 303(d) of the Clean Water Act and current EPA regulations require reasonable assurance that the TMDL load and wasteload allocations can and will be implemented. In the Loch Raven Reservoir watershed, the TMDL analysis indicates that, for six of the eight subwatersheds, the reductions of fecal bacteria loads are beyond the MPR targets. These MPR targets were defined based on a literature review of BMPs effectiveness and assuming a zero reduction for wildlife sources. The tributaries of Loch Raven Reservoir may not be able to attain water quality standards. The fecal bacteria load reductions required to meet water quality criteria in six of the eight Loch Raven Reservoir subwatersheds are not feasible by implementing effluent limitations and cost-effective, reasonable BMPs to nonpoint sources. Therefore, MDE proposes a staged approach to implementation beginning with the MPR scenario, with regularly scheduled follow-up monitoring to assess the effectiveness of the implementation plan.

Additional reductions will be achieved through the implementation of BMPs; however, the literature reports considerable uncertainty concerning the effectiveness of BMPs in treating bacteria. As an example, pet waste education programs have varying results based on stakeholder involvement. Additionally, the extent of wildlife reduction associated with various BMPs methods (e.g., structural, non-structural, etc.) is uncertain. Therefore, MDE intends for the required reductions to be implemented in an iterative process that first addresses those sources with the largest impact on water quality and human health risk, with consideration given to ease of implementation and cost. The iterative implementation of BMPs in the watershed has several benefits: tracking of water quality improvements following BMP implementation through follow-up stream monitoring; providing a mechanism for developing public support through periodic updates on BMP implementation; and helping to ensure that the most cost-effective practices are implemented first.

Low interest loans are available to property owners with failing septic systems through MDE's Linked Deposit Program, for assistance in correction of such systems through replacement or connection to public sewer systems. In addition, Maryland's Bay Restoration Fund provides funding to upgrade onsite sewage disposal systems. These upgrades, which enhance nitrogen removal, will also help reduce human source fecal bacteria loads from failing septic systems in the watershed.

Potential funding sources for implementation include the Maryland's Agricultural Cost Share Program (MACS), which provides grants to farmers to help protect natural resources, and the Environmental Quality and Incentives Program, which focuses on implementing conservation practices and BMPs on land involved with livestock and production. Though not directly linked, it is assumed that the nutrient management plans from the Water Quality Improvement Act of 1998 (WQIA) will have some reduction of bacteria from manure application practices.

The Loch Raven Reservoir watershed is managed under NPDES MS4 permits for Baltimore, Carroll, and Harford Counties, and for the municipality of Hampstead, as well as all other Phase I MS4s in the watershed, including the MD State Highway Administration, Phase II State and federal MS4s, and industrial stormwater permittees. This provides regulatory assurances that

urban stormwater sources will be managed to the maximum extent practicable. The State's NPDES stormwater permits use a watershed approach for improving the water quality of stormwater runoff because it is comprehensive and efficient. By examining all stormwater pollutants including physical and biological impairments at the same time, cost effective control strategies can be developed. This approach is based upon detailed stormwater assessments regarding: water quality conditions, identifying and ranking water quality problems, identifying all structural and nonstructural BMP opportunities, conducting visual watershed inspections, specifying how restoration efforts are monitored, and providing estimated costs and detailed implementation schedules for restoration work. Stormwater BMPs and programs implemented as required by MS4 permits shall be consistent with available WLAs developed under the TMDL. Where fecal bacteria are transported through an MS4 conveyance system, stormwater BMPs implemented to control urban runoff should help in reducing fecal bacteria loads in the Loch Raven Reservoir watershed.

Baltimore County is under a Consent Decree regarding its sanitary sewer overflows. Implementation of the conditions of the Consent Decree should assist in addressing the bacteria sources, particularly the human sources, in the sewered portion of the watershed.

Implementation and Wildlife Sources

It is expected that in some waters for which TMDLs will be developed, the bacteria source analysis indicates that after controls are in place for all anthropogenic sources, the waterbody will not meet water quality standards. Managing the overpopulation of wildlife remains an option for state and local stakeholders.

After developing and implementing, to the maximum extent possible, a reduction goal based on the anthropogenic sources identified in the TMDL, Maryland anticipates that implementation to reduce the controllable nonpoint sources may also reduce some wildlife inputs to the waters.

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Appendix A – Bacteria Data

Table A-1: Measured Bacteria Concentration with Daily Flow Frequency

Station	Date	Daily flow frequency	*E. coli* Concentration (MPN/100ml)
BEV0005	11/05/2003	14.1371	200
	11/19/2003	0.8979	140
	12/03/2003	41.8528	50
	12/17/2003	0.8760	960
	01/05/2004	10.2825	150
	01/20/2004	31.9755	60
	02/02/2004	36.1805	20
	02/17/2004	26.5112	50
	03/01/2004	36.1805	480
	03/15/2004	36.1805	30
	04/05/2004	13.5567	40
	04/19/2004	23.4341	110
	05/10/2004	44.8861	140
	05/24/2004	51.5659	380
	06/07/2004	29.9058	790
	06/21/2004	71.3973	370
	07/06/2004	78.9860	2500
	07/19/2004	48.3574	910
	08/09/2004	85.9396	830
	08/23/2004	90.9220	420
	09/07/2004	91.9076	120
	09/20/2004	71.3973	960
	10/04/2004	71.3973	380
	10/18/2004	82.8625	190

Station	Date	Daily flow frequency	*E. coli* Concentration (MPN/100ml)
GUN0233	11/05/2003	15.7360	130
	11/19/2003	3.8733	100
	12/03/2003	13.0545	70
	12/17/2003	1.2249	14140
	01/05/2004	7.2832	50
	01/20/2004	15.7360	30
	02/17/2004	15.7360	40
	03/01/2004	19.8742	30
	03/15/2004	21.7833	10
	04/05/2004	7.5811	470
	04/19/2004	14.7650	60
	05/10/2004	25.7559	60
	05/24/2004	28.4816	270
	06/07/2004	4.9327	350
	06/21/2004	17.4465	270
	07/06/2004	38.0049	3800
	07/19/2004	31.7921	260
	08/09/2004	29.4968	70
	08/23/2004	38.0049	60
	09/07/2004	47.2633	70
	09/20/2004	20.9777	710
	10/04/2004	24.7848	260
	10/18/2004	37.1993	60

Station	Date	Daily flow frequency	*E. coli* Concentration (MPN/100ml)
GUN0284	11/05/2003	15.7360	50
	11/19/2003	3.8733	40
	12/03/2003	13.0545	30
	12/17/2003	1.2249	250
	01/05/2004	7.2832	40
	01/20/2004	15.7360	30
	02/02/2004	19.6866	30
	02/17/2004	15.7360	30
	03/01/2004	19.8742	10
	03/15/2004	21.7833	10
	04/05/2004	7.5811	320
	04/19/2004	14.7650	30
	05/10/2004	25.7559	50
	05/24/2004	28.4816	210
	06/07/2004	4.9327	300
	06/21/2004	17.4465	230
	07/06/2004	38.0049	770
	07/19/2004	31.7921	70
	08/09/2004	29.4968	90
	08/23/2004	38.0049	170
	09/07/2004	47.2633	70
	09/20/2004	20.9777	420
	10/04/2004	24.7848	160
	10/18/2004	37.1993	20

Station	Date	Daily flow frequency	*E. coli* Concentration (MPN/100ml)
GUN0387	11/05/2003	12.5602	30
	11/19/2003	1.4455	10
	12/03/2003	12.1770	30
	12/17/2003	1.3250	40
	01/05/2004	7.5011	10
	01/20/2004	15.5278	10
	02/02/2004	17.9698	10
	02/17/2004	15.8563	10
	03/01/2004	19.0101	10
	03/15/2004	21.8791	20
	04/05/2004	12.1770	1
	04/19/2004	19.3714	10
	05/10/2004	25.2957	10
	05/24/2004	32.2711	10
	06/07/2004	14.8270	10
	06/21/2004	16.8309	10
	07/06/2004	36.5747	120
	07/19/2004	22.9851	10
	08/09/2004	24.7919	20
	08/23/2004	34.7678	20
	09/07/2004	50.2081	10
	09/20/2004	27.5186	90
	10/04/2004	25.2957	20
	10/18/2004	40.3198	10

Station	Date	Daily flow frequency	*E. coli* Concentration (MPN/100ml)
LIT0002	11/05/2003	12.5602	160
	11/19/2003	1.4455	40
	12/03/2003	12.1770	120
	12/17/2003	1.3250	220
	01/05/2004	7.5011	70
	01/20/2004	15.5278	40
	02/02/2004	17.9698	20
	02/17/2004	15.8563	10
	03/01/2004	19.0101	100
	03/15/2004	21.8791	20
	04/05/2004	12.1770	260
	04/19/2004	19.3714	90
	05/10/2004	25.2957	80
	05/24/2004	32.2711	260
	06/07/2004	14.8270	10
	06/21/2004	16.8309	320
	07/06/2004	36.5747	130
	07/19/2004	22.9851	250
	08/09/2004	24.7919	150
	08/23/2004	34.7678	120
	09/07/2004	50.2081	90
	09/20/2004	27.5186	770
	10/04/2004	25.2957	280
	10/18/2004	40.3198	110

Station	Date	Daily flow frequency	*E. coli* Concentration (MPN/100ml)
SBH0002	11/05/2003	14.1371	100
	11/19/2003	0.8979	1310
	12/03/2003	41.8528	70
	12/17/2003	0.8760	3650
	01/05/2004	10.2825	120
	01/20/2004	31.9755	40
	02/02/2004	36.1805	180
	02/17/2004	26.5112	50
	03/01/2004	36.1805	30
	03/15/2004	36.1805	30
	04/05/2004	13.5567	30
	04/19/2004	23.4341	50
	05/10/2004	44.8861	990
	05/24/2004	51.5659	1440
	06/07/2004	29.9058	720
	06/21/2004	71.3973	770
	07/06/2004	78.9860	4600
	07/19/2004	48.3574	9210
	08/09/2004	85.9396	610
	08/23/2004	90.9220	380
	09/07/2004	91.9076	260
	09/20/2004	71.3973	1070
	10/04/2004	71.3973	170
	10/18/2004	82.8625	380

Station	Date	Daily flow frequency	*E. coli* Concentration (MPN/100ml)
WGP0050	11/05/2003	22.7332	130
	11/19/2003	2.7705	110
	12/03/2003	21.4849	140
	12/17/2003	1.4126	2910
	01/05/2004	10.1621	90
	01/20/2004	21.4849	120
	02/02/2004	17.9260	10
	02/17/2004	20.4008	50
	03/01/2004	25.2738	40
	03/15/2004	23.4012	20
	04/05/2004	7.9720	930
	04/19/2004	15.1226	220
	05/10/2004	21.4849	280
	05/24/2004	32.1507	700
	06/07/2004	17.0061	1100
	06/21/2004	44.8204	430
	07/06/2004	50.1533	200
	07/19/2004	47.3390	910
	08/09/2004	57.9829	400
	08/23/2004	65.8892	190
	09/07/2004	74.4306	450
	09/20/2004	59.3408	1400
	10/04/2004	56.6908	840
	10/18/2004	65.8892	190

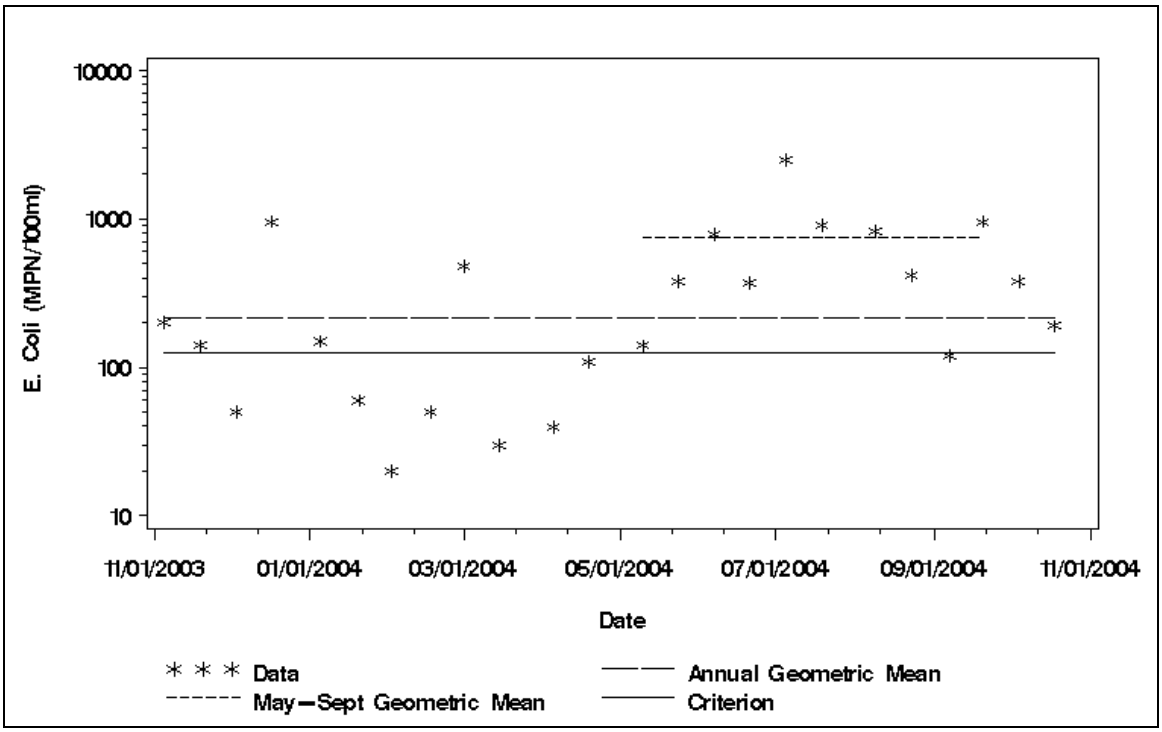

Figure A-1: *E. coli* Concentration vs. Time for MDE Monitoring Station BEV0005

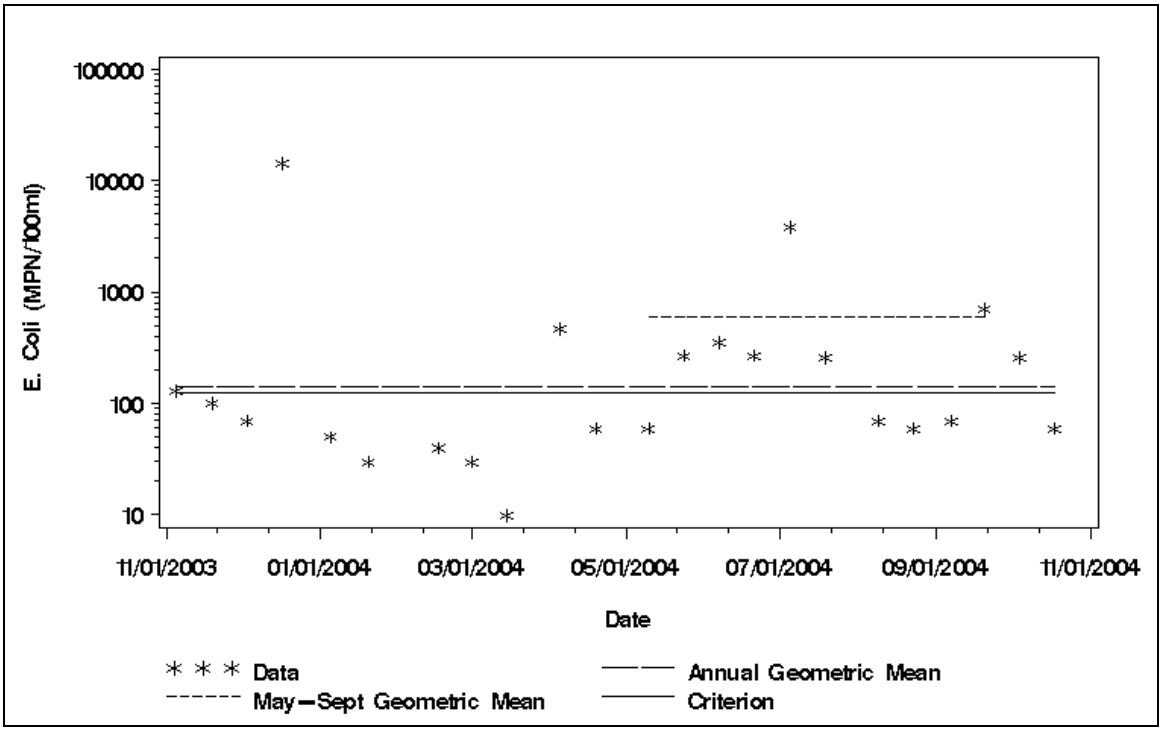

Figure A-2: *E. coli* Concentration vs. Time for MDE Monitoring Station GUN0233

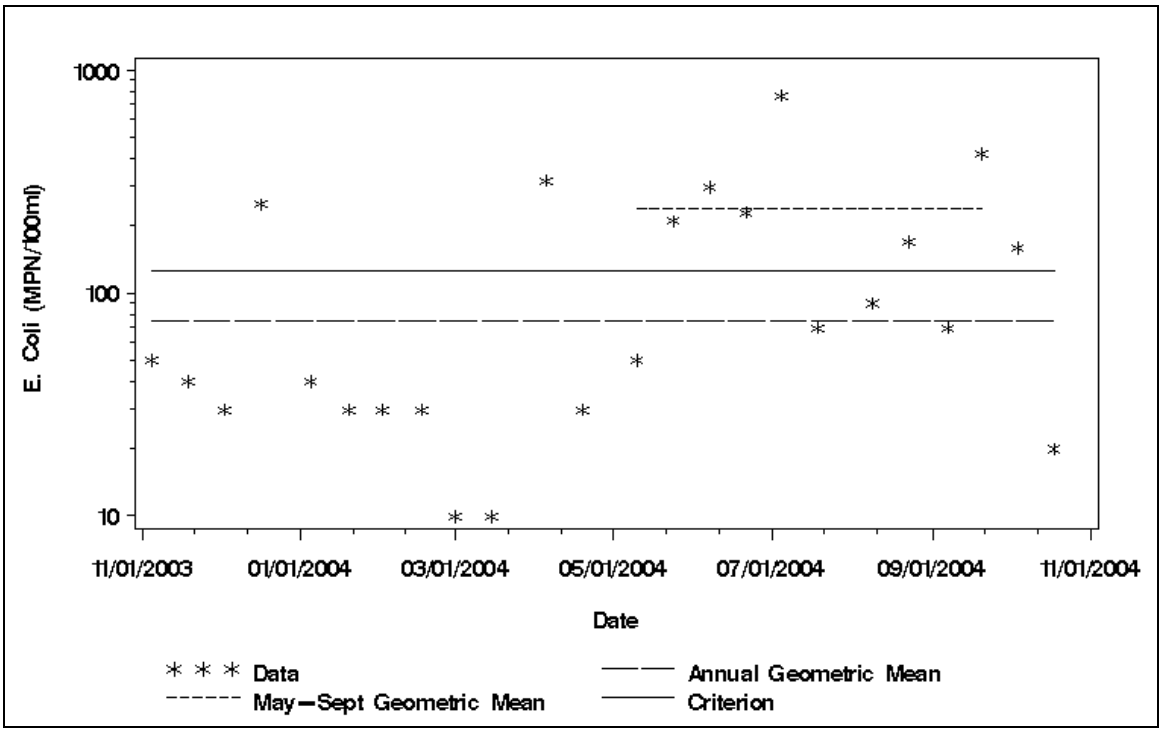

Figure A-3: *E. coli* Concentration vs. Time for MDE Monitoring Station GUN0284

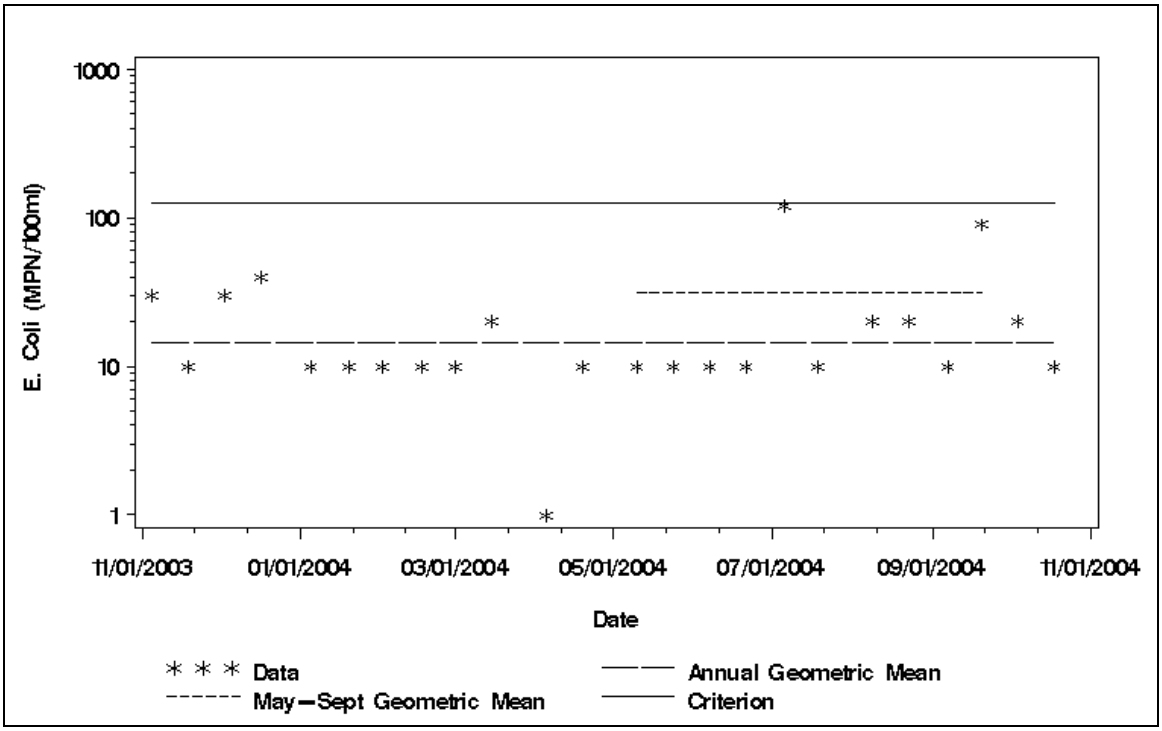

Figure A-4: *E. coli* Concentration vs. Time for MDE Monitoring Station GUN0387

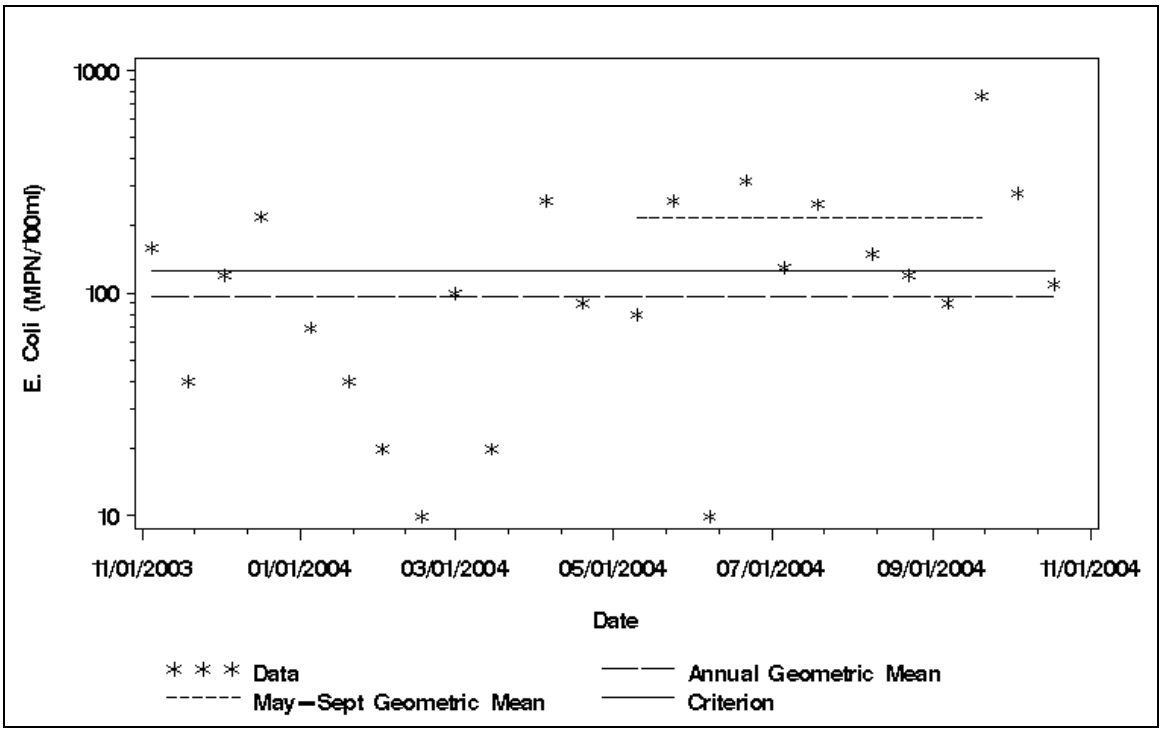

Figure A-5: *E. coli* Concentration vs. Time for MDE Monitoring Station LIT0002

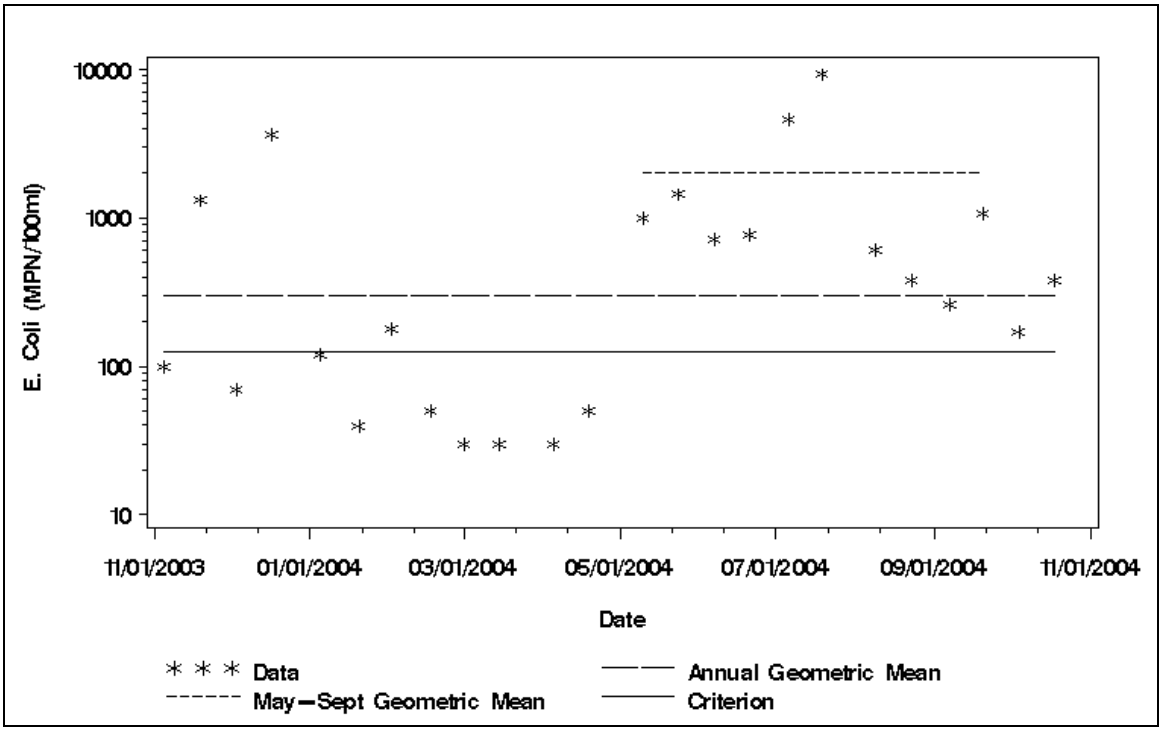

Figure A-6: *E. coli* Concentration vs. Time for MDE Monitoring Station SBH0002

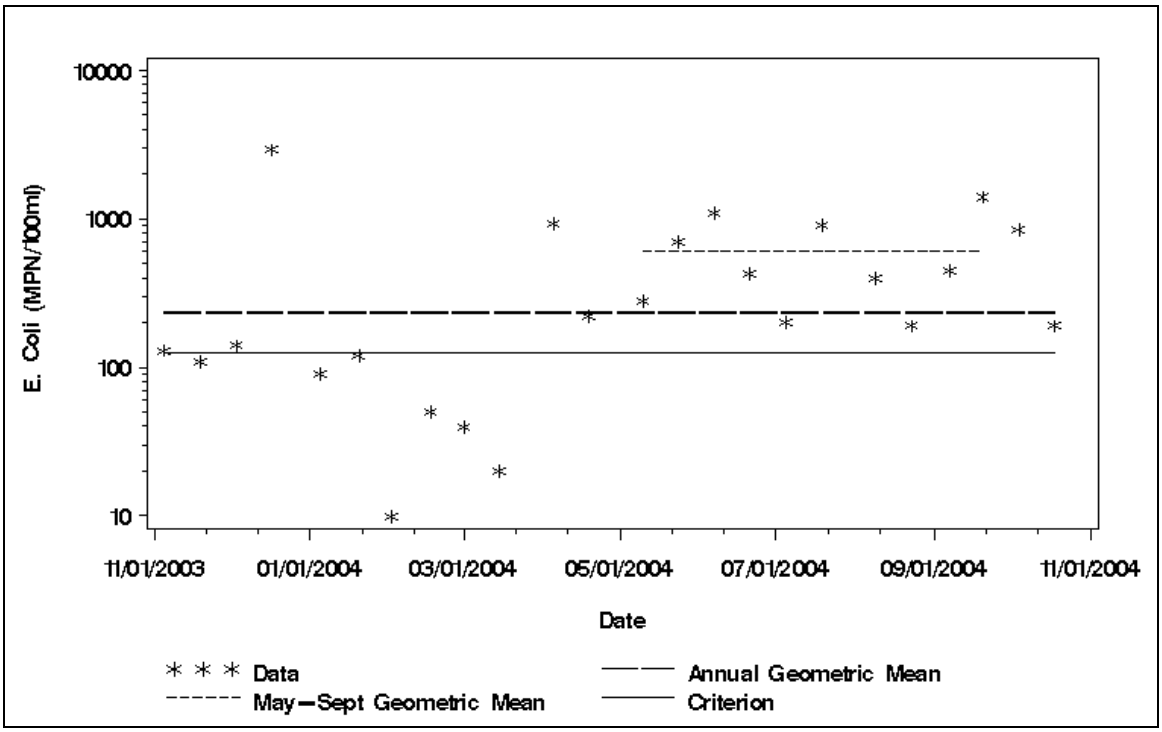

Figure A-7: *E. coli* Concentration vs. Time for MDE Monitoring Station WGP0050

Appendix B - Flow Duration Curve Analysis to Define Strata

The Loch Raven Reservoir watershed was assessed to determine hydrologically significant strata. The purpose of these strata is to apply weights to monitoring data and thus reduce bias associated with the monitoring design. The strata group hydrologically similar water quality samples and provide a better estimate of the mean concentration at the monitoring station.

The flow duration curve for a watershed is a plot of all possible daily flows, ranked from highest to lowest, versus their probability of exceedance. In general, the higher flows will tend to be dominated by excess runoff from rain events and the lower flows will result from drought type conditions. The mid-range flows are a combination of high base flow with limited runoff and lower base flow with excess runoff. The range of these mid-level flows will vary with antecedent soil moisture conditions. The purpose of the following analysis is to identify hydrologically significant groups, based on the previously described flow regimes, within the flow duration curve.

Flow Analysis

There are four USGS gage stations in the Loch Raven Reservoir watershed used for the analysis. These sites are listed in Table B-1. Flow duration curves for these sites are presented in Figure B-1.

Table B-1: USGS Sites in the Loch Raven Reservoir Watershed

USGS Site #	Dates Used	Location
01582000	10/01/1982 – 9/30/2007	Little Falls at Blue Mount, MD
01582500	12/10/1982 – 9/30/2007	Gunpowder Falls at Glencoe, MD
01583500	10/01/1982 – 9/30/2007	Western Run at Western Run, MD
01583600	10/01/1982 – 9/30/2007	Beaverdam Run at Cockeysville, MD

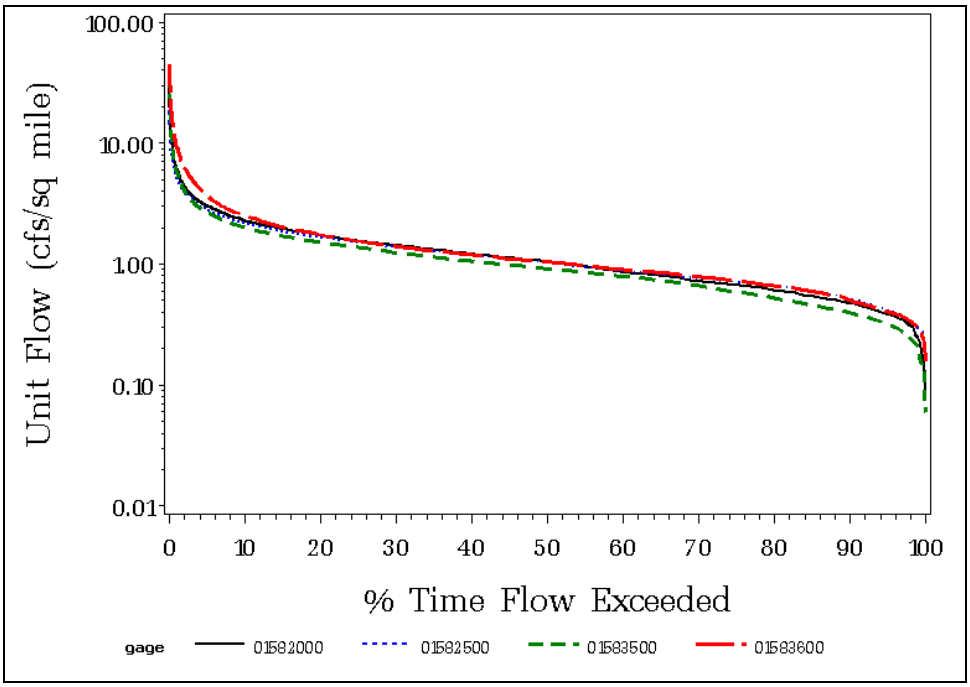

Figure B-1: Flow Duration Curve for Loch Raven Reservoir Watershed USGS Sites

The long-term average daily unit flows at the four stations correspond to a weighted average flow frequency of 34.3%. Using the definition of a high flow condition as occurring when flows are higher than the long-term average flow and a low flow condition as occurring when flows are lower than the long-term average flow, the 34.3 percentile threshold was selected to define the limits between high flows and low flows in this watershed. Therefore, a high flow condition will be defined as occurring when the daily flow duration percentile is less than 34.3% and a low flow condition will be defined as occurring when the daily flow duration percentile is greater than 34.3%. Definitions of high and low range flows are presented in Table B-2.

Table B-2: Definition of Flow Regimes

High Flow	Represents conditions where stream flow tends to be dominated by surface runoff.
Low Flow	Represents conditions where stream flow tends to be more dominated by groundwater flow.

The final analysis to define the daily flow duration intervals (flow regions, strata) includes the bacteria monitoring data. Bacteria (*E. coli*) monitoring data are "placed" within the regions (strata) based on the daily flow duration percentile of the date of sampling.

Maryland's water quality standards for bacteria state that, when available, the geometric mean indicator should be based on at least five samples taken representatively over 30 days. Therefore,

in situations in which fewer than five samples "fall" within a particular flow regime interval, the interval and the adjacent interval will be joined. In the Loch Raven Reservoir watershed there are not sufficient samples in both flow regimes to estimate the geometric means by stratum. Therefore an overall geometric mean will be calculated for both the annual and seasonal conditions.

Appendix C – BST Report

Final Report

Maryland Department of the Environment

MOU U00P7200322

Identifying Sources of Fecal Pollution in Shellfish and Nontidal Waters in Maryland Watersheds

November 2006 – June 2008

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June 30, 2008

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INTRODUCTION

Microbial Source Tracking. Microbial Source Tracking (MST) is a relatively recent scientific and technological innovation designed to distinguish the origins of enteric microorganisms found in environmental waters. Several different methods and a variety of different indicator organisms (both bacteria and viruses) have successfully been used for MST, as described in recent reviews (Scott *et al.*, 2002; Simpson *et al.*, 2002). When the indicator organism is bacteria, the term Bacterial Source Tracking (BST) is often used. Some common bacterial indicators for BST analysis include: *E. coli, Enterococcus* spp., *Bacteroides-Prevotella,* and *Bifidobacterium* spp.

Techniques for MST can be grouped into one of the following three categories: molecular (genotypic) methods, biochemical (phenotypic) methods, or chemical methods. Ribotyping, Pulsed-Field Gel Electrophoresis (PFGE), and Randomly-Amplified Polymorphic DNA (RAPD) are examples of molecular techniques. Biochemical methods include Antibiotic Resistance Analysis (ARA), F-specific coliphage typing, and Carbon Source Utilization (CSU) analysis. Chemical techniques detect chemical compounds associated with human activities, but do not provide any information regarding nonhuman sources. Examples of this type of technology include detection of optical brighteners from laundry detergents or caffeine (Simpson *et al*., 2002).

Many of the molecular and biochemical methods of MST are "library-based," requiring the collection of a database of fingerprints or patterns obtained from indicator organisms isolated from known sources. Statistical analysis determines fingerprints/patterns of known sources species or categories of species (*i.e.*, human, livestock, pets, wildlife). Indicator isolates collected from water samples are analyzed using the same MST method to obtain their fingerprints or patterns, which are then statistically compared to those in the library. Based upon this comparison, the final results are expressed in terms of the "statistical probability" that the water isolates came from a given source (Simpson *et al*. 2002).

In this BST project, we studied the following Maryland nontidal watersheds: Liberty Reservoir, Loch Raven Reservoir, and the Upper Patuxent River Also included in the study were the following tidal shellfish harvesting areas: Honga River, Hunting Creek and Leeds Creek, Little Choptank River, Little Creek, Miles River, Shipping Creek, and Wells Cove watersheds . The methodology used was the ARA with *Enterococcus* spp. as the indicator organism. Previous BST publications have demonstrated the predictive value of using this particular technique and indicator organism (Price *et al*., 2006; Hagedorn, 1999; Wiggins, 1999). A pilot study using PFGE, a genotypic BST method, was used on a subset of deer scat isolates collected from watersheds across Maryland.

Antibiotic Resistance Analysis. A variety of different host species can potentially contribute to the fecal contamination found in natural waters. Many years ago, scientists speculated on the possibility of using resistance to antibiotics as a way of determining the sources of this fecal contamination (Bell *et al.*, 1983; Krumperman, 1983). In ARA, the premise is that bacteria

isolated from different hosts can be discriminated based upon differences in the selective pressure of microbial populations found in the gastrointestinal tract of those hosts (humans, livestock, pets, wildlife) (Wiggins, 1996). Microorganisms isolated from the fecal material of wildlife would be expected to have a much lower level of resistance to antibiotics than isolates collected from the fecal material of humans, livestock and pets. In addition, depending upon the specific antibiotics used in the analysis, isolates from humans, livestock and pets could be differentiated from each other.

In ARA, isolates from known sources are tested for resistance or sensitivity against a panel of antibiotics and antibiotic concentrations. This information is then used to construct a library of antibiotic resistance patterns from known-source bacterial isolates. Microbial isolates collected from water samples are then tested and their resistance results are recorded. Based upon a comparison of resistance patterns of water and library isolates, a statistical analysis can predict the likely host source of the water isolates (Hagedorn 1999; Price *et al*., 2006; Wiggins 1999).

LABORATORY METHODS

Isolation of *Enterococcus* from Known-Source Samples. Fecal samples, identified to source, were delivered to the Salisbury University (SU) BST lab by Maryland Department of the Environment (MDE) personnel. Fecal material suspended in phosphate buffered saline was plated onto selective m-Enterococcus agar. After incubation at 37° C, up to eight (8) *Enterococcus* isolates were randomly selected from each fecal sample for ARA testing.

Isolation of Enterococcus from Water Samples. Water samples were collected by MDE staff and shipped overnight to MapTech Inc, Blacksburg, Va. Bacterial isolates were collected by membrane filtration. Up to 24 randomly selected *Enterococcus* isolates were collected from each water sample and all isolates were then shipped to the SU BST lab.

Antibiotic Resistance Analysis. Each bacterial isolate from both water and scat were grown in Enterococcosel® broth (Becton Dickinson, Sparks, MD) prior to ARA testing. *Enterococci* are capable of hydrolyzing esculin, turning this broth black. Only esculin-positive isolates were tested for antibiotic resistance.

Bacterial isolates were plated onto tryptic soy agar plates, each containing a different concentration of a given antibiotic. Plates were incubated overnight at 37° C and isolates then scored for growth (resistance) or no growth (sensitivity). Data consisting of a "1" for resistance or "0" for sensitivity for each isolate at each concentration of each antibiotic was then entered into a spread-sheet for statistical analysis.

The following table includes the antibiotics and concentrations used for isolates in analyses for all the study watersheds.

Table C-1. Antibiotics and concentrations used for ARA.

Antibiotic	Concentration (µg/ml)
Amoxicillin	0.625
Cephalothin	10, 15, 30, 50
Chloramphenicol	10
Chlortetracycline	60, 80, 100
Erythromycin	10
Gentamycin	5, 10, 15
Neomycin	40, 60, 80
Oxytetracycline	20, 40, 60, 80, 100
Salinomycin	10
Streptomycin	40, 60, 80, 100
Tetracycline	10, 30, 50, 100
Vancomycin	2.5

KNOWN-SOURCE LIBRARY

Construction and Use. Fecal samples (scat) from known sources in each watershed were collected during the study period by MDE personnel and delivered to the BST Laboratory at SU. *Enterococcus* isolates were obtained from known sources (e.g., human, cow, goat, horse, dog, bear, beaver, deer, duck, fox, goose, heron, opossum, rabbit, raccoon, and squirrel). For each watershed, a library of patterns of *Enterococcus* isolate responses to the panel of antibiotics was analyzed using the statistical software CART® (Salford Systems, San Diego, CA). *Enterococcus* isolate response patterns were also obtained from bacteria in water samples collected at the monitoring stations in each basin. Using statistical techniques, these patterns were then compared to those in the appropriate library to identify the probable source of each water isolate. For both the nontidal and tidal watersheds, no combined known-source libraries were used for any shellfish harvesting area; a known-source isolate library collected from each area was used for the particular watershed.

STATISTICAL ANALYSIS

We applied a tree classification method, [1]CART®, to build a model that classifies isolates into source categories based on ARA data. CART® builds a classification tree by recursively splitting the library of isolates into two nodes. Each split is determined by the antibiotic variables (antibiotic resistance measured for a collection of antibiotics at varying concentrations). The first step in the tree-building process splits the library into two nodes by considering every binary split associated with every variable. The split is chosen that maximizes a specified index of homogeneity for isolate sources within each of the nodes. In subsequent steps, the same process is applied to each resulting node until a *stopping* criterion is satisfied. Nodes where an additional split would lead to only an insignificant increase in the *homogeneity index* relative to the *stopping* criterion are referred to as *terminal* nodes.[2] The collection of *terminal* nodes defines the classification model. Each *terminal* node is associated with one source, the source isolate with an unknown source), based that is most populous among the library isolates in the node. Each water sample isolate (*i.e*., an on its antibiotic resistance pattern, is identified with one specific *terminal* node and is assigned the source of the majority of library isolates in that *terminal* node.[3]

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1 The Elements of Statistical Learning: Data Mining, Inference, and Prediction. Hastie T, Tibshirani R, and Friedman J. Springer 2001.

2 An ideal split, i.e., a split that achieves the theoretical maximum for homogeneity, would produce two nodes each containing library isolates from only one source.

3 The CART® tree-classification method we employed includes various features to ensure the development of an optimal classification model. For brevity in exposition, we have chosen not to present details of those features, but suggest the following sources: Breiman L, et al. *Classification and Regression Trees*. Pacific Grove: Wadsworth, 1984; and Steinberg D and Colla P. *CART—Classification and Regression Trees.* San Diego, CA: Salford Systems, 1997.

Loch Raven Reservoir Watershed ARA Results

Known-Source Library. A 620 known-source isolate library was constructed from sources in the Loch Raven Reservoir Watershed. The number of unique antibiotic resistance patterns was calculated, and the known sources in the combined library were grouped into four categories: human, livestock (cow, horse), pet (dog), and wildlife (deer, duck, goose, fox, rabbit, raccoon) (Table C-2). The library was analyzed for its ability to take a subset of the library isolates and correctly predict the identity of their host sources when they were treated as unknowns. Average rates of correct classification (ARCC) for the library were found by repeating this analysis using several probability cutoff points, as described above in the "Statistical Analysis" section of this document. The number-not-classified for each probability was determined. From these results, the percent unknown and percent correct classification (RCCs) was calculated (Table C-3).

Table C-2: Category, total number, and number of unique patterns in the Loch Raven Reservoir known-source library.

Category	Potential Sources	Total Isolates	Unique Patterns
Human	human	187	101
Livestock	cow, horse	96	24
Pet	dog	56	22
Wildlife	deer, duck, goose, fox, rabbit, raccoon	281	65
Total		620	212

For Loch Raven Reservoir Watershed, a cutoff probability of 0.50 (50%) was shown to yield an overall rate of correct classification of 76% (Figure C-1; Table C-3). The resulting rates of correction classification (RCCs) for the four categories of sources in the Loch Raven Reservoir library are shown in Table C-4.

Table C-3: Number of isolates not classified, percent unknown, and percent correct for seven (7) cutoff probabilities for Loch Raven Reservoir known-source isolates using the Loch Raven Reservoir known-source library.

Threshold	0	0.375	**0.5**	0.6	0.7	0.8	0.9
% correct	67.1%	71.6%	**76.3%**	76.9%	81.7%	86.9%	92.2%
% unknown	0.0%	9.2%	**27.7%**	35.8%	49.8%	61.8%	73.2%
# not classified	0	57	**172**	222	309	383	454

Figure C-1: Loch Raven Reservoir Classification Model: Percent Correct versus Percent Unknown using the Loch Raven Reservoir library.

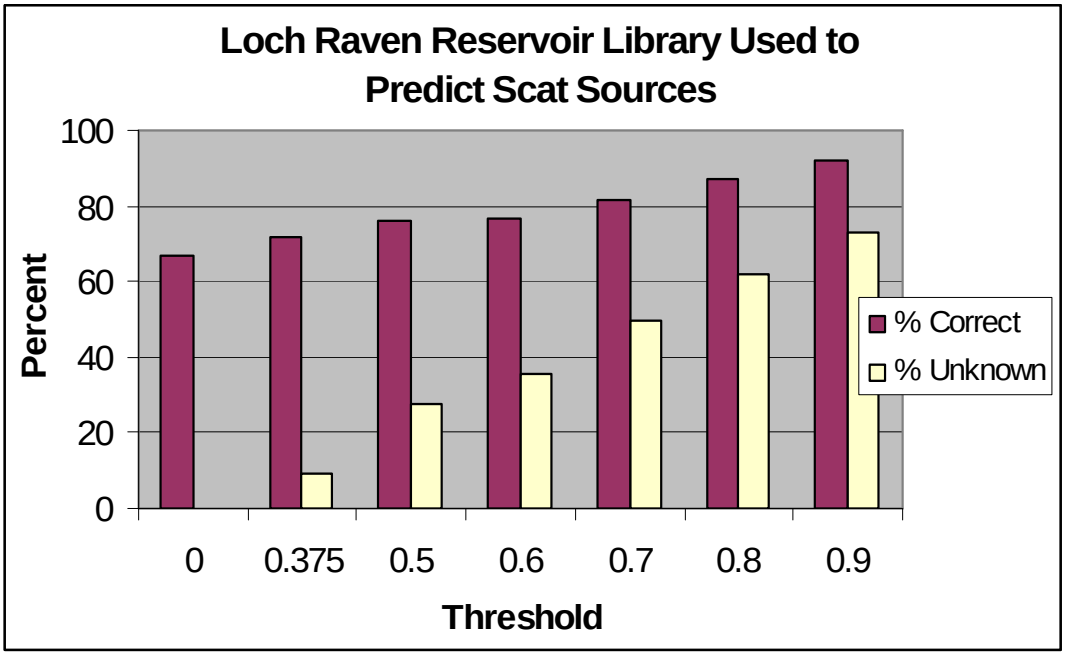


Table C-4: Actual species categories versus predicted categories, at 50% probability cutoff, with rates of correct classification (RCC) for each category.

	Predicted						
Actual	Human	Livestock	Pet	Wildlife	Unknown	Total	RCC*
Human	122	1	8	16	40	187	83.0%
Livestock	1	41	5	12	37	96	69.5%
Pet	1	1	40	1	13	56	93.0%
Wildlife	20	35	5	139	82	281	69.8%
Total	144	78	58	168	172	620	76.3%

*RCC = Actual number of predicted species category / Total number predicted. Example: 163 pet correctly predicted / 175 total number predicted for pet = 163/175 = 93%.

Loch Raven Reservoir Water Samples. Monthly monitoring from seven (7) monitoring stations on Loch Raven Reservoir was the source of water samples. The maximum number of *Enterococcus* isolates obtained per water sample was 24, although the number of isolates that actually grew was sometimes less than 24. A total of 1,447 *Enterococcus* isolates were analyzed by statistical analysis. The BST results by species category, shown in Table C-5, indicate that 97% of the water isolates were able to be classified to a probable host source when using a 0.50 (50%) probability threshold.

Table C-5: Probable host sources of water isolates by species category, number of isolates, and percent isolates classified at a cutoff probability of 50%.

Source	Count	Percent	Percent Without Unknowns
Human	498	34.4%	35.4%
Livestock	238	16.4%	16.9%
Pet	132	9.1%	9.4%
Wildlife	538	37.2%	38.3%
Unknown	41	2.8%	
Total	1447	100.0%	100.0%
% classified	**97.2%**		

*Percentages may not add up to 100% due to rounding.

The seasonal distribution of water isolates from samples collected at each sampling station is shown below in Table C-6.

Table C-6: *Enterococcu*s isolates obtained from water collected during the spring, summer, fall, and winter seasons for Loch Raven Reservoir's seven (7) monitoring stations.

	Season				
Station	Spring	Summer	Fall	Winter	Total
BEV0005	68	71	60	58	257
GUN0233	61	67	60	17	205
GUN0284	58	58	62	32	210
GUN0387	13	8	35	9	65
LIT0002	56	68	49	29	202
SBH0002	60	72	68	51	251
WGP0050	66	68	69	54	257

Tables C-7 and C-8 on the following pages show the number and percent of the probable sources for each monitoring station by month.

Table C-7: BST Analysis: Number of Isolates per Station per Date.

		Predicted Source					
Station	Date	Human	Livestock	Pet	Wildlife	Unknown	Total
BEV0005	11/19/03	5	13	0	4	0	22
BEV0005	12/03/03	2	2	2	7	7	20
BEV0005	01/05/04	15	2	1	5	1	24
BEV0005	02/17/04	6	5	2	9	2	24
BEV0005	03/01/04	2	2	3	3	0	10
BEV0005	04/05/04	18	0	0	0	2	20
BEV0005	05/10/04	3	9	0	12	0	24
BEV0005	06/07/04	9	1	5	9	0	24
BEV0005	07/06/04	6	1	4	12	0	23
BEV0005	08/09/04	18	6	0	0	0	24
BEV0005	09/07/04	11	0	0	12	1	24
BEV0005	10/04/04	5	0	2	11	0	18
GUN0233	11/19/03	7	4	0	11	2	24
GUN0233	12/03/03	4	9	0	3	0	16
GUN0233	01/05/04	0	0	0	4	2	6
GUN0233	02/17/04	5	3	0	1	0	9
GUN0233	03/01/04	0	0	0	2	0	2
GUN0233	04/05/04	5	6	0	12	0	23
GUN0233	05/10/04	3	4	3	5	0	15
GUN0233	06/07/04	11	3	4	5	0	23
GUN0233	07/06/04	7	1	2	14	0	24
GUN0233	08/09/04	5	0	9	10	0	24
GUN0233	09/07/04	2	0	0	17	0	19
GUN0233	10/04/04	1	5	2	12	0	20
GUN0284	11/19/03	0	2	3	13	0	18
GUN0284	12/03/03	5	14	0	5	0	24
GUN0284	01/05/04	3	13	0	8	0	24
GUN0284	02/17/04	0	3	0	3	0	6
GUN0284	03/01/04	0	0	1	1	0	2
GUN0284	04/05/04	13	4	0	7	0	24
GUN0284	05/10/04	7	0	1	1	1	10
GUN0284	06/07/04	3	1	17	3	0	24
GUN0284	07/06/04	2	0	7	13	0	22
GUN0284	08/09/04	7	0	6	7	0	20
GUN0284	09/07/04	1	3	2	10	0	16

Table C-7 (continued): BST Analysis: Number of Isolates per Station per Date.

		Predicted Source					
Station	Date	Human	Livestock	Pet	Wildlife	Unknown	Total
GUN0284	10/04/04	6	1	3	10	0	20
GUN0387	11/19/03	0	0	0	1	0	1
GUN0387	12/03/03	6	0	0	14	1	21
GUN0387	01/05/04	4	0	0	0	0	4
GUN0387	02/17/04	0	0	0	5	0	5
GUN0387	06/07/04	12	0	1	0	0	13
GUN0387	07/06/04	4	0	3	0	0	7
GUN0387	08/09/04	0	0	0	1	0	1
GUN0387	10/04/04	7	0	1	5	0	13
LIT0002	11/19/03	2	2	0	0	0	4
LIT0002	12/03/03	15	1	1	3	1	21
LIT0002	01/05/04	0	16	0	8	0	24
LIT0002	02/17/04	2	0	0	0	0	2
LIT0002	03/01/04	2	0	0	0	1	3
LIT0002	04/05/04	5	1	0	7	0	13
LIT0002	05/10/04	8	0	5	6	0	19
LIT0002	06/07/04	21	1	2	0	0	24
LIT0002	07/06/04	19	0	3	2	0	24
LIT0002	08/09/04	15	2	3	0	0	20
LIT0002	09/07/04	12	5	0	5	2	24
LIT0002	10/04/04	18	2	0	2	2	24
SBH0002	11/19/03	9	11	2	2	0	24
SBH0002	12/03/03	7	0	3	10	1	21
SBH0002	01/05/04	13	3	0	7	0	23
SBH0002	02/17/04	10	7	2	3	0	22
SBH0002	03/01/04	1	0	0	4	1	6
SBH0002	04/05/04	6	1	0	4	1	12
SBH0002	05/10/04	7	5	1	11	0	24
SBH0002	06/07/04	7	9	2	6	0	24
SBH0002	07/06/04	9	1	1	13	0	24
SBH0002	08/09/04	4	5	0	15	0	24
SBH0002	09/07/04	5	3	3	12	1	24
SBH0002	10/04/04	6	2	4	10	1	23
WGP0050	11/19/03	5	0	1	14	3	23
WGP0050	12/03/03	1	9	0	11	1	22
WGP0050	01/05/04	1	3	0	12	1	17
WGP0050	02/17/04	6	2	1	12	0	21

Table C-7 (continued): BST Analysis: Number of Isolates per Station per Date.

		Predicted Source					
Station	Date	Human	Livestock	Pet	Wildlife	Unknown	Total
WGP0050	03/01/04	2	3	1	6	4	16
WGP0050	04/05/04	7	11	0	6	0	24
WGP0050	05/10/04	5	4	0	8	1	18
WGP0050	06/07/04	9	3	7	5	0	24
WGP0050	07/06/04	9	0	0	15	0	24
WGP0050	08/09/04	8	1	5	10	0	24
WGP0050	09/07/04	4	2	0	13	1	20
WGP0050	10/04/04	8	6	1	9	0	24
Total		498	238	132	538	41	1447

Table C-8: BST Analysis: Percent of Isolates per Station per Date.

		Predicted Source					
Station	Date	Human	Livestock	Pet	Wildlife	Unknown	Total
BEV0005	11/19/03	23%	59%	0%	18%	0%	100%
BEV0005	12/03/03	10%	10%	10%	35%	35%	100%
BEV0005	01/05/04	63%	8%	4%	21%	4%	100%
BEV0005	02/17/04	25%	21%	8%	38%	8%	100%
BEV0005	03/01/04	20%	20%	30%	30%	0%	100%
BEV0005	04/05/04	90%	0%	0%	0%	10%	100%
BEV0005	05/10/04	13%	38%	0%	50%	0%	100%
BEV0005	06/07/04	38%	4%	21%	38%	0%	100%
BEV0005	07/06/04	26%	4%	17%	52%	0%	100%
BEV0005	08/09/04	75%	25%	0%	0%	0%	100%
BEV0005	09/07/04	46%	0%	0%	50%	4%	100%
BEV0005	10/04/04	28%	0%	11%	61%	0%	100%
GUN0233	11/19/03	29%	17%	0%	46%	8%	100%
GUN0233	12/03/03	25%	56%	0%	19%	0%	100%
GUN0233	01/05/04	0%	0%	0%	67%	33%	100%
GUN0233	02/17/04	56%	33%	0%	11%	0%	100%
GUN0233	03/01/04	0%	0%	0%	100%	0%	100%
GUN0233	04/05/04	22%	26%	0%	52%	0%	100%
GUN0233	05/10/04	20%	27%	20%	33%	0%	100%
GUN0233	06/07/04	48%	13%	17%	22%	0%	100%
GUN0233	07/06/04	29%	4%	8%	58%	0%	100%
GUN0233	08/09/04	21%	0%	38%	42%	0%	100%
GUN0233	09/07/04	11%	0%	0%	89%	0%	100%
GUN0233	10/04/04	5%	25%	10%	60%	0%	100%
GUN0284	11/19/03	0%	11%	17%	72%	0%	100%
GUN0284	12/03/03	21%	58%	0%	21%	0%	100%
GUN0284	01/05/04	13%	54%	0%	33%	0%	100%

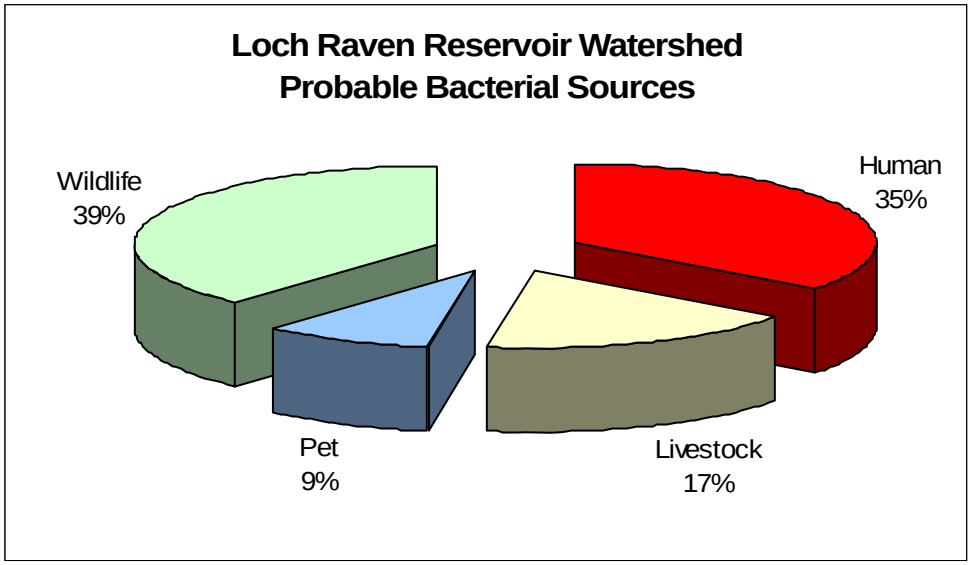
Table C-8 (continued): BST Analysis: Percent of Isolates per Station per Date.

		Predicted Source					
Station	Date	Human	Livestock	Pet	Wildlife	Unknown	Total
GUN0284	02/17/04	0%	50%	0%	50%	0%	100%
GUN0284	03/01/04	0%	0%	50%	50%	0%	100%
GUN0284	04/05/04	54%	17%	0%	29%	0%	100%
GUN0284	05/10/04	70%	0%	10%	10%	10%	100%
GUN0284	06/07/04	13%	4%	71%	13%	0%	100%
GUN0284	07/06/04	9%	0%	32%	59%	0%	100%
GUN0284	08/09/04	35%	0%	30%	35%	0%	100%
GUN0284	09/07/04	6%	19%	13%	63%	0%	100%
GUN0284	10/04/04	30%	5%	15%	50%	0%	100%
GUN0387	11/19/03	0%	0%	0%	100%	0%	100%
GUN0387	12/03/03	29%	0%	0%	67%	5%	100%
GUN0387	01/05/04	100%	0%	0%	0%	0%	100%
GUN0387	02/17/04	0%	0%	0%	100%	0%	100%
GUN0387	06/07/04	92%	0%	8%	0%	0%	100%
GUN0387	07/06/04	57%	0%	43%	0%	0%	100%
GUN0387	08/09/04	0%	0%	0%	100%	0%	100%
GUN0387	10/04/04	54%	0%	8%	38%	0%	100%
LIT0002	11/19/03	50%	50%	0%	0%	0%	100%
LIT0002	12/03/03	71%	5%	5%	14%	5%	100%
LIT0002	01/05/04	0%	67%	0%	33%	0%	100%
LIT0002	02/17/04	100%	0%	0%	0%	0%	100%
LIT0002	03/01/04	67%	0%	0%	0%	33%	100%
LIT0002	04/05/04	38%	8%	0%	54%	0%	100%
LIT0002	05/10/04	42%	0%	26%	32%	0%	100%
LIT0002	06/07/04	88%	4%	8%	0%	0%	100%
LIT0002	07/06/04	79%	0%	13%	8%	0%	100%
LIT0002	08/09/04	75%	10%	15%	0%	0%	100%
LIT0002	09/07/04	50%	21%	0%	21%	8%	100%
LIT0002	10/04/04	75%	8%	0%	8%	8%	100%
SBH0002	11/19/03	38%	46%	8%	8%	0%	100%
SBH0002	12/03/03	33%	0%	14%	48%	5%	100%
SBH0002	01/05/04	57%	13%	0%	30%	0%	100%
SBH0002	02/17/04	45%	32%	9%	14%	0%	100%
SBH0002	03/01/04	17%	0%	0%	67%	17%	100%
SBH0002	04/05/04	50%	8%	0%	33%	8%	100%
SBH0002	05/10/04	29%	21%	4%	46%	0%	100%
SBH0002	06/07/04	29%	38%	8%	25%	0%	100%
SBH0002	07/06/04	38%	4%	4%	54%	0%	100%

Table C-8 (continued): BST Analysis: Percent of Isolates per Station per Date.

		Predicted Source					
Station	Date	Human	Livestock	Pet	Wildlife	Unknown	Total
SBH0002	08/09/04	17%	21%	0%	63%	0%	100%
SBH0002	09/07/04	21%	13%	13%	50%	4%	100%
SBH0002	10/04/04	26%	9%	17%	43%	4%	100%
WGP0050	11/19/03	22%	0%	4%	61%	13%	100%
WGP0050	12/03/03	5%	41%	0%	50%	5%	100%
WGP0050	01/05/04	6%	18%	0%	71%	6%	100%
WGP0050	02/17/04	29%	10%	5%	57%	0%	100%
WGP0050	03/01/04	13%	19%	6%	38%	25%	100%
WGP0050	04/05/04	29%	46%	0%	25%	0%	100%
WGP0050	05/10/04	28%	22%	0%	44%	6%	100%
WGP0050	06/07/04	38%	13%	29%	21%	0%	100%
WGP0050	07/06/04	38%	0%	0%	63%	0%	100%
WGP0050	08/09/04	33%	4%	21%	42%	0%	100%
WGP0050	09/07/04	20%	10%	0%	65%	5%	100%
WGP0050	10/04/04	33%	25%	4%	38%	0%	100%
Total		34%	16%	9%	37%	3%	100%

Figure C-2: Loch Raven Reservoir Watershed relative contributions by probable sources of *Enterococcus* contamination.



Loch Raven Reservoir Summary

The use of ARA was successful for identification of probable bacterial sources in the Loch Raven Reservoir Watershed. When water isolates were compared to the library and potential sources predicted, 97% of the isolates were classified as to category by statistical analysis. The highest RCC for the library was 93% (for pet), with 70% for livestock and wildlife. Human sources had a RCC of 83%.

The largest category of potential sources in the watershed as a whole was wildlife (39% of classified water isolates), followed by human and livestock (35% and 17%, respectively). The lowest potential source contribution was for pet (9%) (Fig. C-2).

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Adjustment of BST Results

As explained in the BST Summary for the Loch Raven Reservoir, the percent of correct classification (RCC) for bacteria sources can introduce a potential misclassification of the more probable sources in the watershed. This is seen in Table C-4, which shows results of the analysis of samples from known sources. For example, out of 620, 96 isolates were known to be of livestock source but only 41 were classified by the analysis as being of livestock source. Of those 96, 1 was classified as human, 5 as pet, 12 as wildlife and 37 as unknown. Similarly, of the other three categories, 1 isolates known to be human, 1 isolates known to be pet, and 35 known wildlife isolates were classified as livestock, resulting in a total of 78 of all 620 isolates classified as livestock of which only 41 were known to be of livestock source.

The results provided by the BST methodology can be adjusted based on the known source percent of correct classification results provided in Table C-4.

Example:

The current BST methodology provides the following source percentages for station GUN0284 during annual conditions:

Source Category	Original Percentage
Pets	20.93 %
Human	22.38 %
Livestock	15.94 %
Wildlife	40.00 %
Unknown	0.75 %

To get the correct human source percentage we redistributed the above percentages based on the % of correct classification as follows.

From Table C-4:

Source Category	Isolates known to be from Human Source	Total Isolates Predicted for Each category	Percentage
Pets	8	58	13.8 %
Human	122	144	84.7 %
Livestock	1	78	1.3 %
Wildlife	16	168	9.5 %
Unknown	40	172	23.3 %

Applying those percentages to the original estimated source distribution presented above will result in the adjusted percentage for human sources:

= (13.8 x 20.93) + (84.7 x 22.38) + (1.3 x 15.94) + (9.5 x 40.00) + (23.3 x 0.75) = 26.04 %

Thus the correct human source percentage, the value used in the TMDL analysis, is 26.04% and not 22.38%. Corrected percentages are also calculated as above for domestic animal (pet), livestock and wildlife sources. The classification of unknown is eliminated in the process as all known isolates are of known source. For station GUN0284 the annual corrected source percentages are as follows:

Source Category	**Adjusted Percentage**
Pets	15.1 %
Human	26.0 %
Livestock	13.4 %
Wildlife	45.5 %

Appendix D – Estimating Maximum Daily Loads

This appendix documents the technical approach used to define maximum daily loads of fecal bacteria consistent with the annual average TMDL which, when met, are protective of water quality standards in the Loch Raven Reservoir watershed. The approach builds upon the TMDL analysis that was conducted to ensure that compliance with the annual average target will result in compliance with the applicable water quality standards. The annual average loading target was converted into allowable *daily* values by using the loadings developed from the TMDL analysis. The approach is consistent with available EPA guidance on generating daily loads for TMDLs.

The available guidance for developing daily loads does not specify a single allowable approach; it contains a range of options. Selection of a specific method for translating a time-series of allowable loads into expression of a TMDL requires decisions regarding both the level of resolution (e.g., single daily load for all conditions vs. loads that vary with environmental conditions) and level of probability associated with the TMDL.

Level of Resolution

The level of resolution pertains to the amount of detail used in specifying the maximum daily load. The draft EPA guidance on daily loads provides three categories of options for level of resolution.

1. **Representative daily load:** In this option, a single daily load (or multiple representative daily loads) is specified that covers all time periods and environmental conditions.
2. **Flow-variable daily load:** This option allows the maximum daily load to vary based upon the observed flow condition.
3. **Temporally-variable daily load:** This option allows the maximum daily load to vary based upon seasons or times of varying source or water body behavior.

Probability Level

Essentially all TMDLs have some probability of being exceeded, with the specific probability being either explicitly specified or implicitly assumed. This level of probability reflects, directly or indirectly, two separate phenomena:

1. Water quality criteria consist of components describing acceptable magnitude, duration, and frequency. The frequency component addresses how often conditions can allowably surpass the combined magnitude and duration components.
2. Pollutant loads, especially from wet weather sources, typically exhibit a large degree of variability over time. It is rarely practical to specify a "never to be exceeded value" for a daily load, as essentially any loading value has some finite probability of being exceeded.

The draft daily load guidance states that the probability component of the maximum daily load should be "based on a representative statistical measure" that is dependent upon the specific TMDL and best professional judgment of the developers. This statistical measure represents

how often the maximum daily load is expected/allowed to be exceeded. The primary options for selecting this level of protection would be:

1. **The maximum daily load reflects some central tendency:** In this option, the maximum daily load is based upon the mean or median value of the range of loads expected to occur. The variability in the actual loads is not addressed.
2. **The maximum daily load reflects a level of protection implicitly provided by the selection of some "critical" period**: In this option, the maximum daily load is based upon the allowable load that is predicted to occur during some critical period examined during the analysis. The developer does not explicitly specify the probability of occurrence.
3. **The maximum daily load is a value that will be exceeded with a pre-defined probability:** In this option, a "reasonable" upper bound percentile is selected for the maximum daily load based upon a characterization of the variability of daily loads. For example, selection of the 95th percentile value would result in a maximum daily load that would be exceeded 5% of the time.

Selected Approach for Defining Maximum Daily Loads for Nonpoint Sources and MS4

To calculate the Loch Raven Reservoir watershed MDL for non-point sources and MS4s, a "representative daily load" option was selected as the level of resolution, and a value "that will be exceeded with a pre-defined probability" was selected as the level of protection. In these options, the maximum daily load is one single daily load that covers the two flow strata, with an upper bound percentile that accounts for the variability of daily loads. The upper bound percentile and the maximum daily loads were estimated following EPA's "Technical Support Document for Water Quality-Based Toxics Control" (1991 TSD) (EPA 1991); and "Approaches For Developing a Daily Load Expression for TMDLs Computed for Longer Term Averages" (EPA 2006).

The 1991 TSD illustrates a way to identify a target maximum daily concentration from a long-term average concentration (LTA) based on a coefficient of variation (CV) and the assumption of a log-normal distribution of the data. The equations for determining both the upper boundary percentile and corresponding maximum daily load described in the TSD are as follows:

$$MDLC = LTA * e^{[Z\sigma - 0.5\sigma^2]} \qquad \text{(D1)}$$

and,

$$MDL = MDLC*Q*F \qquad \text{(D2)}$$

where,

MDLC = maximum daily load concentration (MPN/100ml)
LTAC = long-term average TMDL concentration (MPN/100ml)
MDL = Maximum Daily Load (MPN/day)
Z = z-score associated with upper bound percentile (unitless)

σ^2 = $\ln(CV^2 + 1)$
CV = coefficient of variation
Q = flow (cfs)
F = conversion factor

The first step is to use the bacteria monitoring data to estimate the upper bound percentile as the percentile of the highest observed bacteria concentration in each of the seven monitoring stations of the Loch Raven Reservoir watershed. Using the maximum value of *E. coli* observed in each monitoring station, and solving for the z-score using the above formula, the value of "z" and its corresponding percentile is found as shown below. The percentile associated with the particular value of z can be found in tables in statistics books or using the function NORMSINV(%) in EXCEL©.

$$Z = [\log_{10}(MOC) - \log(AM) + 0.5\sigma^2]/\sigma \qquad \text{(D3)}$$

where,

Z = z-score associated with upper bound percentile
MOC = maximum observed bacteria concentration (MPN/100ml)
AM = arithmetic mean observed bacteria concentrations (MPN/100ml)
σ^2 = $\ln(CV^2 + 1)$
CV = coefficient of variation (arithmetic)

Note that these equations use arithmetic parameters, not geometric parameters as used in the calculations of the long-term annual average TMDL. Therefore, bias correction factors are not necessary to estimate the loads as will be explained below.

The highest percentile of all the stations will define the upper bound percentile to be used in estimating the maximum daily limits. In the case of the Loch Raven Reservoir watershed, a value measured at the GUN0233 station resulted in the highest percentile of the seven stations. This value translates to the 99.8th percentile, which is the upper boundary percentile to be used in the computation of the maximum daily limits (MDLs) throughout this analysis. Results of the analysis to estimate the recurrence or upper boundary percentile are shown in Table D-1.

Table D-1: Percentiles of Maximum Observed Bacteria Concentrations

Subwatershed	Maximum Observed *E. coli* Concentration (MPN/100ml)	Percentile (%)
GUN0387	120	99.0
LIT0002[1]	770	97.0
GUN0284	770	97.5
GUN0233	14,140	99.8
WGP0050	2,910	96.6
BEV0005	2,500	97.3
SBH0002	9,210	97.8

[1]Subwatersheds partially located in Pennsylvania

The 99.8th percentile value results in a maximum daily load that would not be exceeded 99.8% of the time, as, in a similar manner, a TMDL that represents the long term average condition would be expected to be exceeded half the time even after all required controls were implemented.

The MDLCs are estimated based on a statistical methodology referred to as "Statistical Theory of Rollback (STR)". This method predicts concentrations of a pollutant after its sources have been controlled (post-control concentrations), in this case after annual average TMDL implementation. Using STR, the daily TMDLs are calculated as presented below.

First, the long-term average TMDL concentrations (C_{LTA}) are estimated by applying the required percent reduction to the baseline (monitoring data) concentrations (C_b):

From Section 4.3, equations (7):

$$L_b = Q*C_b*F_1$$

And from equation (14):

$$Annual\ Average\ TMDL = L_b * (1 - R)$$

Therefore,

$$L_b*(1-R) = Q*C*F_1*(1-R) \qquad \text{(D4)}$$

As explained before, a reduction in concentration is proportional to a reduction in load, thus the bacteria concentrations expected after reductions are applied are equal to the baseline concentrations multiplied by one minus the required reduction:

$$C_{LTA} = C_b * (1-R) \qquad \text{(D5)}$$

The TMDL concentrations estimated as explained above are shown in Table D-2.

Table D-2: Long-term Annual Average (LTA) TMDL Bacteria Concentrations

Subwatershed	LTA Geometric Mean *E. coli* Concentration (MPN/100ml)	LTA Arithmetic Mean* *E. coli* Concentration (MPN/100ml)
GUN0387	14	22
LIT0002[1]	84	154
GUN0284	55	112
GUN0233	83	307
WGP0050	61	157
BEV0005	42	96
SBH0002	31	130

*Only arithmetic parameters are used in the daily loads analysis.
[1]Subwatersheds partially located in Pennsylvania

The next step is to calculate the 99.8th percentile (the MDL concentrations) of these expected concentrations (LTA concentrations) using the coefficient of variation of the baseline concentrations. Based on a general rule for coefficient of variations, the coefficient of variation of the distribution of pollutant concentrations does not change after these concentrations have been reduced or controlled by a fixed proportion (Ott 1995). Therefore, the coefficient of variation estimated using the monitoring data concentrations does not change, and it can be used to estimate the 99.8th percentile of the long-term average TMDL concentrations (LTAC) using equation (D1). These values are shown in Table D-3.

Table D-3: Maximum Daily Load (MDL) Concentrations

Subwatershed	Coefficient of Variation	MDL *E. coli* Concentration (MPN/100ml)
GUN0387	1.15	196
LIT0002[1]	1.54	1,933
GUN0284	1.77	1,640
GUN0233	3.56	8,255
WGP0050	2.39	3,077
BEV0005	2.04	1,611
SBH0002	4.13	3,875

[1]Subwatersheds partially located in Pennsylvania

With the 99.8th percentiles of LTA TMDL bacteria concentrations estimated as explained above, the maximum daily load for MS4 and non-point sources for each subwatershed can be now estimated as:

$$\textit{Daily TMDL (MPN/day)} = Q*(99.8^{th}C_{LTA})*F_1 \qquad \text{(D6)}$$

Selected Approach for Defining Maximum Daily Loads for Other Point Sources

The TMDL also considers contributions from other point sources (i.e., municipal and industrial WWTP) in watersheds that have NPDES permits with fecal bacteria limits. The TMDL analysis that defined the average annual TMDL held each of these sources constant at their existing NPDES permit limit (daily or monthly) for the entire year. The approach used to determine maximum daily loads was dependent upon whether a maximum daily load was specified within the permit. If a maximum daily load was specified within the permit, then the maximum design flow is multiplied by the maximum daily limit to obtain a maximum daily load. If a maximum daily limit was not specified in the permit, then the maximum daily loads are calculated from guidance in the TSD for Water Quality-based Toxics Control (EPA 1991). The long-term average annual TMDL was converted to maximum daily limits using Table 5-2 of the TSD assuming a coefficient of variation of 0.6 and a 99th percentile probability. This results in a dimensionless multiplication factor of 3.11. The average annual bacteria loads for WWTPs are reported in billion MPN/year. In the Loch Raven Reservoir watershed, to estimate the maximum daily loads for WWTPs, the annual average loads are multiplied by the multiplication factor as follows:

$$\textit{WWTP-WLA MDL (billion MPN/day)} = [\textit{WWTP-WLA (billion MPN/year)}]*(3.11/365) \qquad \text{(D7)}$$

The Maximum Daily Loads for the Loch Raven Reservoir subwatersheds, including those partially located in PA, are presented in Table D-4 below. For the unmonitored downstream

subwatershed an average load of the upstream stations, GUN0233, WGP0050 and BEV0005, is used.

Table D-4: Maximum Daily Loads Summary

Subwatershed	**Maximum Daily Load** (Billion *E.* coli MPN/day)
GUN0387	11
LIT0002[1]	3,327
GUN0284sub	157
GUN0233	2,186
WGP0050	5,251
BEV0005	1,194
SBH0002	212
Downstream Subwatershed	5,613

[1]Subwatersheds partially located in Pennsylvania

Maximum Daily Loads Allocations

Using the MDLs estimated as explained above, loads are allocated following the same methodology as the annual average TMDL (See section 4.8). The maximum daily load allocations for the Loch Raven Reservoir watershed are presented in Table D-5.

Table D-5: Loch Raven Reservoir Watershed Maximum Daily Loads in MD

Subwatershed	Total Allocation	LA_{LR}	$SW\text{-}WLA_{LR}$	$WWTP\text{-}WLA_{LR}$
	(Billion MPN *E. coli* /day)			
GUN0387	11	10	1	0
LIT0002[1]	3,084	2,956	128	0
GUN0284sub	157	152	5	0
GUN0233	2,186	2,139	47	0
WGP0050	5,251	5,128	110	13
BEV0005	1,194	960	234	0
SBH0002	212	35	177	0
Downstream Subwatershed	5,613	5,496	117	0
Total	**17,708**	**16,876**	**819**	**13**

[1]MD portion of the subwatershed only.

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APPENDIX H:

TMDL of Mercury for Loch Raven Reservoir

Total Maximum Daily Load of Mercury for Loch Raven Reservoir in Baltimore County, Maryland

FINAL

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List of Abbreviations

AAWCC	Allowable Ambient Water Column Concentration
BAF	Bioaccumulation Factor
BMP	Best Management Practice
CAA	Clean Air Act
CWA	Clean Water Act
COMAR	Code Of Maryland Regulations
DE	Delaware
DNR	Maryland Department of Natural Resources
Eh	Oxidation Potential
EPA	U.S. Environmental Protection Agency
ESP	Electrostatic Precipitator
ft^3/s	Cubic feet per second
g	gram
Hg	Mercury
kg	kilogram
km^2	Square kilometers
LA	Load Allocation
L	liter
µg/L	micrograms per liter = ppm (parts per billion)
µg/kg	micrograms per kilogram = ppm (parts per billion)
MDE	Maryland Department of the Environment
MD	Maryland
MeHg	Methylmercury
MGD	Millions of gallons per day
M^2	Square meters
mm	millimeter
mi^2	Square miles
MOS	Margin of Safety
MRL	Mercury Load Reduction
m^3/s	Cubic meters per second
ng/L	nanograms per liter = ppt (parts per trillion)
NADP-MDN	National Atmospheric Deposition Program – Mercury Deposition Network
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
PCS	Permit Compliance System (An EPA database – *Envirofacts Warehouse* on the EPA website)
pH	The inverse logarithm of the hydrogen ion concentration
ppb	Parts per billion
ppm	Parts per million
PS	Point Source
RGM	Reactive Gaseous Mercury
TMDL	Total Maximum Daily Load

UMCES	University of Maryland Center for Environmental Science, Chesapeake Biological Laboratory
USGS	United States Geological Survey
WLA	Waste Load Allocation
WQS	Water Quality Standard
WQLS	Water Quality Limited Segments
WTP	Water Treatment Plant
WWTP	Waste Water Treatment Plant
yr	Year

EXECUTIVE SUMMARY

Loch Raven Reservoir is an impoundment in the Gunpowder River Watershed (sub-watershed code 02-13-08-05) in Baltimore County, Maryland. It lies in series below the Prettyboy Reservoir. Loch Raven Reservoir was identified on the State of Maryland's draft2002 list of Water Quality Limited Segments [303(d) list] as impaired by mercury contamination, based on data for mercury concentrations in fish tissue. Concentrations in the water are well below the threshold for concern in regard to drinking water. The Maryland water quality standards Surface Water Use Designation [Code of Maryland Regulations (COMAR 26.08.02.07)] for Loch Raven Reservoir is Use III-P – *Natural Trout Waters and Public Water Supply*. The Maryland Department of the Environment's (MDE) current public fish consumption advisory to eat limited amounts of fish from Loch Raven Reservoir is not supportive of the recreational fishing use. Therefore, this document proposes to establish a Total Maximum Daily Load (TMDL) for mercury in Loch Raven Reservoir.

The methodology used to compute this mercury TMDL consists of two broad steps, which have been modified to coordinate this analysis with the analysis of Prettyboy Reservoir. The first step is to determine a maximum Allowable Ambient Water Column Concentration (AAWCC) of mercury in the water column that ensures the bioaccumulation of mercury by fish will remain below a maximum fish tissue concentration. The second step is to determine a maximum allowable load that is consistent with the maximum water column concentration. The resultant TMDL includes a Load Allocation (LA), a Waste Load Allocation (WLA), a Future Allocation (FA) and a margin of safety (MOS). The TMDL methodology considers all sources, including direct atmospheric deposition to the surface of the lake, nonpoint source contributions from the watershed, point source loads and loads from the upstream Prettyboy Reservoir. Because no specific data was available to estimate point source contributions, literature information was used to estimate the potential point source contributions. These estimates were used to set aside a future allocation that may be used for point source waste load allocations after the results of future point source monitoring are available.

The TMDL for mercury to Loch Raven Reservoir is an average annual load of 843.5 grams per year (2.3109 grams per day). This is the total amount of mercury that can be assimilated by Loch Raven Reservoir without significantly increasing the risk from mercury in fish tissue. This TMDL includes a 14 % Future Allocation (FA) and an 86% nonpoint source allocation (LA). As better information is available from point sources, the future allocation may be shifted to them. For nonpoint sources, an estimate is provided of suballocations between direct atmospheric deposition to the surface of the lake and atmospheric loads to the watershed, which includes Prettyboy Reservoir watershed. The TMDL implementation through reduced atmospheric contributions is expected to be accomplished over time through existing and proposed regulatory controls (e.g., Clean Air Act (CAA)). These controls are expected to be implemented in phases.

1.0 INTRODUCTION

The federal Clean Water Act (CWA) and Maryland regulations require the State to maintain water quality that supports fish and aquatic life, and fishing as a recreational activity. The U.S. Environmental Protection Agency (EPA) interprets the "fishable" use under section 101(a) of the Clean Water Act to include, at a minimum, the protection of aquatic communities and human health related to the consumption of fish and shellfish. In other words, "fishable" means that not only can fish and shellfish survive in a waterbody, but when harvested, can also be safely eaten by humans and terrestrial wildlife. (OWOW Memorandum # WQSP-00-03, October 2000).

Based on mercury data in fish tissue from a subset of lakes across the State, the Maryland Department of Environment (MDE) announced a statewide fish consumption advisory for lakes this year. This advisory has been established statewide as a precautionary measure because the primary source of mercury is understood to be atmospheric deposition, which is widely dispersed. Based on additional fish tissue data, Maryland has verified that Loch Raven Reservoir is impaired due to mercury in fish tissue.

Section 303(d) of the federal CWA and EPA's implementing regulations direct each state to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specific substance are inadequate to achieve water quality standards. The CWA requires the development of a Total Maximum Daily Load (TMDL) for all impaired waters on their Section 303(d) list. A TMDL reflects the maximum pollutant loading of an impairing substance a waterbody can receive and still meet water quality standards. A TMDL can be expressed in mass per time, toxicity or any other appropriate measure (40 CFR 130.2(i)). A TMDL must take into account seasonal variations, critical conditions and a margin of safety (MOS), to allow for uncertainty. Maryland's 2002 proposed 303(d) list prepared by MDE lists Loch Raven Reservoir as impaired for mercury in fish tissue.

Immediate public health benefits will be derived from the enhanced public awareness that will be generated through this TMDL process. The timely development of this TMDL will increase public awareness of the need for upgrading controls on the atmospheric emissions of mercury, which are anticipated to result in water quality improvements.

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting and Source Assessment

Loch Raven Reservoir is an impoundment located near Timonium in Baltimore County, Maryland (Figure 1). The impoundment, which is owned by the Baltimore City Department Public Works, lies on the Gunpowder River. Prettyboy Reservoir lies in the Loch Raven Reservoir watershed and drains into Loch Raven Reservoir. The Prettyboy watershed comprises approximately 26% of the area of the Loch Raven watershed. The City of Baltimore Department of Public Works owns both water bodies and uses them in

a system to provide a major source of public water to the Baltimore metropolitan area. The Loch Raven Dam was constructed in 1923 and modified in 1986.

Inflow to the Reservoir is primarily via the Gunpowder River. The watershed map (Figure 2) shows that land use in the area draining to Loch Raven Reservoir is predominately mixed agricultural and forest/herbaceous. Land use distribution in this watershed is approximately 42% mixed agricultural, 37% forest/herbaceous, 19% developed and 2% water. (Figure 3) (Maryland Department of Planning, 2000 Land Use Data).

Table 1: Physical Characteristics for Loch Raven Reservoir

Location:	Baltimore County, Maryland Latitude 39.43 Longitude 76.54 (At the dam)
Surface Area:	9.7125 km^2
Normal Depth:	23.2 meters
Normal Volume	8.97×10^7 m^3
Drainage Area to Lake:	788.81 km^2 *
Average Annual Flow	8.6 m^3/s *

* Includes contribution from Prettyboy Reservoir Watershed

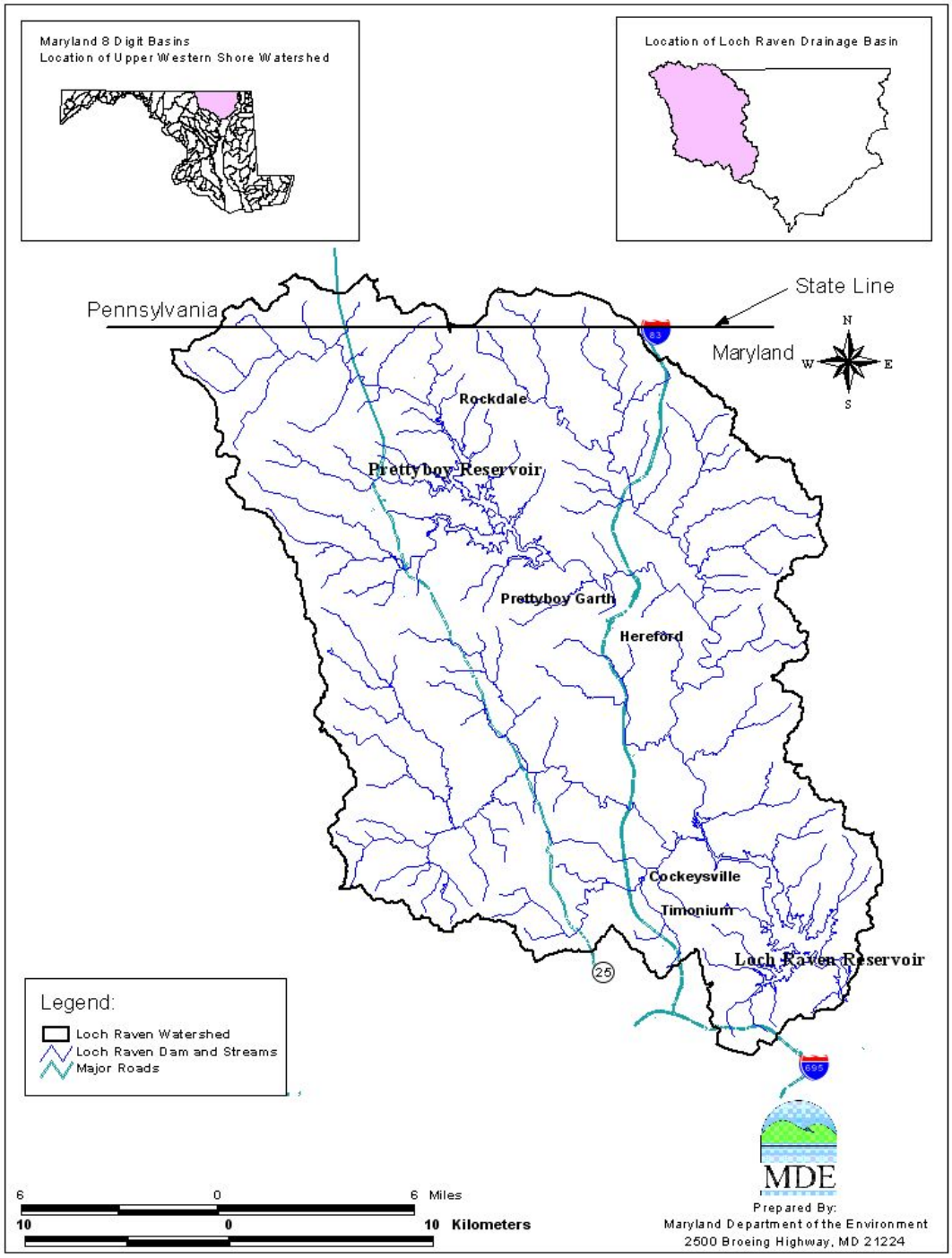

Figure 1: Location Map of Loch Raven Reservoir in Baltimore County, Maryland

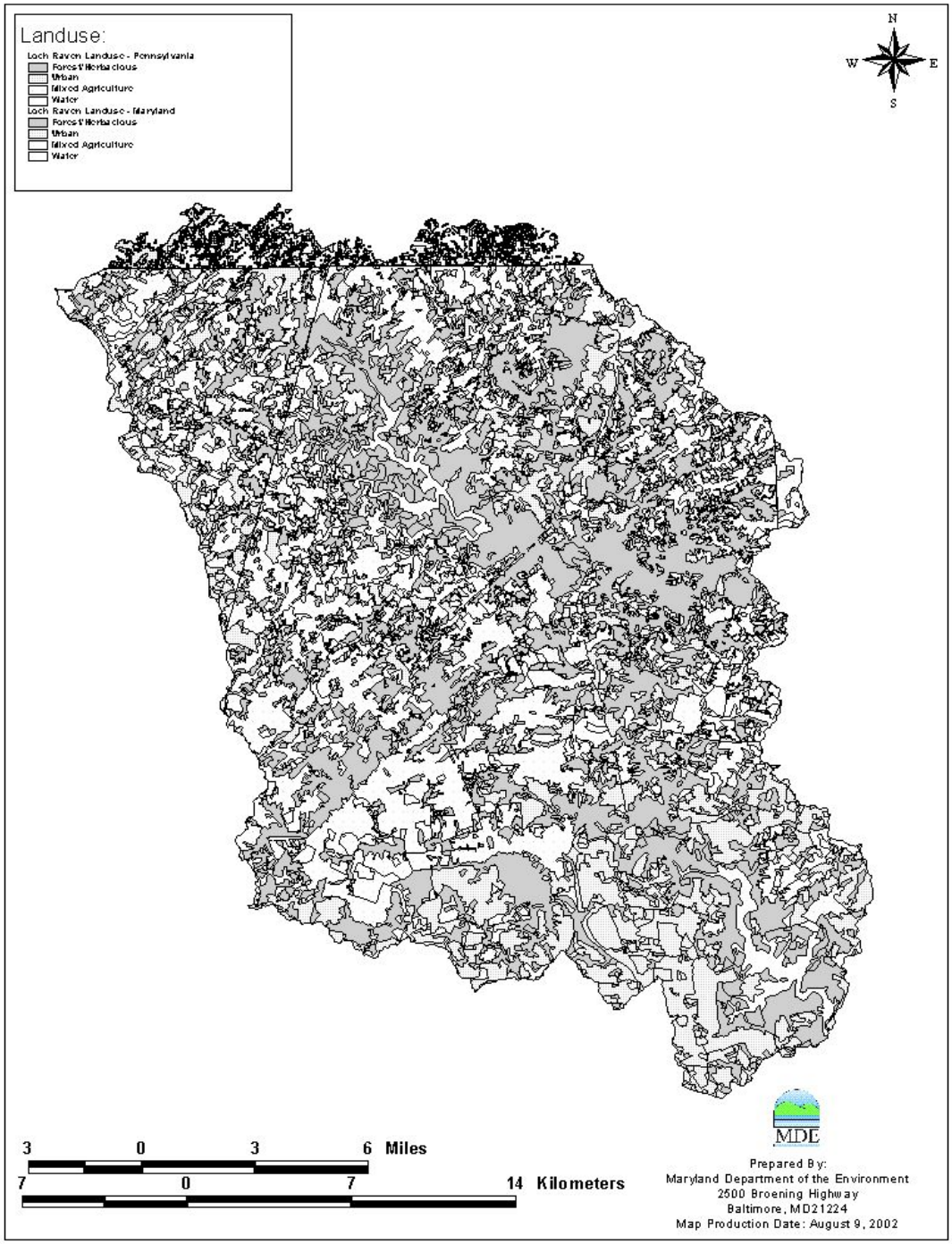

Figure 2: Predominant Land Use in the Loch Raven Reservoir Subwatershed

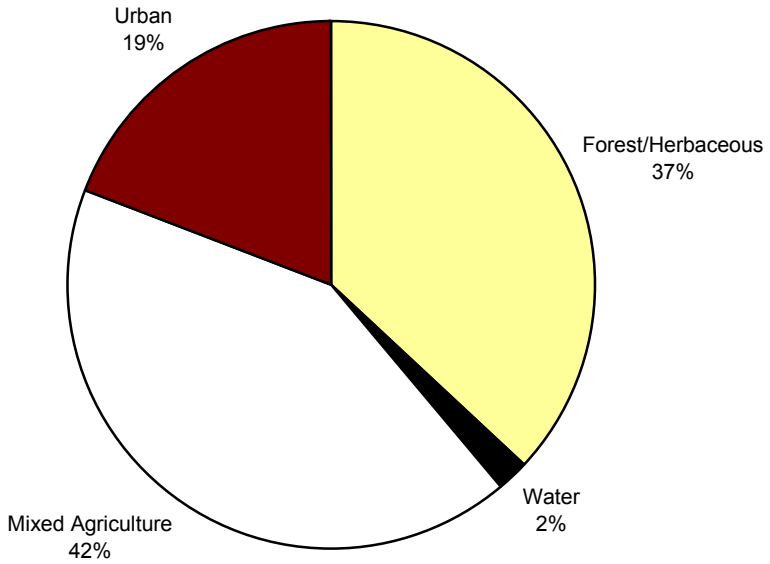

Figure 3: Land Use Distribution in the Loch Raven Reservoir Subwatershed

Loch Raven Reservoir is located in a watershed in which the mercury impairment is dominated by nonpoint source mercury contributions (via atmospheric deposition). The EPA considers coal-fired electric power generating plants to be the largest anthropogenic source of mercury emissions in the nation (EPA, 2000). Therefore an essentially one-to-one relationship between the Allowable Ambient Water Column Concentration (AAWCC) and atmospheric deposition of mercury is assumed.

The National Atmospheric Deposition Program – Mercury Deposition (NADP-MDN) was instituted in 1995 by federal, state, non-governmental research organizations and state agricultural experimental stations in order to monitor the amount of mercury deposited regionally in precipitation. Five sites of this network were used to estimate mercury air deposition rates in Maryland: Maryland (Wye), Delaware (Lewes), and Pennsylvania (Valley Forge, Arendtsville, Holbrook). Data obtained from this network was analyzed to estimate annual deposition rates (Appendix A). Estimates of current loads are included in Section 4.3.3.

In Maryland, the major sources of mercury air emissions are as follows: 43% attributed to power plants, 31% municipal waste combustors, 19% medical waste incinerators, 6% Portland Cement plants, and 1% other (e.g., landfills, oil-fired power plants, other industries).[1]

[1]www.mde.state.md.us/programs/landprograms/hazardous_waste/mercury/mercuryinfo.asp

US industrial demand for mercury dropped 75% from 1988 to 1997. This drop can be attributed to actions including:

- Federal bans on mercury additives in paint and pesticides;
- Industry efforts to reduce mercury in batteries;
- Increasing state regulation of mercury emissions and mercury in products;
- State-mandated recycling programs; and
- Voluntary actions by industry.[2]

The permitted point sources are summarized in Table 2. Although data exists to provide estimates of point source flows, mercury concentration data is not presently available to determine the mercury contributions from these dischargers[3]. To assess the potential influence of the point source contribution, relative to other sources, a sensitivity analysis was conducted. In the absence of observed mercury concentration data, literature values were considered for the analysis as presently described.

For the purpose of estimating potential loads from the point sources in Table 2, Lafarge/Imerys Quarry was addressed separately. The Lafarge Quarry functions like a reservoir that must be drained regularly. In the absence of other mercury concentration data, it was assumed that the concentration of mercury from the Lafarge Quarry would be similar to that of the current concentration in Loch Raven Reservoir (4.77 ng/l). An average flow of 3.0 mgd was used for Lafarge in the sensitivity analysis to determine the potential point source contribution.

Of the other point sources, the Hampstead WWTP makes up the vast majority of the flow. Additionally, by the nature of their operations, there is no reasonable potential that the small industrial sources are significant contributors of mercury. With these considerations in mind, the remaining discharges were assumed to have concentrations similar to municipal WWTPs.

To determine a potential concentration for these remaining point sources, data from the state of Maine was used. In Maine, 75 municipal WWTPs were analyzed using Mercury Method 1631, which has a detection level of 0.5 ng/l (Maine's information referenced by the State of Michigan, February 2000). The mean value of these samples was 11 ng/l. The maximum value was 59 ng/l (Waldoboro Sewer District). As a conservative assumption, a concentration of 60 ng/l was assumed for the remaining point sources.

Under the previous assumptions, in which the flow-weighted average concentration of mercury from all point sources was computed to be about 18 ng/l, the sensitivity analysis suggests that a high estimate of the current potential point source contribution would be

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[2]Source: www.epa.gov/mercury/information.htm

[3] A program is under development to conduct periodic monitoring using a new analytical technique that will provide meaningful estimates of potential point source contributions. When this information becomes available, the future allocations developed in this analysis may be reallocated to point sources.

about 7% of the total load. If atmospheric mercury loads are reduced to achieve the allowable ambient water column concentration that is protective of fish tissue, the point source contribution would make up a greater proportion of the total load, which is estimated be about 12 %. Based on this analysis, a 14% future allocation has been set aside for potential use by point sources.

Table 2: NPDES Permit Holders in the Loch Raven Reservoir Subwatershed (02-13-08-05)

Permittee	NPDES Permit No.	County	Average Annual Flow (MGD)	Maximum Flow (MGD)
Hampstead WWTP	MD0022446	Carroll	0.539	0.9
Manchester WWTP*	MD0022578	Carroll	0.343	0.5
Exxon Service Station #2-5019	MDG916093	Baltimore	0.0009	None
Carroll Independent Fuel Company	MDG3444218	Baltimore	0.0001	None
Southern States Cooperative, Inc. – Cockeysville	MDG344461	Baltimore	0.000002	None
Gray & Son, Inc.	MD0063568	Baltimore	0.001	None
Lafarge/Imerys – Texas Quarry	MD0000175	Baltimore	3.0	None
Noxell Corporation - Baltimore	MD0002348	Baltimore	0.017	None
Teledyne Energy Systems	MD0065901	Baltimore	0.022	None

Flow Source: EPA's Permit Compliance System (PCS) Database
* Drains to Prettyboy Reservoir and is included in load from Prettyboy.

2.2 Water Quality Characterization

To characterize the water quality of Loch Raven Reservoir, two site-specific elements are addressed below: mercury residue in fish tissue data and mercury concentrations in the water column.

2.2.1 General Discussion

Trophic level 4 fish (Largemouth Bass) were harvested from Loch Raven Reservoir and were analyzed for mercury tissue concentrations. Water column samples were also taken and analyzed for mercury concentrations. A bioaccumulation factor was developed based on the above samples (see section 4.3.1 for details of the calculation). Samples were collected by the Maryland Department of Natural Resources (DNR) and the University of Maryland Center for Environmental Science, Chesapeake Biological Laboratory (UMCES) and were analyzed by UMCES.

In fish tissue, mercury is not usually found in concentrations high enough to cause fish to exhibit signs of toxicity, but the mercury in sport fish (trophic level 4) can present a potential health risk to humans. The health risk to humans represented by the mercury content in consumed fish tissue is due to methylmercury. Typically, almost all of the mercury found in fish tissue (90 to 95%) is in the methylmercury form. Mercury chemistry in the environment is complex and not totally understood. Mercury has the properties of a metal, specifically, persistence in the environment because it is not chemically broken down beyond the elemental mercury form (Hg^0) or its ionic forms

(Hg^{+} and Hg^{+2}). It also has properties similar to a hydrophobic organic chemical due to its ability to be methlyated through a bacterial process. Methylation of mercury can occur in water, sediment, and soil solution under anerobic conditions and, to a lesser extent, under aerobic conditions. In water, methylation occurs mainly at the water-sediment interface and at the oxic-anoxic boundary within the water column. Methylmercury is readily taken up by organisms and will bioaccumulate as it has a strong affinity for muscle tissue. It is effectively transferred through the food web, with tissue concentrations magnifying at each trophic level. This process can result in high levels of mercury in organisms high on the food chain, despite nearly immeasurable quantities of mercury/methylmercury concentrations in the water column.

For public health purposes, the MDE has the responsibility to monitor and evaluate the contaminant levels in Maryland fish, shellfish and crabs, and to determine if contaminant levels are within the limits established as safe for human consumption. In fulfillment of this public health responsibility, MDE has issued a statewide fish consumption advisory for mercury in fish. This advisory provides guidelines (Table 3) on fish consumption (allowable meals per month) for recreational anglers and their families (not including commercially harvested fish) and includes fish species in publicly accessible lakes and impoundments.

Table 3: Maryland Department of the Environment Fish Consumption Guidelines

Total mercury in Fish Tissue Range (µg/kg)	Fish Consumption: Maximum Recommended Meals per Month (based on an 8 oz. meal size)
117 – 235	7 - 4
236 - 322	3
322 – 409	2
410 – 939	1
> 939	< 1

These guidelines were developed, in part, to be protective for neurobehavioral effects during human fetal development and early childhood. An 8 ounce meal size is recommended for the general population. Recommended meal sizes for women of childbearing age and children (0-6 years) are 6 ounces and 3 ounces respectively. Thus levels of mercury in fish tissue above 235 µg/kg are an indication of impairment. When data for mercury concentrations in fish tissue is not available, data for methylmercury concentrations is used alternately for impairment decisions.

2.2.2 Mercury in Fish Tissue Data

Samples of fish were taken from Loch Raven Reservoir. Trophic level 4 fish (largemouth bass) were targeted in the collection because they represent the top of the bioaccumulation food chain and provide a conservative estimate of the mercury dose associated with fish consumption from this reservoir. The fish fillets obtained during the

sampling effort were analyzed for mercury concentrations and were measured for length and weighed. Appendix G lists the individual fish data.

Table 4: Summary of Mercury in Fish Tissue Concentrations from Loch Raven Reservoir

Trophic Level	Sample Count	Geometric Mean Methylmercury Concentration (µg/kg)
4	16	272.8

2.2.3 Water Column Mercury Concentrations

Water column samples were taken from Loch Raven Reservoir and were analyzed for total mercury and methylmercury concentrations using EPA Method 1631. Samples were analyzed for both constituents in both whole water and as dissolved (filtered).
The geometric mean value of total mercury in the water column is 4.95 ng/L. The geometric mean value of dissolved total mercury in the water column is 3.61 ng/L.
The geometric mean value of methylmercury in the water column is 0.170 ng/L. The geometric mean value of dissolved methylmercury in the water column is 0.155 ng/L.
Appendix G contains the individual data sets and a discussion of data reduction.

2.3 Water Quality Impairment

The Maryland water quality standards Surface Water Use Designation [Code of Maryland Regulations (COMAR) 26.08.02.07] for Loch Raven Reservoir is Use III-P designation – *Natural Trout Waters and Public Water Supply*. The water quality impairment of Loch Raven Reservoir being addressed by this TMDL analysis consists of a higher than acceptable level of mercury. Maryland water quality standards, under the federal CWA, require that water quality support public health and welfare for this designated use. An existing public health fish consumption advisory for Loch Raven Reservoir recommends significant limits on the consumption of fish from this impoundment. This is a violation of the State's narrative water quality standards, because the designated use of "fishing" is not fully supported. This loss of use results in Loch Raven Reservoir's identification on Maryland's 2002 303(d) list as impaired for mercury residue in fish tissue. Mercury concentrations in the water are well below the threshold for concern in regard to drinking water.

3.0 TARGETED WATER QUALITY GOAL

The objective of the TMDL established in this document is to reduce mercury loads to levels that are expected to result in meeting water quality criteria that support the Use III-P designation – *Natural Trout Waters and Public Water Supply.* See COMAR

26.08.02.02 B (1). Specifically, limiting the mercury loads is intended to ensure that concentrations in fish tissue are consistent with the protection of human health.

- MDE considers the term "suitable……. for fishing" (see COMAR 26.08.02.02 B (1) (c)) or "fishable" as the ability for the general population to eat at least 4 meals per month of any single common recreational fish species from the given waterbody. This upper threshold value for fish tissue is 235 μg/kg for methylmercury[4].

The fish tissue endpoint is designed to ensure that the general population can safely consume at least four meals per month. This is consistent with water quality standards, which must protect the overall population and do not have to be protective of more sensitive subpopulations. The risk assessment used by MDE to determine this concentration threshold incorporates the same risk level, Reference Dose and body weights and is consistent with the guidance adopted by the U.S. EPA for the protection of human health from methylmercury described in "Water Quality Criteria for the Protection of Human Health: Methylmercury" (EPA-823-R-01-001).

4.0 TOTAL MAXIMUM DAILY LOADS AND ALLOCATIONS

4.1 Overview

This section describes how the mercury TMDL and loading allocations were developed for Loch Raven Reservoir. The second subsection describes the analysis framework for developing the AAWCC and the TMDL calculation. The third subsection describes the steps in the TMDL calculation and the fourth subsection describes the TMDL allocations. This includes discussion of the relationship with the Prettyboy Reservoir TMDL. The fifth subsection addresses seasonal variations and critical conditions, and the sixth subsection explains the rational for the margin of safety (MOS). Finally, in the seventh subsection, the pieces of the equation are combined in a summary accounting of the TMDL.

4.2 Analysis Framework

The computational framework used for this TMDL calculation is a refinement of the methodology described in *" Total Maximum Daily Load for Total Mercury in Fish Tissue Residue in Big Haynes Reservoir,"* which was developed and proposed by the EPA, Region 4 for the State of Georgia, dated August 30, 2001. Maryland has refined the method by using a fish tissue threshold for mercury that is consistent with its fish consumption guidelines and more stringent than the EPA guidelines applied in Georgia. In addition, Maryland has estimated loads from air deposition and watershed sources

[4] To determine if a waterbody is impaired, the contaminant concentration from a sample of fish fillets of any single common species of recreational fish is compared to the established threshold. Generally, the geometric mean of 10 trophic level 4 fish make up the sample. If the threshold is exceeded, the waterbody's use is not met and the waterbody is considered impaired.

using mass balance calculations. Finally, the methodology was refined to address two reservoirs in series.

The TMDL analysis sets a maximum allowable ambient water column concentration (AAWCC), which ensures that bioaccumulation of the mercury concentration in fish tissue will remain below the threshold stated in Section 3.0. The AAWCC is computed using bioaccumulation factors based on site-specific fish tissue mercury concentration data and water column mercury concentration data. The TMDL is expressed in terms of an average annual load into the waterbody, which is computed from direct waterbody deposition and a watershed contribution. A future allocation of 14% is set aside, which may be used in the future if additional information indicates it is necessary to provide an explicit allocation to point sources.

The TMDL analysis framework can be summarized in the following steps:

(1) Determine the Biological Accumulation Factor (BAF) based on observed fish tissue data and observed water column concentrations.
(2) Using the BAF, calculate a maximum AAWCC that will ensure the targeted water quality goal of a mean fish tissue concentration of methylmercury remains below 235 μg/kg.
(3) Using a mass balance approach, estimate the TMDL that will result in the desired water quality target. This target consists of the AAWCC that is adjusted to account for particulate mercury, because the AAWCC is solely the dissolved component. (See Appendix H).
(4) This TMDL is coupled to the Prettyboy Reservoir TMDL so that both are consistent with each other. (Prettyboy Reservoir drains to Loch Raven Reservoir).

4.3 Total Maximum Daily Load Analysis

This section expands upon the three steps outlined immediately above.

4.3.1 Bioaccumulation Factor

A BAF is the ratio of the concentration of a chemical in fish tissue to the concentration of the chemical in the water column. As defined in Mercury Study Report to Congress (EPA 1997), the BAF is "The concentration of the methylmercury in fish divided by the concentration of total dissolved methylmercury in water." When computing a BAF, MDE considered one of the three methods utilized in the Mercury Study report to Congress. Specifically this entails the direct estimation of BAF for trophic level 4 fish from site-specific criteria. The BAF calculated for this analysis is site specific, because it uses data from Loch Raven Reservoir. More details are given in the U.S. EPA technical support document for BAFs (EPA-820-B-95-005, March 1995). Also see, the EPA Science Advisory Board report, EPA-SAB-EPED/DWC-93-005, December 1992.

A food chain can be described in terms of trophic levels, in which higher levels represent species that are higher on the food chain.

$BAF = \{TL_4Fc_{(MeHg)} / Wc_{(MeHg)}\}$

Where:
(MeHg) means the particular concentration is for methylmercury
TL_4Fc = Trophic level 4 fish tissue concentration (µg/kg), from Table 4
Wc = Water column concentration (µg/L); from Appendix G, Table G5

The BAF calculation for Loch Raven Reservoir is expressed as:

BAF = 272.8 µg/kg /0.000155µg/L

BAF = 1,760,000 L/kg

4.3.2 Maximum Allowable Ambient Water Column Concentration

The maximum AAWCC is the concentration in the water that ensures that bioaccumulation will not exceed a fish tissue concentration that serves as the water quality endpoint. The water quality endpoint, stated in Section 3.0 is an average total mercury fish tissue concentration of 235 µg/kg for any trophic level.

The AAWCC uses the following equation from EPA guidelines (EPA, 2000):

$$AAWCC = \frac{\{(RfD-RSC)*BW*\text{Conversion Units}\}}{(CR*\ BAF*\text{Fraction MeHg})}$$

Where:

RfD = 0.1 µg/kg/day MeHg	Combined consumption rate: fresh + saltwater fish.
RSC = 0.027 µg/kg/day MeHg	Relative Source contribution (saltwater fish). This value is subtracted because the system under study is fresh water.
BW = 70 kg	Body weight (average of males and females).
CR = 29.8 g/day	Consumption rate (4 meal/month) based on MD fish consumption advisory risk analysis.
BAF= (L/kg)	Bioaccumulation Factor (site specific). See Section 4.3.1.

Fraction MeHg — Ratio of methylmercury to total mercury in the water column Appendix G.

Conversion units = 1,000,000 (ug/g) To convert the AAWCC to units of ng/L

Therefore:

$$AAWCC = \frac{(0.1-0.027) * 70 * 1{,}000{,}000}{29.8 * 1{,}760{,}000 * (0.155/3.61)}$$

AAWCC = 2.27 ng/L Dissolved Total Mercury

The fraction of methylmercury was calculated using the geometric mean values for dissolved concentrations for total mercury and methylmercury values (Table G3, and Table G5). Because the AAWCC accounts only for the dissolved component of the total mercury concentration, it is necessary to estimate the particulate mercury component expected to be present under conditions of a TMDL. To this end, a total mercury component, which is used in the load calculation for the TMDL, is computed in Appendix H.

4.3.3 Total Maximum Daily Load Calculation

The key finding in this overall analysis is the AAWCC, which is the water column concentration below which fish tissue concentrations will be protected to support human consumption. This section presents a computation of the estimated average annual load that corresponds to achieving the AAWCC. This annual load constitutes the TMDL.

The computation used to estimate the average annual load is a straightforward mass balance calculation. The computational procedure assumes a constant direct atmospheric deposition of mercury to the surface of the lake, and a constant loading from the watershed that feeds the lake. The contribution from the watershed is a combination of atmospheric loads that wash off the landscape and any other terrestrial sources. In this case, the contribution from Prettyboy Reservoir was also taken into consideration. A Future Allocation is set aside for future use in the event future data indicates an explicit allocation is necessary for point sources.

Briefly, the calculation involves an estimation of current loads that are necessary to produce the observed water column concentration. This is done using mass balance calculations. After the current loads are determined, reductions are calculated by using a load reduction factor. These steps are described in more detail below with values that apply to Loch Raven Reservoir.

<u>Current Load</u>: The calculation of the current total mercury load is performed in Appendix I. The current load includes the effect of direct atmospheric deposition to the surface of the reservoir and the nonpoint sources from the watershed, which includes

atmospheric mercury that is deposited to the surface of the land and is passed through the watershed.

Based on the mass balance estimates, which assumes steady state conditions, the current loads are summarized as follows:

Load from direct Air Deposition to the reservoir =	0.3759 g/day	(10.61 %)
Load from NPS from the Surrounding Watershed* =	1.9581 g/day	(55.24 %)
Load from Prettyboy Reservoir =	0.9672 g/day	(27.29 %)
Point Sources** =	0.2431 g/day	(6.86 %)
Current Daily Load =	3.5443 g/day	(100 %)

* Much of this is from atmospheric deposition to the land.
** The point source value is not based on observed data. Rather, it is the load that would occur assuming effluent concentrations discussed in Section 2.1.

Maximum Allowable Load: The maximum allowable load is calculated by adjusting the estimated current direct atmospheric load and watershed load downward until the target concentration is achieved (Appendix I). The target concentration is the adjusted AAWCC, which accounts for the particulate mercury (See Appendix H). Once the TMDL is determined, a Future Allocation is determined by adjusting the atmospheric and watershed contributions downward maintaining their relative proportions. The Future Allocation is determined on the basis for potential need for future point source allocations.

The results of the TMDL computation are summarized as follows:

Load from direct Air Deposition to the reservoir =	0.1643 g/day	(7.11 %)
Load from NPS from the Surrounding Watershed* =	0.8559 g/day	(37.04 %)
Load from Prettyboy Reservoir =	0.9672 g/day	(41.85 %)
Future Allocation =	0.3235 g/day	(14.00 %)
Total Maximum Daily Load =	2.3109 g/day	(100 %)

* Much of this is from atmospheric deposition to the land.

4.4 Total Maximum Daily Load Allocations

In a TMDL assessment, the total allowable load is divided and allocated to the various pollutant sources. The allocations described in this section demonstrate how the subject TMDL can be implemented to achieve water quality standards in Loch Raven Reservoir. Specifically, these allocations show that the sum of mercury loadings to the Loch Raven Reservoir from existing nonpoint sources can be maintained safely within the TMDLs established here.

The CWA and EPA regulations provide for flexibility in implementation of TMDLs, as long as the overall load is not exceeded. The allocations are generally classified as waste

load allocation (WLA) for point sources, load allocation (LA) for nonpoint sources, and a future allocation (FA). As future information becomes available, MDE expressly reserves the right to allocate this TMDL among different sources and land use categories in any manner that is reasonably calculated to achieve water quality standards. In particular, the future allocation of 14 % may be used in the future if additional information indicates that it is necessary to provide an explicit allocation to point sources.

4.5 Seasonal Variations and Critical Conditions

Seasonal Variations: This TMDL is effectively represented as an AAWCC level that is designed to reduce mercury concentrations in fish, thus protecting human health by minimizing exposure through fish consumption. The analysis is based on long-term averages. Although many factors might vary over a given year, the effect is averaged out over several years during which fish accumulate mercury. An analysis of the length and weight of individual fish used in the BAF calculation (Table G1) indicates they were of legal (keepable) size and the average age was approximately five years (DNR, 2000). The averaging effect of long-term bioaccumulation is reflected in the analysis and supports the use of an average annual AAWCC and average annual load. Specifically, the fish tissue concentration at the time of sampling is the result of long-term accumulation in fish that are several years old. The bioaccumulation factor is, in turn, computed on the basis of this long-term accumulation. An AAWCC is then calculated based on the relationship between the BAF, water column mercury concentration ratios and risk parameters related to fish consumption. Finally, the average annual loading values for the waterbody are calculated to meet the AAWCC.

Critical Conditions: Critical conditions concerns do not arise in this analysis because acute conditions are not a concern at the observed concentrations and the allowable concentrations of mercury are based on human fish consumption over a long time period, which averages out critical events. Also, the TMDL is protective of human health from fish consumption at all times, so that any "critical conditions" within that time frame are considered. Finally, the TMDL level established to be protective of human health is more conservative than the mercury levels to protect environmental resources, implying that critical conditions for environmental resources are also addressed by the previous logic that is applied to human health.

The annual average load is of primary significance because mercury bioaccumulation and the resulting risk to human health that results from mercury consumption is a long-term phenomenon. Therefore shorter seasonal inputs are less meaningful than total annual loads over many years. The use of annual loads allows for integration of short-term or seasonal variability.

The reader should also note that, although this analysis presents a loading limit, the fish tissue concentration depends on mercury water column concentration, not on load. Thus, annual loads are not highly relevant; that is, if a fish is exposed to the same concentration of mercury, but more water or less water of the same concentration passes through the reservoir due to seasonal differences in rainfall, the fish tissue accumulation will be the

same. This understanding is important when interpreting future information to evaluate the success of implementing controls to achieve the TMDL.

4.6 Margin of Safety

A margin of safety (MOS) is required as part of a TMDL in recognition of the fact that there are many uncertainties in scientific and technical understanding of water quality in natural systems. Specifically, knowledge is incomplete regarding the exact nature and magnitude of pollutant loads from sources and the specific impacts of those pollutants on the chemical and biological quality of complex, natural water bodies. The MOS is intended to account for such uncertainties in a manner that is conservative from the standpoint of environmental and human health protection.

Based on EPA guidance, the MOS can be achieved through one of two approaches (EPA, April 1991). One approach is to reserve a portion of the loading capacity as a separate term in the TMDL (i.e., TMDL = WLA + LA + FA+ MOS). The second approach is to incorporate the MOS as conservative assumptions in the design analysis. For purposes of this mercury TMDL methodology, Maryland has adopted margins of safety that make use of conservative assumptions, that is, a built-in MOS.

(1) When computing the bioaccumulation factor (BAF), it is assumed that anglers consume only trophic level four fish, which results in a larger BAF. Trophic level four fish are near the top of the food chain, and thus have the highest observable fish tissue concentrations due to bioaccumulation. Adopting the assumption that people eat only trophic level four fish represents a conservative assumption of exposure. This larger BAF is used in the denominator of the formula for computing the allowable ambient water column concentration (AAWCC), which makes the AAWCC tighter (a lower allowable water column concentration).

(2) EPA's recommended threshold for mercury in fish tissue is for 300 µg/kg, but MDE is using a value of 235 µg/kg. This lower threshold is based on a risk analysis used for Maryland's fish consumption procedures. The analysis assumes that some people consume more meals of fish over a given period of time than is assumed by EPA.

(3) The AAWCC formula includes the computation of the maximum allowable mercury in fish tissue, based on human health risk principles. Subtracting the relative source contribution (RSC), associated with mercury contribution to a typical diet due to marine fish, has the effect of allowing a maximum fish tissue concentration of about 172 µg/kg, rather than 235 µg/kg. This is a conservative assumption.

Items (2) and (3) immediately above result in a combined MOS of about 43%. The loss of mercury from the waterbody through reduction and volatilization is not accounted for

in the analysis. Therefore, credit for this phenomenon is taken as an additional margin of safety.

4.7 Summary of Total Maximum Daily Loads

The annual TMDL for mercury is calculated from the equation:

TMDL = WLA + LA + FA + MOS

Where: WLA = Waste Load Allocation
LA = Load Allocation
FA = Future Allocation
MOS = Margin of Safety

The TMDL for mercury (g/yr) is presented below in Table 5.

Table 5: Summary of Mercury TMDL for Loch Raven Reservoir

TMDL (g/yr)	Waste Load Allocation[a] (g/yr)	Load Allocation (g/yr)	Future Allocation (g/yr)	Margin of Safety
843.5	0.0	725.4	118.1	Implicit (Approximately 43%)

a. The future allocation may be used for point sources if warranted by future information.

On average, the TMDL will result in loads of approximately 2.3109 g/day.

The current total mercury load to Loch Raven Reservoir is the sum of the future allocation and NPS loads. MDE reserves the right to update the TMDL calculation and the TMDL source allocations as additional information from currently active or future programs becomes available and is analyzed.

5.0 ASSURANCE OF IMPLEMENTATION

Loch Raven Reservoir is located in a watershed in which the mercury impairment is dominated by nonpoint source mercury contributions (resulting from atmospheric deposition). The EPA considers coal-fired electric power generating plants to be the largest anthropogenic source of mercury emissions in the nation. As such, the TMDL implementation provisions may differ from the implementation of TMDLs from other pollutants (nutrients and toxics - other than mercury). EPA Region 4 and EPA Region 6 have indicated that reductions in atmospheric contributions will be accomplished over time through existing and proposed Clean Air Act regulatory controls that will ensure significant reductions in mercury loading on a nationwide basis by reducing atmospheric emissions. However, they believe it is too early to estimate the reductions in mercury emissions that may result from the future regulation of electric power generating utilities.

The EPA expects to see reduced emissions of mercury from this industry sector as a number of regulations are implemented to control sulfur dioxide emissions and nitrous oxide emissions, since some control technologies used to limit these pollutants collaterally reduce mercury emissions to some degree. .

EPA has taken a number of actions to reduce mercury pollution, including regulations for industries that contribute significantly to mercury pollution. These actions, once fully implemented, are expected to reduce nationwide mercury emissions caused by human activities by about 50% over 1990 levels. Examples include:

- Municipal waste combustors. EPA issued final regulations on October 31, 1995. These regulations were expected (by 2000) to reduce mercury emissions from these facilities by about 90%, from 1990 levels;
- Medical waste incinerators. EPA issued emission standards on August 15, 1997. These were expected (by 2002) to reduce mercury emissions from these facilities by about 94%, from 1990 levels.[5]

In addition to controls on mercury air emissions, proper management of mercury containing productions and source reduction are critical components to reducing mercury in the waste stream and to the environment. To this end, the following activities are examples of actions taken within Maryland:

- About 11 counties in Maryland have instituted household hazardous waste collection programs, where wastes including mercury containing products can be collected for safe management and disposal;
- Effective October 1, 2002, there is a prohibition on the sale and distribution of mercury fever thermometers in Maryland except by prescription (with certain exceptions, such as hospitals;
- Effective October 1, 2003, primary and secondary schools cannot use or purchase elemental or chemical mercury. MDE is required to provide outreach to schools on the management, recycle and disposal of mercury products.[6]
- Effective November 1, 2002, MDE will be implementing EPA's Universal Waste Rule which encourages the collection and recycling of wastes including mercury containing thermostats, lamps, and other products.
- Maryland is part of EPA Region 3's "e-cycling" project, which encourages the collection, refurbishment, and recycling of electronic devices. Four permanent sites in Maryland have been established for collection of computers, tv's, monitors, etc.
- Five sites in Maryland are partners and another MD company is a champion in the Hospitals for a Healthy Environment (H2E) program. Under this program, a Memorandum of Understanding was signed between USEPA and the American Hospital Association, calling for, among other things, virtual elimination of

[5]Source: www.epa.gov/mercury/information.htm

[6]Source: www.mde.state.md.us/assets/document/Retailers_Manu_web_version.pdf

mercury-containing hospital wastes by the year 2005. As of November 1, 2002, the program has 338 partners representing 1021 health care facilities.[7] The program's website, www.h2e-online.org/tools, provides additional tools to these facilities for waste management and pollution prevention.

As additional data and information are collected for the Loch Raven Reservoir watershed and as new legal requirements are imposed under the Clean Air Act and other environmental statutes, MDE will continue to evaluate the effectiveness of the regulatory and non-regulatory programs in achieving the water quality targets under this TMDL.

As part of Maryland's Watershed Cycling Strategy, follow-up monitoring and assessment will be conducted to evaluate the impairment status of Loch Raven Reservoir. For public health purposes, the MDE has the responsibility to monitor and evaluate the contaminant levels in Maryland fish, shellfish and crabs, and to determine if contaminant levels are within limits established as safe for human consumption. The currently issued fish consumption advisories are one result of the execution of this responsibility.

[7]Source: www.h2e-online.org

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Appendix A

Mercury Air Deposition

Summary

Mercury air deposition data was utilized to quantify the contribution of nonpoint air sources to mercury loads in impaired water bodies. Air deposition data provided total annual loads of mercury to various water bodies.

Method

Five sites of the National Atmospheric Deposition Program – Mercury Deposition Network (NADP – MDN; http://nadp.sws.uiuc.edu/mdn/) were used to estimate mercury air deposition rates in Maryland: Maryland (Wye), Delaware (Lewes), and Pennsylvania (Valley Forge, Arendtsville, Holbrook). This network was instituted in 1995 by federal, state, non-governmental research organizations, and state agricultural experiment stations in order to monitor the amount of regional deposition of total mercury in precipitation. These sites spanned the western, northern, and central regions of Maryland (Figure A1). Data obtained from the network were converted to an annual basis (ug/m2-wk) and then plotted as a frequency histogram. Plots and estimates of kurtosis and skewness revealed non-normally distributed data. Geometric means were therefore calculated for each site. An average of the geometric means was then taken (8.43 ± 1.26 ug/m^2-yr) in order to estimate the statewide wet deposition of mercury (in precipitation) per year (Table A1).

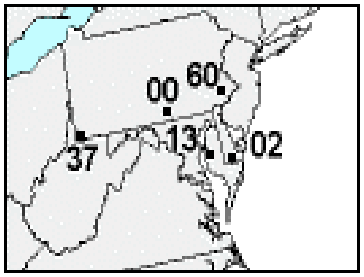

Figure A1: Mercury Deposition Network Monitoring Stations

Table A1: Wet Deposition of Total Mercury

Site	Location	Start Date	End Date	Geo Mean (ug/m2-yr)
DE02	Lewes, DE	03/14/95	10/08/96	7.71
MD13	Wye, MD	10/03/95	10/08/96	8.10
PA60	Valley Forge, PA	11/23/99	06/26/01	10.48
PA00	Arendtsville, PA	12/12/00	06/26/01	8.63
PA37	Holbrook, PA	06/22/99	11/21/00	7.21
			Average	8.43
			Stdev	1.26

Estimates for the amount of wet mercury deposition (8.43 ug/m^2-yr) were then applied to dry deposition estimates used in EPA-approved RELMAP air deposition analyses (http://www.epa.gov/region4/water/tmdl/georgia/index.htm). These analyses calculated the amount of mercury that is deposited from wet and dry sources in the United States using measured amounts of wet deposition and estimated proportions of dry deposition (RELMAP estimates; EPA, 1997).

Particulate, reactive gas (RGM; Hg^{2+}), and elemental (Hg0) mercury were considered for final depositional estimates in Maryland. Distinction was not made between locally deposited mercury species (RGM; Hg^{2+}) and those that deposit farther from source emitters (particulate and Hg^0), since all forms of mercury are ultimately incorporated into the food web. Final calculations determined that approximately 14.12 ug/m^2-yr of mercury is deposited in Loch Raven Reservoir (Table A2).

Table A2: Measured, Estimated, and Total Mercury Deposition

Total Wet Deposition in MD (ug/m^2-yr)[8]	RELMAP wet deposition	µg/m^2/yr[9]	Hg Species Ratios (EPA, 1997)[10]	Wet Deposition Total (ug/m^2/yr)[11]
8.43	Hg^{2+} (RGM) from US	2.65	0.267	2.25
	Particulate Hg from US	1.96	0.197	1.66
	Hg^0 from US sources	0.18	0.018	0.15

RELMAP dry/wet deposition ratio	0.676[12]

Dry deposition (RELMAP estimate; µg/m^2-yr)[13]	RELMAP dry deposition	µg/m^2/yr[14]	Hg Species Ratios (EPA, 1997)[15]	Dry Deposition Total (µg/m^2-yr)[16]
5.27	Hg^2+ (RGM) from US	4.10	0.98	5.59
	Particulate Hg from US	0.08	0.02	0.11
	Total	4.18	1.00	5.70

Total Deposition of Reactive Gas Mercury (Hg^{2+}; RGM; µg/m^2-yr)	7.84
Total Deposition of Particulate Mercury (µg/m^2-yr)	1.77
Total Deposition of Elemental Mercury (µg/m^2-yr)	4.51
Total Deposition of Mercury (µg/m^2-yr)	14.12

The wet deposition numbers are taken from the indicated monitoring data. The RELMAP modeled deposition numbers are used to estimate the wet/dry ratio, which is then used to determine dry deposition and then total deposition (wet + dry). The

[8]Average geomean from Table A1.
[9] Data from RELMAP model.
[10] Individual species divided by total RELMAP
[11]= footnote 8 x footnote 10
[12] Data from RELMAP model.
[13]= footnote 8 x footnote 12
[14] Data from RELMAP model.
[15] Individual species divided by total RELMAP
[16]= footnote 13 x footnote 15

RELMAP estimates are from a national model, so extrapolating to a finer watershed is important, as there are differences in deposition rates within Maryland, which should be considered important. The calculated mercury deposition rate for Loch Raven Reservoir (14.12 ug/m^2-yr) was multiplied by waterbody area (Table A3) to generate annual mercury loadings directly deposited to the waterbody.

Table A3: Mercury Deposition Estimates for a Select Waterbody

Lake/Impoundment	Area (km^2)	Direct Mercury Deposition to Waterbody (kg/year)
Loch Raven Reservoir	9.7125	0.1371

Uncertainty in Mercury Air Deposition Estimates

Quantification of the deposition of mercury from the air relies on many factors that are not derived empirically or from Maryland data. Four of the five mercury deposition network sites used in the estimation of atmospheric mercury deposition were in states adjacent to Maryland (PA and DE). These sites may be influenced by site-specific conditions, and therefore may alter overall deposition means used in subsequent calculations. Extrapolation from wet deposition means relies on modeling factors and estimates proposed in Savannah River TMDLs (EPA, 2000). Specifically, they rely on older regional-scale LaGrangian model (Regional LaGrangian Model of Air Pollution; RELMAP) output that may not represent smaller scales (Maryland) accurately (EPA, 2001). The output is also based on 1996 mercury emissions estimates and mercury speciation patterns that have not been rigorously investigated. Alteration of speciation ratios would change total depositional estimates directly. Modeling estimates for wet and dry deposition were also not quantified specifically for Maryland areas. Consideration of Maryland RELMAP isopleth model data could change the wet: dry deposition ratio, and hence the overall estimates of total mercury deposition.

Estimates of watershed area for some water bodies (e.g. Potomac River impoundments) could also be revised to include adjacent state estimates (VA, WV, and DE) of watershed areas calculated from GIS information (as was done for other Maryland watersheds).

Derivation of the total load relies in part on accurate estimation of the waterbody volume. Waterbody volumes were obtained from an inventory of Maryland dams and impoundments (PPRP, 1999). These were defined as the "volume of water stored below the normal operating pool elevation, excluding any flood storage" and the "impounding capacity in acre-feet, obtained from plans, design computations, or estimated". Waterbody volume estimates, therefore, may not represent current conditions that have been changed because of subsequent impoundment infilling by sediment or dredging and channelization.

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Appendix B

Addendum For Toxics Methodology – MD 2002 303(d) List: Designated Use Impairments Based on Fish Tissue.

Background:

Section 101(a)(2) of the CWA establishes as a national goal "water quality which provides for the protection and propagation of fish, shellfish, and wildlife, and recreation in and on the water, wherever attainable." These are commonly referred to as the "fishable/swimmable" goals of the Act. Section 303(c)(2)(A) requires water quality standards to protect the public health and welfare, enhance the quality of water, and serve the purposes of the Act (EPA 2000). EPA, along with the Department, has interpreted these regulations to mean that not only should waters of the State support thriving and diverse fish and shellfish populations, but when caught, may also be safely consumed. Some water bodies may have elevated levels of contaminants, especially in the sediment. Some of these contaminants (especially mercury and PCBs) tend to bioaccumulate to elevated levels in the tissues of game fish and "bottom-feeders" (largemouth bass and catfish, respectively). When tissue levels of a contaminant are sufficiently elevated to increase the risk of chronic health effects if the fish is consumed regularly, the State has the responsibility to issue a fish consumption advisory to protect public health. Fish consumption advisories are designed to protect the general population as well as sensitive populations (i.e. young children; women who are or may become pregnant). If consumption advisory is issued for a waterbody, its designated use may not be supported and that waterbody may be listed as impaired for the contaminant(s) responsible for the fish consumption advisory.

The Department of the Environment has defined "fishable" as the ability to eat AT LEAST 4 meals/month (general population level) for common recreational fish species from a given waterbody. The tissue level corresponding to this will be the upper threshold at the 4 meal/month level for a given contaminant. In addition to this, if the tissue concentration is within 5% of the threshold, the water body's designated use will be considered impaired. The 5% "safety factor" accounts for the uncertainty and spatial/temporal variability in monitoring data and sampling regimes. This safety factor is designed to protect and maintain the "fishable" designated use status of a waterbody. To determine if a waterbody is impaired, the appropriate measure of central tendency (i.e. geometric mean) for a contaminant from the fillet samples of common recreational fish species will be compared to the established threshold. If the threshold is exceeded, the water body's designated use is not met, and the waterbody is considered impaired.

Data Requirements:

The data required to list a waterbody as impaired are similar to the data requirements for the development of a fish consumption advisory. The same decision rules are used to test data adequacy, and spatial and temporal representation. Consumption advisories based on the minimum required samples that resulted in an impairment decision will be

re-sampled prior to TMDL development to insure that the advisory was not due to a localized condition, and that the impairment is still temporally relevant. The data requirements for listing a waterbody are:

a. The advisory is based on fish and shellfish tissue data. All available data will be used.
b. The data are collected from the specific waterbody in question.
c. A minimum of 5 fish from a given species (individual or composite analysis)for a given waterbody.
d. Species used to determine impairment should be representative of the waterbody; migratory and transient species may be used if they are the dominant recreational species, but should only be used in conjunction with resident species, especially in the case of tidal rivers of the Chesapeake Bay.
e. Contaminant thresholds used will reflect concentrations used to set consumption recommendations for the general population. The general population is defined as women beyond the years of childbirth (~45); and adult males.

In some instances, it may be inappropriate to consider certain fish and shellfish consumption advisories in making an impairment determination. For example, a State may have issued a statewide or regional warning, based on data from a subset of water bodies and species or a higher consumption value may have been used in determining the need for an advisory to protect a specific sensitive population compared to the value used in establishing water quality criteria for the protection of human health. In such instances, these types of advisories were not considered for making an impairment determination. This approach is consistent with EPA's current recommendations regarding impairment determinations using contaminant data from fish advisories.

Appendix C

Mercury Chemistry

Mercury is a Group IIB (Periodic Table) element, as are zinc and cadmium. Elemental metallic mercury exists as a high luster silver-colored liquid at room temperature. Selected physical properties are listed in Table C1. Among the varied industrial and consumer uses of mercury are electrical apparatus, such as fluorescent light tubes, and control instruments - including thermometers and barometers. It is also used in the manufacture of pharmaceuticals, antifouling paints, mercury fulminate, electrolytic cells and dental amalgams. Mercury is a constituent of a number of antiseptics such as *mercurochrome, merthiolate and mercressin*. Mercury and all its compounds are toxic. Mercury fulminate, $Hg(CNO)_2$, is used as a detonator for initiating the explosion of smokeless powder and various high explosives (TNT, dynamite). Mercury fulminate is very unstable and can be exploded by shock; its explosion causes the main explosive to be detonated. Mercury electrolytic cells are used in a manufacturing process for chlorine/ alkali production. Liquid mercury dissolves many metals, especially the softer ones such as copper, silver, gold and the alkali elements. The resulting alloys, which may be solids or liquids, are called amalgams. Dental amalgam is an alloy of mercury and silver.

Table C1: Physical Properties of Metallic Mercury

Atomic Number	80
Atomic Weight	200.59
Density	13.5 g/cm^3 @ 25^{0}C
Melting Point	-39^{0}C
Boiling Point	357^{0}C
Water Solubility (molarity)	3.0 x 10^{-7} (mol/L) @25^{0}C
Water Solubility (mass basis)	60 µg/L @ 25^{0}C

Source: Dean, 1992.

Mercury exists in three oxidation states: the metallic, uncharged state (Hg^0); the mercurous state (Hg^{+1}); and the mercuric state (Hg^{+2}). These states are separated by only a small oxidation potential, and the metal readily participates in redox chemical reactions. In particular, Hg^{+1} salts disproportionate under many conditions to yield the Hg^{+2} salt and metallic mercury. Reduction of both the mercurous and the mercuric salts normally yields the metal state (PPRP).

Mercury in natural waters may assume any of the three oxidation states. The predominate state is determined by the hydrogen ion concentration (described as pH) and the oxidation potential (Eh) of the water. Since chloride and sulfide complex Hg^{+1} and Hg^{+2} ions, concentrations of these compounds also affect the relative species distribution (Gilmour, 1971, Gilmour and Henry 1991; Shimomora 1989). Ammonium, carbonate, bicarbonate and phosphate concentrations do not affect speciation (PPRP).

In natural systems, pH is generally in the range of 5 to 8 and the Eh is typically less than 0.5 Volts. For these systems, HgS and metallic mercury are the most likely solids to be found in equilibrium with saturated solutions of mercury salts at moderate Cl^{-1} and S^{-2} concentrations. The predominate species in the corresponding solutions will be $Hg(OH)_2$ and $HgCl_2$ in well oxygenated waters and Hg metal in poorly oxygenated waters (Gavis and Ferguson 1972) In reducing sediments, HgS will predominate the solid phase (PPRP).

Methylated forms of mercury, CH_3HgCl and $(CH_3)_2Hg$, are formed in both aerobic and anaerobic sediments through the action of bacteria. Methylated mercury is thought to be thermodynamically unstable in water; quantities of organic mercury found in surface waters are probably preserved through reaction barriers that prevent degradation. Methylation does not occur in the presence of moderate to high sulfide concentrations which immobilize the Hg^{+2} ion (PPRP).

In fish tissue, mercury is not usually found in concentrations high enough to cause fish to exhibit signs of toxicity, but the mercury in sport fish (trophic level 4) can present a potential health risk to humans. The health risk to humans represented by the mercury content in consumed fish tissue is due the chemical, methylmercury. Typically, almost all of the mercury found in fish tissue (90 to 95%) is in the methylmercury form. Mercury chemistry in the environment is complex and not totally understood. Mercury has the properties of a metal, specifically, persistence in the environment because it is not chemically broken down beyond the elemental mercury form (Hg^0) or its ionic forms (Hg^+ and Hg^{+2}). It also has properties similar to a hydrophobic organic chemical due to its ability to be methlyated through a bacterial process. Methylation of mercury can occur in water, sediment and soil solution under anerobic conditions and to a lesser extent under aerobic conditions. In water, methylation occurs mainly at the water-sediment interface and at the oxic-anoxic boundary within the water column. Methylmercury is readily taken up by organisms and will bioaccumulate as it has a strong affinity for fish muscle tissue. It is effectively transferred through the food web, with tissue concentrations magnifying at each trophic level. This process can result in high levels of methylmercury in organisms high on the food chain, despite nearly immeasurable quantities of mercury/methylmercury concentrations in the water column.

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Appendix D

Details of Mercury Source Assessment

Appendix D presents background information regarding potential sources of mercury.

Table D1: Industrial and Consumer Uses of Mercury

U. S. Mercury consumption (10^3 kg) by end-use (based on Neme 1991)				
Use	1980	1985	1987	1989
Chlorine and Caustic Soda	326	234	310	380
Paint	298	168	198	191
Other Chemical Manufacturing Uses	104	74	78	58
Wiring and Switches	106	96	130	140
Batteries	958	950	532	250
Lighting and Other Electrical Uses	40	40	46	30
Dental Equipment/Instruments	174	128	118	126
Miscellaneous	28	20	34	36
Total	2,034	1,710	1,446	1,211
Sources: U.S. Department of the Interior (1983,1990,1991)				

In Maryland, the major sources of mercury air emissions are as follows: 43% attributed to power plants, 31% municipal waste combustors, 19% medical waste incinerators, 6% Portland Cement plants, and 1% other (e.g., landfills, oil-fired power plants, other industries).[17]

US industrial demand for mercury dropped 75% from 1988 to 1997. This drop can be attributed to actions including:

- Federal bans on mercury additives in paint and pesticides;
- Industry efforts to reduce mercury in batteries;
- Increasing state regulation of mercury emissions and mercury in products;
- State-mandated recycling programs; and
- Voluntary actions by industry.[18]

[17]www.mde.state.md.us/programs/landprograms/hazardous_waste/mercury/mercuryinfo.asp

[18]Source: www.epa.gov/mercury/information.htm

Table D2: Incineration Facilities

Major Municipal Solid Waste Incineration Facilities in Maryland			
Facility	Location	Total Waste Burned (kg/year)	Air Pollution Control Equipment
Waste Energy Partners	Edgewood	215×10^{6}	ESP
Pulaski Highway	Baltimore	491×10^{6}	ESP
Baltimore Refuse Energy System Co. (BRESCO)	Baltimore	$1,281 \times 10^{6}$	ESP

Electrostatic precipitators (ESP), which are widely used to control fine particulate matter, are ineffective at capturing gaseous emissions, including mercury vapor. The most efficient mercury controls include multi-stage wet scrubbers, high efficiency ESPs in series with wet scrubbers, activated carbon filters and removal of the waste stream prior to incineration.

Table D3: Maryland Estimated Mercury Emissions from Coal-burning Power Plants

Plant	Parent Company	City	Estimated* Total Mercury Released 1998 (pounds)	Estimated** Mercury Air Pollution 1998 (pounds)
Brandon Shores	Baltimore Gas & Electric Co.	Baltimore, MD	604	489
Morgantown	Potomac Electric Power Co.	Newberg, MD	645	404
Chalk Point	Potomac Electric Power Co.	Aquasco, MD	549	302
Dickerson	Potomac Electric Power Co.	Dickerson, MD	483	290
H. A. Wagner	Baltimore Gas & Electric Co.	Baltimore, MD	221	149
C. P. Crane	Baltimore Gas & Electric Co.	Baltimore, MD	225	117
R. Paul Smith	Allegheny Power System, Inc.	Williamsport, MD	45	28
State Total			2,774	1,781

*Estimated mercury in coal is calculated using plant specific coal contamination and coal consumption data. Release includes disposal in ponds and landfills as well as reuse applications such as fertilizer.

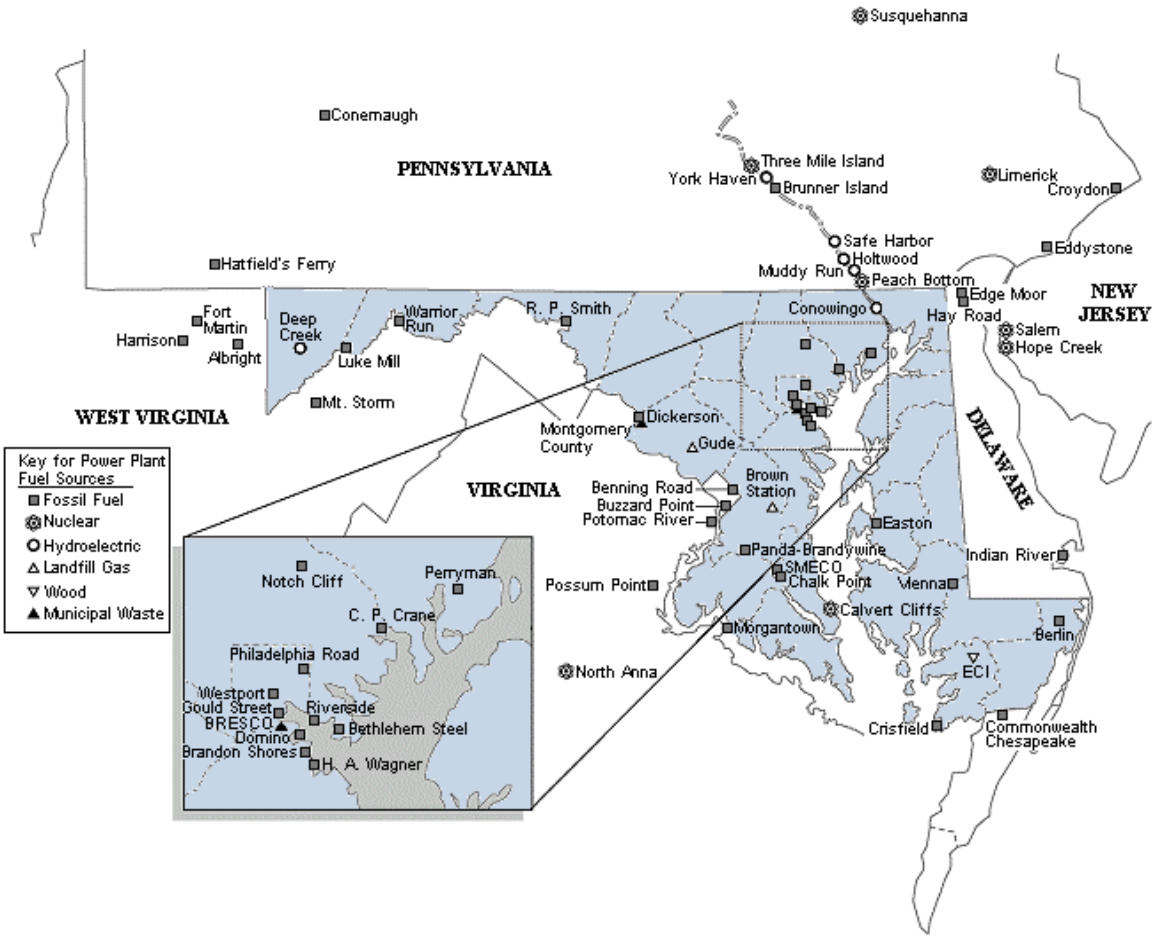


Figure D1: Power Plant Locations In and Around Maryland

** Total stack emissions are calculated by applying mercury released to plant specific modification factors.

Sources:
Environmental Working Group. Compiled from U. S. Department of Energy and U. S. Environmental Protection Agency databases. Plant ownership is attributed to the parent company of the plant as of January 1, 1999.

Source: Maryland Power Plant Research Program - Fact Book

Appendix E

Risk Assessment

Fish consumption advisory thresholds were determined by utilizing human health risk assessment procedures presented in EPA (1997) and modifications as in MDE (in prep, 2002). These advisories recommend that a certain number of meals per month of a particular fish species not be exceeded in order to avoid long-term health effects from exposure to methymercury.

Variables considered in the advisory risk assessment included: **meal frequency** (0, 1, 2, 4, 8, or unlimited meals per month), **meal size** (8 ounces for people 18-75 (GP) and women 18-45 (WOM) years of age, 3 ounces for children (CHD) 0-6 years of age), and **population weights** of 70 (GP), 64 (WOM), and 14.5 (CHD) kilograms. A **methylmercury reference dose** (RfD, 0.1ug/kg-day), based on neurological and developmental studies of infants chronically exposed to methylmercury through fish consumption, was also used in the risk analysis. These factors can be seen in Table E1

Table E1: Human Health Risk Assessment Parameters for MDE's Fish Consumption Advisories

RfD (ug/kg-day)	Body Weight (kg)	Meal Size (ounces/meal)	Fish Consumption Rate (kg/day)	Recommended Meal Frequency (meals/month)	Mercury Concentration in Fish Tissue (ppm)		
Men and Women 18 - 75 Years Old							
0.1	70	8	3.7	No Consumption		>	0.939
0.1	70	8	7.5	1	0.470	-	0.939
0.1	70	8	14.9	2	0.236	-	0.469
0.1	70	8	29.8	4	0.118	-	0.235
Women 18 - 45 Years Old							
0.1	64	8	3.7	No Consumption		>	0.858
0.1	64	8	7.5	1	0.430	-	0.858
0.1	64	8	14.9	2	0.216	-	0.429
0.1	64	8	29.8	4	0.108	-	0.215
Children 0 - 6 Years Old							
0.1	14.5	3	1.4	No Consumption		>	0.519
0.1	14.5	3	2.8	1	0.260	-	0.519
0.1	14.5	3	5.6	2	0.131	-	0.259
0.1	14.5	3	11.2	4	0.066	-	0.130

EPA. 2000. Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories; Third Edition. Office of Science and Technology, Office of Water, U.S. Environmental Protection Agency, Washington, D.C.

Appendix F

UMCES Procedures

Sample Collection:

Clean double-bagged 2L Teflon bottles, partially filled with dilute trace metal grade HCl, were used for water collection. Prior to sampling, each bottle was emptied of the HCl downstream from the sampling location. Next, the bottle was rinsed three times with reservoir water and filled with water collected approximately 6 to 12 inches below the surface. After being filled with sample-water, the bottle was immediately recapped, double-bagged and stored in a cooler for transport back to the laboratory.

Sample filtration and storage:

Approximately 0.5 L of sample from each bottle was filtered through an acid cleaned AquaPrep 600 in line filter (0.45 um) into an acid washed and sample rinsed 500 ml Teflon bottle for dissolved Hg and MeHg. All equipment used for filtering was acid washed between samples and rinsed with Q-water. Both unfiltered and filtered water samples were spiked with Optima HCl acid (to 0.5%) and stored in a refrigerator until analysis for HgT and MeHg was performed.

Total Mercury
Based on U.S. EPA, *Method 1631, mercury in Water by Oxidation, Purge and Trap, and Cold Vapor Atomic Fluorescence Spectrometry*, October 2001.

Methylmercury
Bloom, NS (1992) Determination of picogram levels of methylmercury by aqueous phase ethylation, followed by cryogenic gas chromatography with cold vapor atomic fluorescence detection. Canadian Journal of Fisheries and Aquatic Sciences, vol 461131-1140; Bloom, NS.

MeHg analysis
Water samples were distilled with additions of a 50% sulfuric acid solution and a 20% potassium chloride solution (Horvat et al., 1993). The MeHg in the distillate was derivited with sodium tetraethylborate to convert it to volatile methyl-ethyl-mercury (Bloom, 1989). The volatile adduct was then purged from solution and collected onto a graphitic carbon trap. The MeHg was then thermally desorbed from the trap and analyzed by isothermal gas chromatography separation with CVAFS.

Total Hg analysis
BrCl was added to each sample at least 2 hours prior to analysis. Just prior to analysis, hydroxylamine hydrochloride was added to destroy any excess bromine in the sample. The samples were trapped by gold amalgamation after reduction with SnCl . The Hg

was then thermally desorbed from the trap and analyzed by CVAFS. (Mason et al., 1997; 1983; Bloom, 1989).

Chemical form of mercury in edible fish and marine invertebrates
Canadian Journal of Fisheries and Aquatic Sciences, vol. 49, 1010 – 1017.

Appendix G

Individual Sample Data and Analysis

This appendix presents all of the data for fish tissue samples and water column samples. The data reduction steps are also described.

Table G1: Individual fish sample data for mercury residue in fish tissue from Loch Raven Reservoir

Sample ID No.	Trophic Level	Species	Collection date	Methylmercury (µg/kg) wet weight	Length (mm)	Weight (gm)
LOR061201LMB1	4	Largemouth Bass	6/20/2001	461.5	378	647.0
LOR061201LMB2	4	Largemouth Bass	6/20/2001	162.3	369	758.0
LOR062001LMB3	4	Largemouth Bass	6/20/2001	462.0	386	789.2
LOR062001LMB4	4	Largemouth Bass	6/20/2001	497.6	420	911.0
LOR062001LMB5	4	Largemouth Bass	6/20/2001	145.8	347	559.1
LOR062001LMB6	4	Largemouth Bass	6/20/2001	241.1	305	382.2
LOR062001LMB7	4	Largemouth Bass	6/20/2001	258.4	307	375.0
LOR062001LMB8	4	Largemouth Bass	6/20/2001	164.5	320	463.3
LOR062001LMB9	4	Largemouth Bass	6/20/2001	172.1	312	399.9
LOR062002LMB10	4	Largemouth Bass	6/20/2001	210.2	308	387.0
LOR050602LMB1	4	Largemouth Bass	5/6/2002	290.4	390	703.8
LOR050602LMB2	4	Largemouth Bass	5/6/2002	61.7	396	691.4
LOR050602LMB3	4	Largemouth Bass	5/6/2002	595.2	420	1,004.9
LOR050602LMB4	4	Largemouth Bass	5/6/2002	430.6	431	1,040.0
LOR050602LMB5	4	Largemouth Bass	5/6/2002	267.7	455	1,198.3
LOR050602LMB6	4	Largemouth Bass	5/6/2002	824.4	455	1,185.3

An analysis of the length and weight of the fish used in the BAF calculation indicates that the fish were of legal (keepable) size and that the average age was approximately five Years (MDDNR, 2000).

It is recognized that there are not many samples of water column analyses, and that in some cases, the results from the same sample show a larger concentration for a dissolved concentration than a total concentration. Intuitively this does not seem reasonable. The analytical method used for these analyses (*U. S. EPA Method 1631*) has a minimum detection level of 0.5 ng/L. One nanogram per liter represents a detection level of one part per trillion. As all analytical methods have, *Method 1631* has an inherent +/- variability. All the data was subject to laboratory quality assurance/quality control procedures, (such as blanks, spiked samples, etc) prior to being released to MDE. However due to the sensitive nature of this test, a data reduction process was developed and employed.

Water Column Data Reduction Process

The TMDL analysis requires that we aggregate a number of samples into a single value that represents an estimate of the central tendency of the data. This data reduction process also must account for any data that we suspect is not valid.

Performing a laboratory analysis for trace elements is a very sensitive undertaking. The potential error in the measurements for mercury in the water column is about 15 % in either direction (over or under estimation). This implies that two samples that are within 30% of each other cannot be considered different.

The measurement of whole concentrations (dissolved plus particulate) is less subject to error than measurements of dissolved concentrations. This is because measuring whole concentrations does not require a filtration step, which can introduce error. In cases where the dissolved values are significantly greater than the whole sample (20% or more), it has been advised that the dissolved sample not be used due to the potential contamination during the filtration process (Mason, 2002, personal communications).

The data reduction process described below addresses pairs of water column samples of total mercury representing whole samples and dissolved samples. It is outlined in the form of decision rules to address all of the different cases that can be confronted.

For each pair of results from a given sample, whole and dissolved:

i. If the whole sample is more than 20% greater than the dissolved sample, keep both numbers as good, and interpret the difference as being the particulate fraction.

ii. If the whole sample and dissolved are within 20% of each other, compute the arithmetic mean of the two numbers. Use this average value to represent both whole and dissolved values in future calculations.

iii. If the dissolved number is more than 20% greater than the whole, discard the dissolved as being contaminated. Interpret the whole value as dissolved, and use this value to represent both whole and dissolved values in future calculations.

Table G2: Water Column Total Mercury Concentration Data from Loch Raven Reservoir

Sample Date	Sample Site	Total Mercury Concentration (Whole) ng/L	Total Mercury Concentration (Dissolved) ng/L	% Difference (whole-dissolved) / dissolved
4/30/2001	Downstream of Inflow	7.76	3.03	156
4/30/2001	Mid Reservoir	4.12	5.07	19
4/30/2001	Upstream of Outfall	3.39	8.81	62
	Geometric Mean Value	4.77	3.73	

Table G3 presents the reduced water column data for whole total mercury and dissolved total mercury. We check the percentage difference of each pair of samples presented in Table G2. For the Downstream sample the percentage difference is greater than 20 % (whole >dissolved) and thus the sample follows case i. For the Mid Reservoir sample the percentage difference is less than 20 % and thus the sample follows case iii. For the Upstream sample the percentage difference is greater than 20 % (whole < dissolved), thus the sample follows case ii. The results of the data reduction process are presented in Table G3. The value of 4.95 ng/L represents the expected whole water column concentration for total mercury. The value of 3.61 ng/L represents the expected water column concentration of dissolved mercury. The difference represents the expected particulate fraction.

Table G3: Data Reduction for Total Mercury Water Column Concentrations for Loch Raven Reservoir

Sample site	Total Mercury Concentration (Whole) ng/L	Total Mercury Concentration (Dissolved) ng/L
Downstream of inflow	7.76	3.02
Mid Reservoir	4.60	4.60
Upstream of Outfall	3.39	3.39
Geometric Mean Values	4.95	3.61

Table G4: Water Column Methylmercury Concentration Data from Loch Raven Reservoir

Sample Date	Sample Site	Methylmercury Concentration (Whole) ng/L	Methylmercury Concentration (Dissolved) ng/L	% Difference (whole-dissolved) / dissolved
4/30/2001	Downstream of Inflow	0.286	0.214	34
4/30/2001	Mid Reservoir	0.090	0.085	6
4/30/2001	Upstream of Outfall	0.209	0.182	15
	Geometric Mean Value	0.175	0.149	

Table G5 presents the reduced water column data for whole methylmercury and dissolved methylmercury. We check the percentage difference of each pair of samples in Table G3. For the Downstream sample the percentage difference is greater than 20 %, (whole > dissolved) so case i applies. For the Mid Reservoir sample the percentage difference is less than 20% and thus the sample follows case ii. For the upstream sample, the percentage difference is less than 20 %, so case ii applies again. The value of 0.170 ng/L represents the expected whole water column concentration for total mercury. The value of 0.155 ng/L represents the expected water column concentration of dissolved mercury. The difference represents the expected particulate fraction.

Table G5: Data Reduction for Dissolved Methylmercury Water Column Concentrations for Loch Raven Reservoir

Sample site	Methylmercury Concentration (Whole) ng/L	Methylmercury Concentration (Dissolved) ng/L
Downstream of inflow	0.286	0.214
Mid Reservoir	0.088	0.088
Upstream of Outfall	0.196	0.196
Geomean Values	0.170	0.155

Appendix H

TMDL Target Concentration (AAWCC Value Adjustment)

The AAWCC initially calculated in Section 4.3.2 is just the dissolved part of the total mercury in the reservoir. However when we compute a total load to the reservoir we are assuming that that both dissolved and particulate components are included in the load. That is, when we when we compute the TMDL via a mass balance calculation, we need the calculation target to be a whole value (dissolved + particulate). The dissolved component is the AAWCC; the particulate part is determined by the ratio of the dissolved and particulate that was observed for the existing data. Implied in this is the assumption that when the load is reduced, the ratio of dissolved to particulate total mercury remains constant. Therefore the formula for calculating the TMDL target concentration is expressed as:

$$\frac{\text{Observed whole total Hg value}}{\text{Observed dissolved total Hg value}} = \frac{X}{\text{AAWCC}}$$

Solving for X yields the TMDL target concentration:

$$\frac{4.95}{3.61} = \frac{X}{2.27}$$

$$X = 3.11 \text{ ng/L total mercury}$$

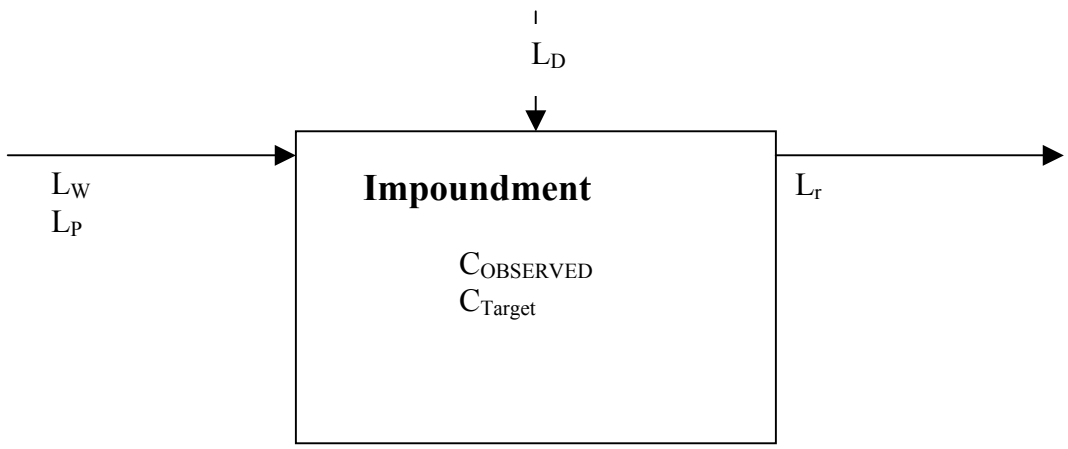
As explained, X – AAWCC equals the particulate fraction.

Appendix I

Steady State Mass Balance Calculations

This Appendix describes the mass balance calculations used to estimate the mercury loads into and out of the impoundment and is divided into four sections. The first section describes the mass balance equations. The second section describes parameters used, lists general definition of terms and identifies the location in the report to find data. The third and fourth sections show in detail the calculations for current loads and the total maximum daily loads, respectively.

Mass Balance Equations:



The assumptions for the Mercury TMDL calculation is that the system is in steady state and therefore the outflow load can be calculated from the impoundment discharge and a specified water column concentration. To calculate the current load, the observed water column concentration is used and to calculate the TMDL, the target water column concentration is used (see Appendix H for details on the target water column concentration). Therefore the following steady state mass balance equation can be used to determine current loads and future allocations.

$$\Sigma \text{ Load In} = \Sigma \text{ Load out}$$

The above equation can be further expanded to

$$L_P + L_D + L_W = L_r$$

It is important to note that if no point sources are present into the impoundment then L_P equals zero.

Definitions:

Point Source Information:

Parameter	Description	Source
Q_P	Point source flow into the impoundment	Table 2
C_P	Mercury concentration into the impoundment, attributed to point sources	Section 2.1
L_P	Mercury load into the impoundment, attributed to point source loads	Calculated
Q_{fp}	Future permitted maximum point source flow into the impoundment	Table 2
C_{fp}	Future permitted point source Mercury concentration into the impoundment (Same as C_P)**	Section 2.1
L_{fp}	Future mercury load into the impoundment, du to anticipated increased point source flows	Calculated
% Time Active	Percent of time point source is active during on year period.	Section 2.1

Reservoir Information:

Parameter	Description	Source
Qr	Average annual flow out of reservoir	Table 1
Cr	Observed reservoir water column total mercury concentration after data reduction	Appendix G
Lr	Current mercury load from reservoir	Calculated

Atmospheric Deposition:

Parameter	Description	Source
RSA	Reservoir surface area	Table 1
TDM	Total deposition of mercury	Appendix A
Ld	Mercury load due to direct atmospheric deposition to the impoundment	Calculated
Lda	Allowable mercury load due to direct atmospheric deposition to the impoundment	Calculated

* Point source contributions of mercury are currently unknown. All estimates are intentionally high to ensure that the future allocation developed in this TMDL is sufficient to address a future point source allocation if deemed appropriate.

** It is assumed that the concentration stays constant, although the point source flows may increase over time.

Definitions (Continued):

Watershed:

Parameter	Description	Source
Lw	Existing mercury load from the watershed to the impoundment	Calculated
Lwa	Allowable mercury load from the watershed to the impoundment	Calculated

TMDL Calculation:

Parameter	Description	Source
	Corrected Water Column Concentration Target	Appendix H
Fr	TMDL coefficient is the factor by which the atmospheric deposition and watershed loads mu be multiplied by to determine the allowable loa	Calculated
1-Fr	The percent reduction required from the atmospheric deposition and watershed loads.	Calculated
FA	The future allocation, which may be used to address point sources if warranted by future information	Calculated
LA	The load allocation is the sum of the atmospher deposition load and the watershed load after the TMDL reduction factor (Fr) is applied LA=Fr*(Ld+Lw)	Calculated

Location: Loch Raven

Point Source Contribution

Average Annual

%time active= 100%

Qp= 3.579 MGD *(3.785l/gal)*(1e6gal/1MGal)(%time)= 13,547,947 l/d

Note: Qp accounts for percent of time active

Cp= 17.9467 ng/l Flow-weighted average of Lafarge @ 4.77 ng/l and the remaining sources at 60 ng/l

Lp= 0.243141 g/day =Qp[l/d]*Cp[ng/l]*(1e-9g/ng)

Permit Maximum

%time active= 100%

Qfp= 3.94000 MGD *(3.785l/gal)*(1e6gal/1MGal)(%time)= 14,914,476 l/d

Note: Qp accounts for percent of time active

Cfp= 17.9467 ng/l

Lfp= 0.267666 g/day =Qp[l/d]*Cp[ng/l]*(1e-9g/ng)

Upstream Reservoir Information

Current

Qr= 2.9 m^3/s *(1000l/m^3)*(86400sec/1day)= 250,560,000 l/d

Cr= 3.86 ng/l

Lr= 0.9672 g/d =Qr[l/d]*Cr[ng/l]*(1e-9g/ng)

Future

Qr= 2.9 m^3/s *(1000l/m^3)*(86400sec/1day)= 250,560,000 l/d

Cr= 2.15 ng/l

Lr= 0.5387 g/d =Qr[l/d]*Cr[ng/l]*(1e-9g/ng)

Reservoir Information

Qr= 8.6 m^3/s *(1000l/m^3)*(86400sec/1day)= 743,040,000 l/d

Cr= 4.77 ng/l

Lr= 3.5443 g/d =Qr[l/d]*Cr[ng/l]*(1e-9g/ng)

Atmospheric Deposition

RSA= 9.7125 km^2 =Reservoir Surface Area

TDM= 14.127 ug/m^2/yr =Total Deposition of Mercury

Ld= 0.137208 kg/yr =RSA*TDM*((1000m/1km)^2)*(1g/1e6ug)*(1kg/1000g)

0.3759 g/d =Ld*(1000g/kg)*(1yr/365day)

Watershed

Lw=Lr-Ld-Lp

Lw= 1.9581 g/d

Summary-Current Daily Total Load

Lp=	0.243141	g/d	(6.86%)
Ld=	0.375914	g/d	(10.61%)
Lw=	1.958085	g/d	(55.25%)
Lpb=	0.967162	g/d	(27.29%)
Ld+Lw+Lp=	3.544301	g/d	(100.00%)

TMDL Calculation

Corrected Water Column Conc. Target= 3.11 ng/l

Reservoir Flow (Qr)= 743,040,000 l/d

TMDL=(Qr)[l/d]*(Ct)[ng/l]*[1e-9g/ng]= 2.3109 g/d Annual TMDL=2.3109g*365= 843.46 g/yr

Future Allocation

Future Point Source Contribution = 11.5830% =Lfp/TMDL Lfp= 0.267666 g/d

Total Future Allocation w/ ps~ 14.00% FA= 0.323520 g/d

Note: Total Future Allocation includes max permit point source Future Allocation=TMDL*(%contribution)

TMDL Reduction Factor

APPENDIX I:

Baltimore County Synoptic Survey Results

Synoptic Survey
Area I Small Watershed Action Plan
Conducted in March 2011

Baltimore County
Department of Environmental Protection and Sustainability
Watershed Management and Monitoring Section
November 2011

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Introduction

A synoptic survey for water quality was conducted during March 2011 in the Beaverdam Run, Baisman Run and Oregon Branch watersheds (Area I) as part of the Small Watershed Action Plan (SWAP). Water samples were analyzed from twenty sites throughout the watershed for dissolved nutrients, total suspended sediment, chloride, bacteria, hardness, sulfates and metals.

The synoptic sampling was scheduled for early spring to coincide with the period of maximum nitrogen concentrations in the free flowing fresh water streams. The major proportion of the nitrogen compounds are carried dissolved in the ground water rather than in surface runoff. The higher nitrogen concentrations in the late winter and early spring reflect the higher proportion of nitrogen rich shallow ground water present in the base flow at this time of year. Nitrogen concentrations are reduced in summer as the proportion of shallow ground water is reduced through plant uptake, and replaced by deeper ground water that may have lower nitrate concentrations, or has been denitrified through interaction with anoxic conditions in the soils below the streambed. Point sources can also contribute to in-stream nitrate concentrations.

Ranges used for interpretation of total nitrogen concentrations (Table 1) and yields (Table 2) were derived from Frink (1991) and are used in the Baltimore County National Pollution Discharge Elimination System (NPDES) annual report (2010). The low end values are based on estimated nutrient exports from forested watersheds, and the high end values are based on estimated nutrient exports from intensively agricultural watersheds. As an additional benchmark, the Chesapeake Bay Program uses 1 mg/L total nitrogen as a threshold for indicating anthropogenic impact. Reported ranges for total nitrogen yield are converted from kilograms/hectare to pounds/acre/day.

Table 1. Total Nitrogen Ranges and Rating

Rating	Total Nitrogen (mg/L)
Low	<1.0
Moderately Elevated	1.0- <2.0
Elevated	2.0- <3.0
High	3.0- <4.0
Very High	>4.0

Table 2. Total Nitrogen Yield Ranges and Rating

Rating	Total Nitrogen Yield (lbs/ac/day)
Low	< 0.009
Moderate	0.009 - 0.018
High	0.018 – 0.027
Excessive	> 0.027

Methods

Synoptic water chemistry samples were collected in early spring throughout the watershed on March 14 and 15, 2011. Baseflow sampling is conducted with a minimum of 72 hours after rainfall events. Grab samples of whole water (1000 ml) were collected just below the water surface at mid-stream. The samples were stored on ice and delivered to the Baltimore County Department of Public Works laboratory the same day. Bacteria samples (100 mL) were collected in sterile sample containers containing sodium thiosulfate, stored on ice, and brought to the EPS lab for analysis. The samples were analyzed for E. coli using IDEXX methodology and equipment including Colilert-18 and Quanti-Tray/2000, and read after 18-24 hours of incubation.

Stream discharge measurements were taken at the time of all water chemistry samples. Water temperature and pH were measured in the field with an Oakton pHtestr30 at all sites at the time of water quality collections. Site drainage areas were used to calculate nutrient yields per unit area. The drainage areas were determined from a digitized watershed map using Arcview software.

Where sites are nested in a watershed, the mapped concentration data for the downstream site is shown only for the area between the sites. Yield calculations for a downstream site are based on the entire area upstream of the site, but are mapped showing just the area between sites. The downstream sites therefore illustrate the cumulative impact from all upstream activities. Tables 3 and 4 describe water quality parameters and instrumentation used.

Table 3. Water Quality Parameters

Parameter	Code	Method	Reporting Limit	Holding Time
Total Suspended Solids	TSS	EPA 160.2	1 mg/L	7 days
Total Solids	TS	EPA 160.3	1 mg/L	7 days
Total Kjeldahl Nitrogen	TKN	EPA 351.3	0.2 mg/L	28 days
Nitrate/Nitrite Nitrogen	NO_2-NO_3	EPA 353.2	0.06 mg/L	28 days
Total Phosphorus	TP	EPA 365.3	0.05 mg/L	28 days
Orthophosphorus	OP	EPA 365.3	0.1 mg/L	48 hours
Biological Oxygen Demand	BOD	EPA 405.1	2 mg/L	48 hours
Chemical Oxygen Demand	COD	EPA 410.4	5 mg/L	28 days
Total Copper	Cu	EPA 200.7	0.001 mg/L	6 months
Total Lead	Pb	EPA 239.2	0.001 mg/L	6 months
Total Zinc	Zn	EPA 200.7	0.001 mg/L	6 months
Total Cadmium	Cd	EPA 213.2	0.001 mg/L	6 months

Table 4. Instrumentation

Instrument	Measure	Units	Range	Accuracy
Son Tek Flowtracker Handheld ADV	Water Velocity	Feet per second	0.1 to 15.0	± 0.1
Oakton Waterproof pH Testr30	pH	-log[H^+]	-1.00 to 15.00	± 0.1
Oakton Waterproof pH Testr30	Temperature	°C	0 to 50 °C	±0.5 °C

Results

Sampling site locations are noted in Table 5. Water samples were analyzed for dissolved nutrients, total suspended sediment, chloride, bacteria, hardness, sulfates and metals. All data is presented in Table 6.

Total nitrogen concentrations were found to be low (<1.0 mg/L) in two sites, moderately elevated (1.0-<2.0) at ten sites, and elevated (2.0- <3.0) at eight sites. No sites were found to be high (3.0- <4.0) or very high (>4.0 mg/L) for total nitrogen (Figure 1).

A calculation of total nitrogen yield was completed which computed the pounds of total nitrogen per acre per day (Table 6). This analysis resulted in nine of the sites within or below the moderate range, one site in the high and the remaining ten sites in the excessive category (Figure 2). The excessive scores included all of the furthest downstream sites and a few headwater systems.

For consideration, estimates of annual total nitrogen loads/yields from spring samples will result in inflated load estimates, but the relative contributions of subwatersheds should remain reasonably stable. More accurate estimates need to include sampling during the growing season to account for potential lower concentrations and discharges. Storm flows can also significantly impact loads delivered to a watershed outlet.

Only one site exceeded the Maryland Water Quality Criteria for chronic chloride of 230 mg/L. The chloride for the site was 321.89 mg/L, but did not exceed the acute level of 860 mg/L (Figure 3).

Bacteria results are given in Most Probable Number (MPN), an estimate based on the number of organisms present per sample, and are analyzed based on a limit of 126 MPN for human contact in recreational waters. E. coli counts were found to be very low (<10 MPN) at five sites, fair (>10-75 MPN) at eleven sites, approaching bacteria standard (75- >126 MPN) at three sites, and only one site exceeding the 126 MPN standard (Figure 4).

Total phosphorus was below the detection limit of 0.05 mg/L for all sites. No sites exceeded the water quality criteria limit of 250 mg/L sulfate. No sites exceeded the chronic or acute levels of dissolved copper, 0.013 mg/L and 0.009 mg/L. No sites exceeded the chronic or acute levels of dissolved zinc, 0.12 mg/L for both. Only one site exceeded the expected hardness, and only slightly at a level of 202.13 mg/L. Normal levels in streams are 100-200 mg/L. Water temperatures were all under 23.9 Celsius and pH levels were almost all between 6 and 9. Two sites had a pH of 5.3 and 5.8.

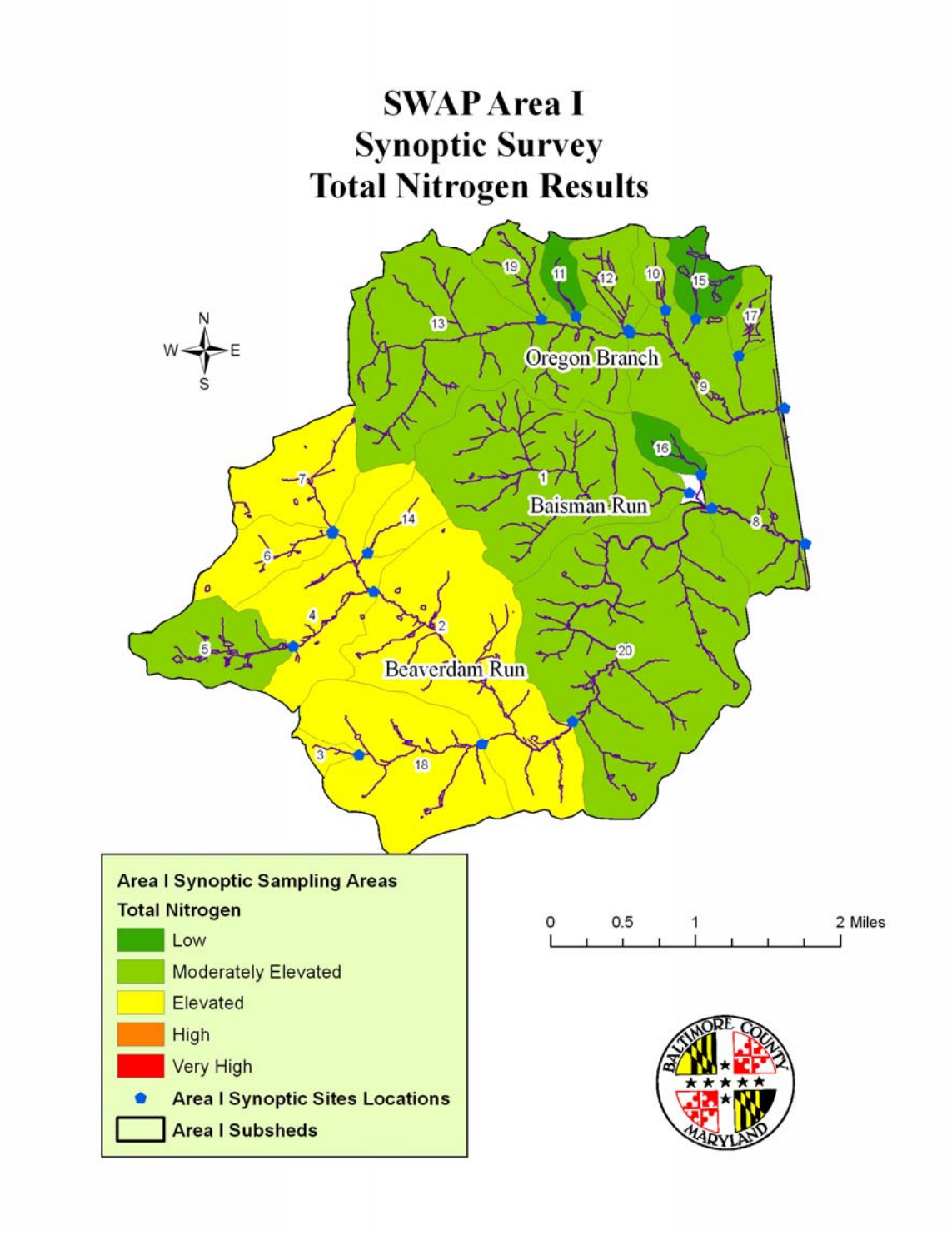

Figure 1. Total Nitrogen Results, SWAP Area I Synoptic Survey

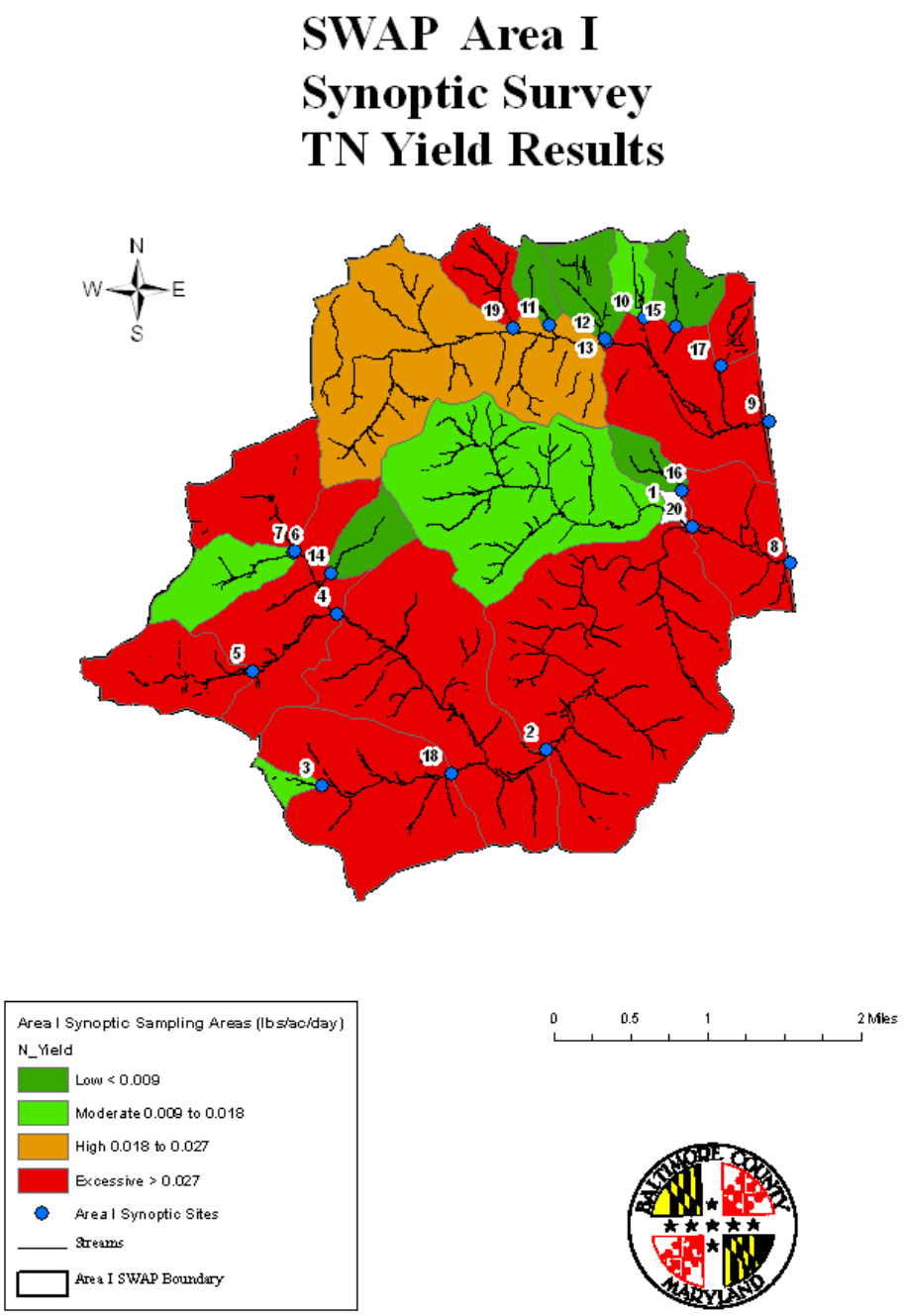

Figure 2. Total Nitrogen Yield, SWAP Area I Synoptic Survey

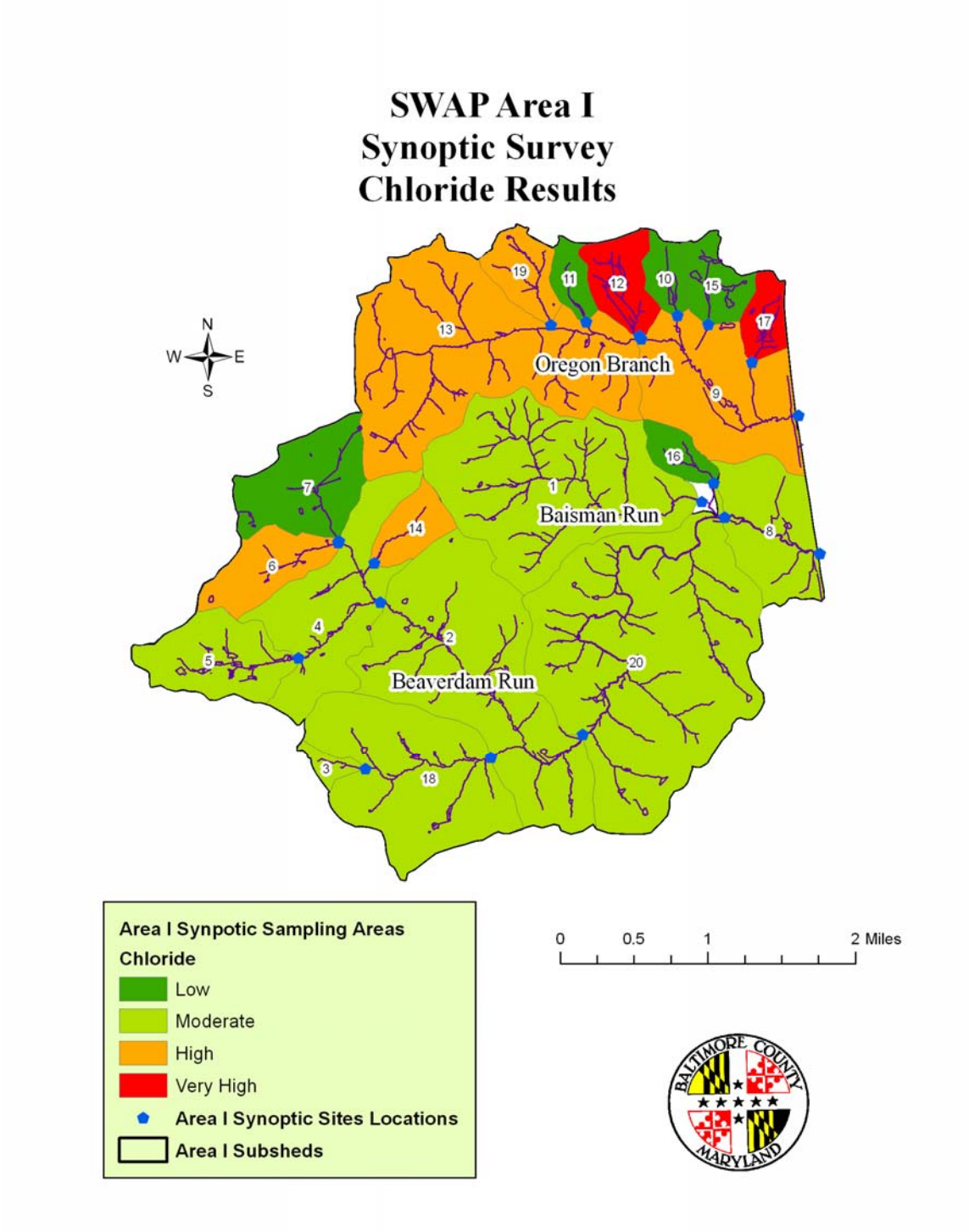

Figure 3. Chloride Results, SWAP Area I Synoptic Survey

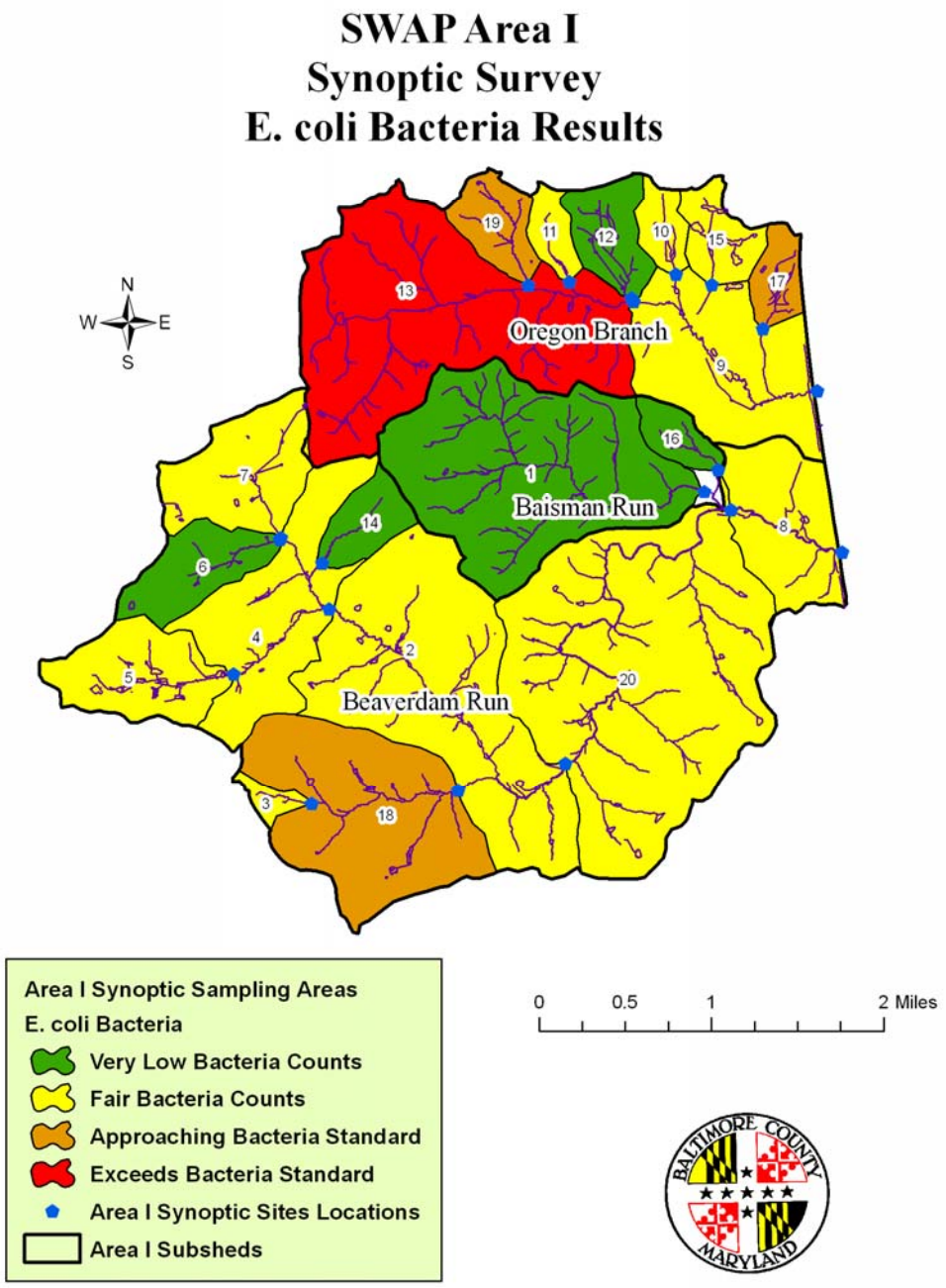

Figure 4. E. coli Bacteria Results, SWAP Area I Synoptic Survey

Table 5. Sampling Site Locations

Sample	LOCATION	Lat	Long
I – 01	Baisman Run – Upstream of Ivy Hill Road	39.47943	-76.67806
I – 02	Beaverdam Run – Downstream Falls Road	39.45671	-76.69322
I – 03	UT to Beaverdam Run – Ridge Valley Road	39.45337	-76.72068
I – 04	Beaverdam Run – Upstream Ridge Road	39.46970	-76.71872
I – 05	UT to Beaverdam Run – Dover Road	39.46427	-76.72906
I – 06	UT to Beaverdam Run – at Knox Road	39.47553	-76.72403
I – 07	Beaverdam Run – Knox Road	39.47568	-76.72392
I – 08	Beaverdam Run – Downstream I - 83	39.47429	-76.66317
I – 09	Oregon Branch – Downstream I - 83	39.48783	-76.66582
I – 10	UT to Oregon Branch – at Shawan Road – East of Cuba Road	39.49765	76.68107
I – 11	UT to Oregon Branch – at Shawan Road – West of Cuba Road	39.49705	-76.69259
I – 12	UT to Oregon Branch – Downstream Kurtz Road	39.49566	-76.68591
I – 13	Oregon Branch – Downstream Kurtz Road	39.49539	-76.68563
I – 14	UT to Beaverdam Run – at Bridle Path Road	39.47354	-76.71945
I – 15	UT to Oregon Branch – at Shawan Road – West of I - 83	39.49676	-76.67722
I – 16	UT to Baisman Run – Upstream of Ivy Hill Road	39.48128	-76.67658
I – 17	UT to Oregon Branch – at Weil Mandel Road	39.49306	-76.67169
I – 18	UT to Beaverdam Run – at Berans Road	39.45444	-76.70483
I – 19	Oregon Branch – Upstream Shawan Road	39.49676	-76.69704
I – 20	Beaverdam Run – Upstream Jerome Jay Way	39.47788	-76.67523

Table 6. Dissolved Nitrogen Concentrations and Yields

Site	DATE	TKN mg/L	NO2+NO3 mg/L	TN mg/L	Discharge CFS	AREA Acres	TN YIELD lbs/a/day
I – 01	03/14/11	0.10	1.07	1.17	42.000	956.3	0.0134
I – 02	03/14/11	0.10	2.18	2.28	7.661	1,007.2	0.095754
I – 03	03/14/11	0.10	2.65	2.75	0.033	35.8	0.013996
I – 04	03/14/11	0.10	2.31	2.41	3.186	492.3	0.086116
I – 05	03/14/11	0.28	1.72	2.00	0.738	286.3	0.028465
I – 06	03/14/11	0.10	2.84	2.94	0.184	195.6	0.01527
I – 07	03/14/11	0.10	2.37	2.47	0.997	319.2	0.042597
I – 08	03/15/11	0.10	1.45	1.55	14.629	331.0	0.378242
I – 09	03/15/11	0.10	1.14	1.24	5.245	528.2	0.067986
I – 10	03/15/11	0.10	1.75	1.85	0.131	77.4	0.017288
I – 11	03/15/11	0.10	0.59	0.69	0.027	71.0	0.001449
I – 12	03/15/11	0.10	0.97	1.07	0.173	155.6	0.006569
I – 13	03/15/11	0.10	1.34	1.44	2.998	1,121.3	0.021258
I – 14	03/14/11	0.10	2.78	2.88	0.055	119.9	0.007294
I – 15	03/15/11	0.10	0.93	1.03	0.144	127.3	0.006433
I – 16	03/14/11	0.10	0.06	0.16	0.025	80.1	0.000276
I – 17	03/15/11	0.10	1.71	1.81	0.253	90.4	0.027969
I – 18	03/14/11	0.10	2.62	2.72	1.732	690.0	0.037698
I – 19	03/15/11	0.10	1.86	1.96	1.550	136.3	0.123068
I – 20	03/14/11	0.10	1.78	1.88	15.627	1,509.1	0.10749

Table 7. Select Water Quality Parameter Results

Site	Date	Temp °C	pH	Chloride (mg/L)	TSS (mg/L)	SO4 (mg/L)	Copper (mg/L)	Zinc (mg/L)	Hardness	*E. coli* MPN
I – 01	03/14/11	8.4	6.9	37.68	<1.0*	4.64	0.0005	0.0005	26.32	8.5
I – 02	03/14/11	8.2	6.7	47.67	<1.0*	3.26	0.0020	0.0005	42.59	45.7
I – 03	03/14/11	7.3	6.5	40.21	<1.0*	1.58	0.0010	0.0005	44.02	30.5
I – 04	03/14/11	7.4	6.2	40.38	<1.0*	1.82	0.0005	0.0005	38.13	72.3
I – 05	03/14/11	8.2	6.0	26.31	<1.0*	2.66	0.0005	0.0005	30.59	45.7
I – 06	03/14/11	8.1	6.4	64.45	<1.0*	1.95	0.0005	0.0005	48.63	4.1
I – 07	03/14/11	7.9	5.6	22.05	<1.0*	1.12	0.0010	0.0010	32.72	72.8
I – 08	03/15/11	5.3	6.7	41.94	<1.0*	4.38	0.0010	0.0005	65.22	37.9
I – 09	03/15/11	5.8	7.54	97.08	<1.0*	10.41	0.0020	0.0040	166.33	69.1
I – 10	03/15/11	8.2	7.46	10.02	<1.0*	10.31	0.0010	0.0010	124.52	14.5
I – 11	03/15/11	8.5	7.65	16.41	<1.0*	14.26	0.0010	0.0005	130.57	13.5
I – 12	03/15/11	9.5	7.65	115.02	<1.0*	9.72	0.0005	0.0005	163.88	7.3
I – 13	03/15/11	6.8	7.72	54.17	<1.0*	8.57	0.0005	0.0005	130.33	222.4
I – 14	03/14/11	7.4	6.20	67.63	<1.0*	1.25	0.0005	0.0005	59.18	7.3
I – 15	03/15/11	7.5	7.64	11.71	<1.0*	9.42	0.0010	0.0005	148.83	22.6
I – 16	03/14/11	8.4	6.20	6.03	<1.0*	3.27	0.0005	0.0005	2.78	4.1
I – 17	03/15/11	7.2	7.81	321.89	<1.0*	20.64	0.0005	0.0010	202.13	88.6
I – 18	03/14/11	6.8	6.60	44.56	<1.0*	3.46	0.0010	0.0005	48.49	88.9
I – 19	03/15/11	8.3	7.68	59.08	<1.0*	7.27	0.0020	0.0010	113.49	108.1
I – 20	03/14/11	7.9	7.90	48.85	<1.0*	5.11	0.0005	0.0005	39.85	16.1

*1.0 mg/L is the detection limit for total suspended solids.

Discussion

Total nitrogen results for Oregon Branch and Baisman Run are moderately elevated, except for two sites in Oregon Branch and one in Baisman Run. In the Beaverdam Run samples, all showed an elevated total nitrogen level, except for one site that was moderately elevated. The concern with nitrogen is not in the freshwater streams, lakes and reservoirs, but downstream in the Chesapeake Bay. The bay is vulnerable to eutrophication from over-enrichment of nitrogen, leading to dead zones. Reduction of total nitrogen is required in order to meet the Chesapeake Bay TMDL.

Total nitrogen yield in Oregon Branch samples range from low (two sites) to excessive in the downstream part of the subwatershed. All samples from Baisman Run are low or moderate for total nitrogen yield, while Beaverdam Run had all excessive results with the exception of two moderate samples and one low. Total nitrogen is the product of concentration and discharge. In the late winter, when the sampling for this study was conducted, total nitrogen yield is at its highest. As the weather warms, total nitrogen decreases due to an increase in denitrification by

bacteria, and an increase in uptake of nitrogen by vegetation. Baseflow also plays a part. The water table is high in the winter, which increases baseflow from groundwater to streams. Increased baseflow means an increase in discharge, and also adds to the total nitrogen yield. As trees leaf out in the spring, the water table is drawn down by their use of water, thus contributing to the seasonal decrease in total nitrogen loads.

Oregon Branch had the only very high chloride results (two sites), though most were high with three sites being low. Baisman Run had only low or moderate chloride results for its sites. In the Beaverdam Run, all sites were moderate for chloride, except for two high and one low. Chloride from road salt is a water quality problem in the watershed. The two samples that tested very high for chloride are in close proximity to roads. One of these locations is along Interstate 83, and the other is along Cuba Road where a small stream is immediately adjacent to the road. Over the past several decades, there has been an increase in the chloride and sodium concentrations in the Loch Raven Reservoir, and other drinking water reservoirs. A high sodium concentration in drinking water (20 mg/l) is a human health risk for sodium-sensitive individuals. A high chloride concentration makes water treatment for the public drinking water supply more difficult, and more costly. It also gives the water a salty taste, if over 250 mg/l. The Maryland Department of Environment (2009) has identified a chloride concentration of 50 mg/l as detrimental to freshwater aquatic communities. Baltimore County has been investigating alternative mechanisms for clearing roadways of snow and ice, but must maintain public safety.

One sample in the Oregon Branch exceeded the human health standard for E. coli bacteria in recreational waters. Other samples from the subwatershed ranged from very low to high. All sites in the Baisman Run subwatershed are very low level for bacteria. All samples in the Beaverdam Run are fair, except for two low sites, and one site that is approaching the standard. A single sample for bacteria at a site does not necessarily indicate a bacteria problem, however should be followed up with additional sampling. If additional sampling does show a problem, then upstream monitoring should be conducted to identify possible sources. Potential sources of E. coli bacteria contamination are livestock, failing septics, and wildlife.

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APPENDIX J:

Biological Assessment of Beaverdam Run Watershed

Biological Assessment of Beaverdam Run Watershed

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December 17, 2010

Introduction

This report is in support of a Small Watershed Action Plan (SWAP), which is a watershed management function of the Baltimore County Department of Environmental Protection and Resource Management (DEPRM). The report describes the benthic macroinvertebrate and fish communities of Beaverdam Run and its tributaries. The benthic data was compiled from an annual sampling program managed by DEPRM and the fish data was collected during August and September 2010, by biologists from DEPRM and the Maryland Department of Natural Resources Fisheries Service (MD DNR). A primary goal of the fish sampling was to assess the status of naturally reproducing trout populations, especially native brook trout. Brook trout are extremely sensitive to environmental disturbance, and their presence indicates good water quality. Fish will be discussed in the first section of the report, and benthic macroinvertebrates will be discussed in the second section.

Section 1 - Fish

Thirteen stations were sampled along the Beaverdam Run mainstem and its tributaries. Maryland Biological Stream Survey (MBSS) protocols were followed. The specific goals of the sampling were (1) to assess the abundance and distribution of naturally reproducing brook and brown trout, (2) to document the abundance and distribution of the general fish community, and use that data to determine the biological health of the watershed, and (3) to assess physical habitat quality at all stations sampled for fish.

Methods

A combination of mapping, examination of existing data, field reconnaissance surveys, and cooperation of private landowners provided thirteen stations for fish sampling. Stations were also selected to represent the major land uses within the watershed (forest, agricultural, residential, and commercial/industrial). Stations are shown in Figure 1, and detailed station locations are provided in Table 1. Brief station descriptions are provided following the methods. Electrofishing was conducted between August 16 and September 23, 2010. A 75-m reach was sampled at each station, using the two-pass removal method with Smith-Root® LR12 backpack electrofishing units. All fish species were identified, counted, and weighed. Trout young-of-year and adults were counted and weighed separately. Non-trout fish species were weighed in aggregate. An MBSS Summer Index Period physical habitat assessment was completed at each station. The MBSS Fish Index of Biotic Integrity (FIBI) and Physical Habitat Index (PHI) were calculated for each station.

<u>Station Descriptions</u>

BDR-1: Station BDR-1 (Beaverdam Run mainstem) is in Cockeysville, MD, upstream of York Road. It is downstream of an area of dense commercial/industrial use in Hunt

Valley, MD.

BDR-2: Station BDR-2 is on the Beaverdam Run mainstem in a well-forested residential area of Hunt Valley, MD. Short ridges with stable, bedrock-controlled stream banks and wide, forested floodplains characterize the reach.

BDR-3: Station BDR-3 (Beaverdam Run mainstem) has land-use similar to BDR-2, but with less topographic relief and slightly lower stream gradients.

BDR-4 and BDR-5: These stations are in the headwaters of the mainstem of Beaverdam Run. Heavily forested riparian zones behind large residential properties characterize the stations. The stream channels are narrow and low gradient with low, stable stream banks.

BDR-6: This is the downstream-most station on the Beaverdam Run mainstem. It is downstream of Beaverdam Road in Cockeysville, MD, in the most heavily commercial/industrial area of the watershed. Rip-rap and gabion have been added to the stream banks to accommodate the businesses surrounding the stream.

BDRT-1 and BDRT-2: These stations are on the lower end of Oregon Branch, in the commercial/industrial area of Hunt Valley, MD. BDRT-1 is downstream of Gilroy Road and BDRT-2 is upstream of Gilroy Road. Oregon Branch is disconnected from its floodplain in both reaches, as the banks are earthen berms created for the surrounding industries.

BDRT-3: This station is on Oregon Branch, in Oregon Ridge Park, which is owned by Baltimore County. It captures forest, light residential, and agricultural land uses. The stream is disconnected from its floodplain, and has high, eroded banks.

BDRT-4: This station is on Baisman Run, a well-forested tributary to Beaverdam Run located almost entirely within the boundaries of Oregon Ridge Park. The reach is one of eight reference stations, which DEPRM biologists monitor annually. The reference stations represent streams in Baltimore County with the highest biological integrity.

BDRT-5: This is an unnamed tributary to Beaverdam Run, located in a forested, light residential area in the middle reach of the watershed. There are short sections of severe erosion in several places along the reach. Upstream of the station the banks are stable and composed of small outcrops of bedrock.

BDRT-6: This station is on Goodwin Run, a restored tributary to Beaverdam Run. The stream channel is sinuous with steep banks that are disconnected from the floodplain.

BDRT-7: This station is on an unnamed tributary to Beaverdam Run in the headwaters of the watershed. It is in an area of light residential development.

Results

Brook trout

Native brook trout were found in Baisman Run and in the uppermost reaches of the mainstem of Beaverdam Run (Table 2). Four adult brook trout (145 mm/31 g, 150 mm/31 g, 165 mm/44 g, and 210 mm/93 g) were captured during qualitative electrofishing in the reach between stations BDR-4 and BDR-5, but only one brook trout was found within the station limits in the mainstem of Beaverdam Run. Three year-classes of brook trout were present in Baisman Run (Figure 2).

Brown trout

Wild brown trout were collected at all stations except the most downstream station on the mainstem of Beaverdam Run (BDR-1). Length-frequency analysis for brown trout suggests three year-classes of fish in both Beaverdam Run and Oregon Branch (and possibly a fourth year-class in Beaverdam Run), and two year-classes in Baisman Run (Figure 2). Brown trout were not equally abundant within the study reach, as shown by the standing crop estimates. The highest biomass of brown trout was found in station BDR-3 (Figure 3a), and in station BDRT-5, the nearby un-named tributary at Berans Road (Figure 3b). Otherwise, brown trout were present in moderate to small numbers.

Non-trout Fish Community

The Beaverdam Run watershed supports a diverse fish community composed of cold-, cool-, and warm-water fish species (Table 2). Fish IBI values are shown in Table 3. Four stations rated Good and six stations rated Fair. Stations BDR-1 and BDRT-3 rated Poor and station BDRT-3 rated Very Poor.

Stream Physical Habitat

Stream habitat was “minimally degraded” at seven of the 13 stations, “partially degraded” at three stations, and “degraded” at three stations, based on the Physical Habitat Index (Table 3). Stream bank condition (based on estimates of erosion extent and severity) and stream substrate quality (estimated as amount and quality of substrate available for benthic macroinvertebrate colonization) were the parameters that were most frequently altered and resulted in ratings less than “minimally degraded.”

Discussion

Although most stations showed high biological quality based on biological and habitat indices, our data show that the core native brook trout population is in the extreme upper reaches of the mainstem of Beaverdam Run and Baisman Run. It is likely that native brook trout were once found throughout the Beaverdam Run watershed. As recently as 1995, small numbers of brook trout were found as far downstream as one-quarter mile upstream of Interstate 83 (Mark Bowermaster, MD DNR, personal communication). That they remain only in the upper end of the Beaverdam Run mainstem and in Baisman Run suggests that human activity has degraded streams in the watershed. Increased water

temperatures, siltation, changes in channel morphology, and competition from non-native, introduced brown trout are likely to have caused the reduction in the range of native brook trout. Although water chemistry was not measured for this study, water temperature is one of the most important determinants of the presence or absence of brook trout (Heft, 2006). The presence of species adapted to cool or warm water, such as creek chub, bluegill and other sunfish, and largemouth bass, suggests that Beaverdam Run and its tributaries have warmed. Siltation and changes in channel morphology reduce the amount of habitat available for spawning and predator avoidance. Brown trout are known to out-compete brook trout for food and cover, because they are typically larger, more aggressive, and more tolerant of environmental conditions. Ironically, these same physical stressors are likely responsible for the depressed brown trout populations found in the industrialized areas near Hunt Valley, MD.

The composition of brown trout populations in Beaverdam Run compare favorably to other naturally reproducing brown trout populations within the Piedmont region of Maryland. Recent standing crop estimates for streams in the Patapsco River and Gunpowder Falls drainages ranged from 3-37 kg/ha (Klotz et al., 2008). The highest standing crop of brown trout was found at BDR-3 and BDRT-5. These mainstem and tributary stations are located near each other in the middle portion of the watershed. Habitat at both stations was minimally degraded. Significant portions of the stream banks of Beaverdam Run in this area are stabilized by bedrock outcrops. Although some severe erosion is present within the tributary station, the area upstream is also stabilized by bedrock. This, combined with the wide, forested riparian zone creates good habitat for brown trout.

This survey shows that a small population of native brook trout remains in Beaverdam Run. Fish community composition and the stream habitat condition show where the watershed has been most affected by human activity.

References

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Heft, A. (ed.). 2006. Maryland Brook Trout Fisheries Management Plan. Maryland Department of Natural Resources, Annapolis, MD 21041.

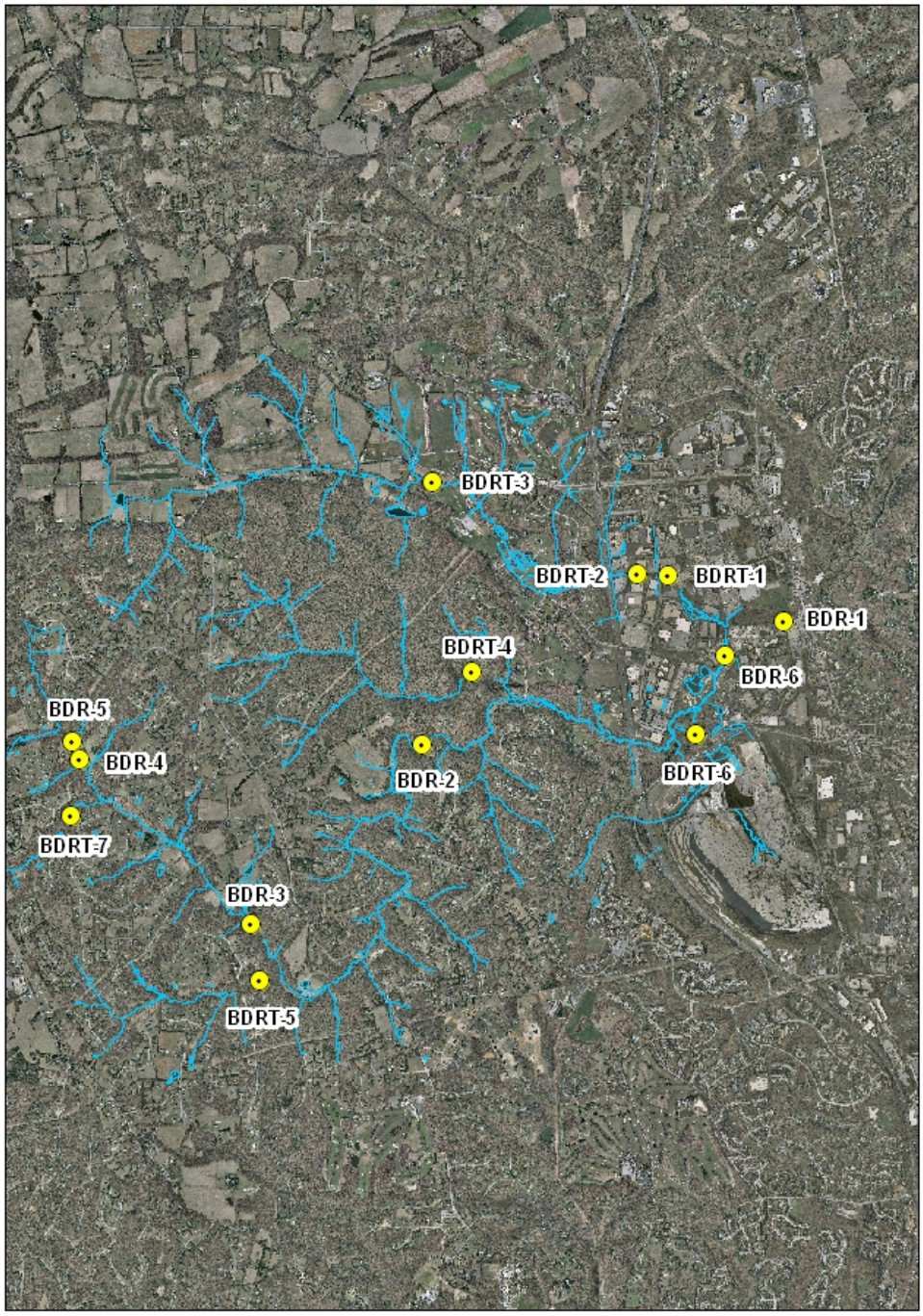
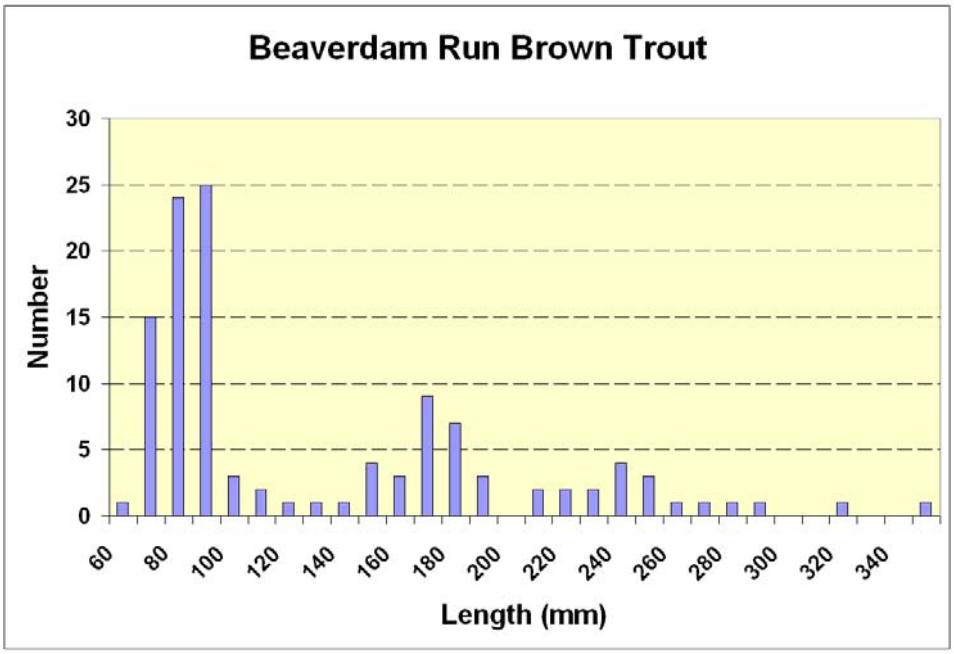
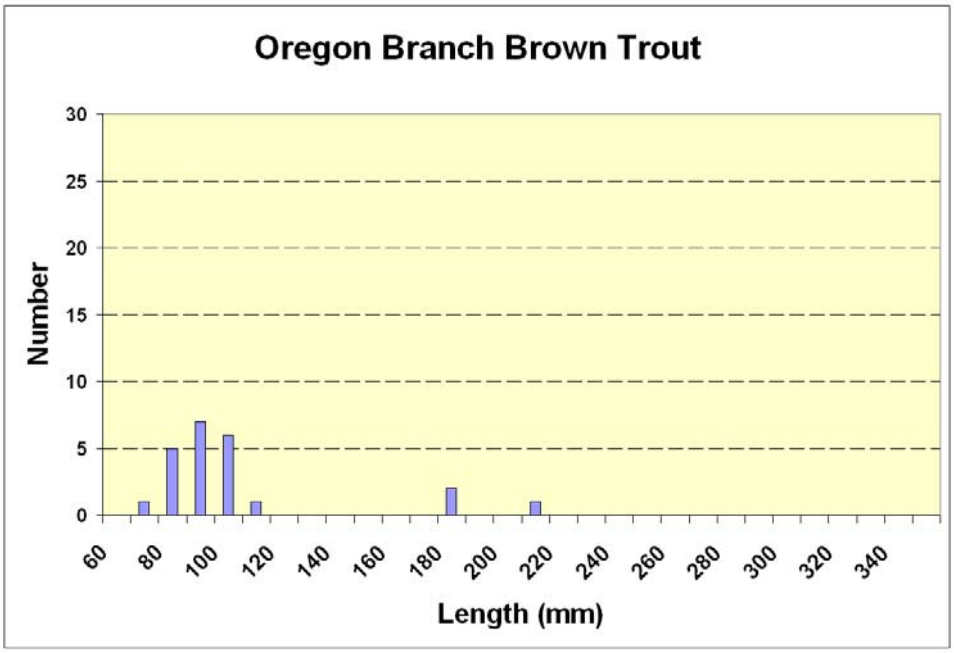


Figure 1. Beaverdam Run fish sampling stations.

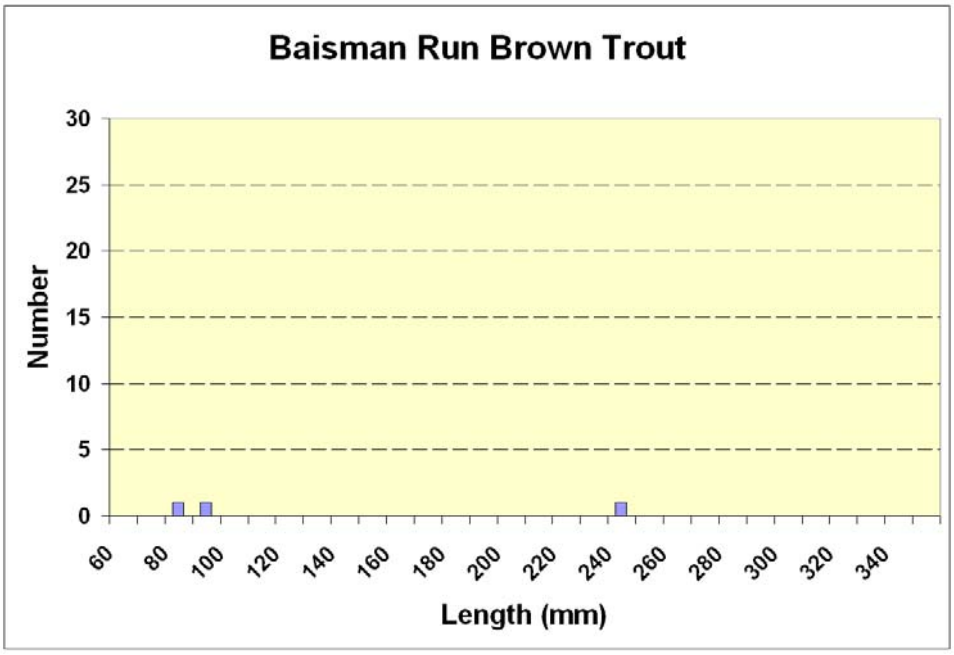


(a)



(b)

Figure 2. Length-frequency distributions for brown trout in (a) Beaverdam Run, (b) Oregon Branch, (c) Baisman Run, and brook trout in (d) Beaverdam Run and Baisman Run.



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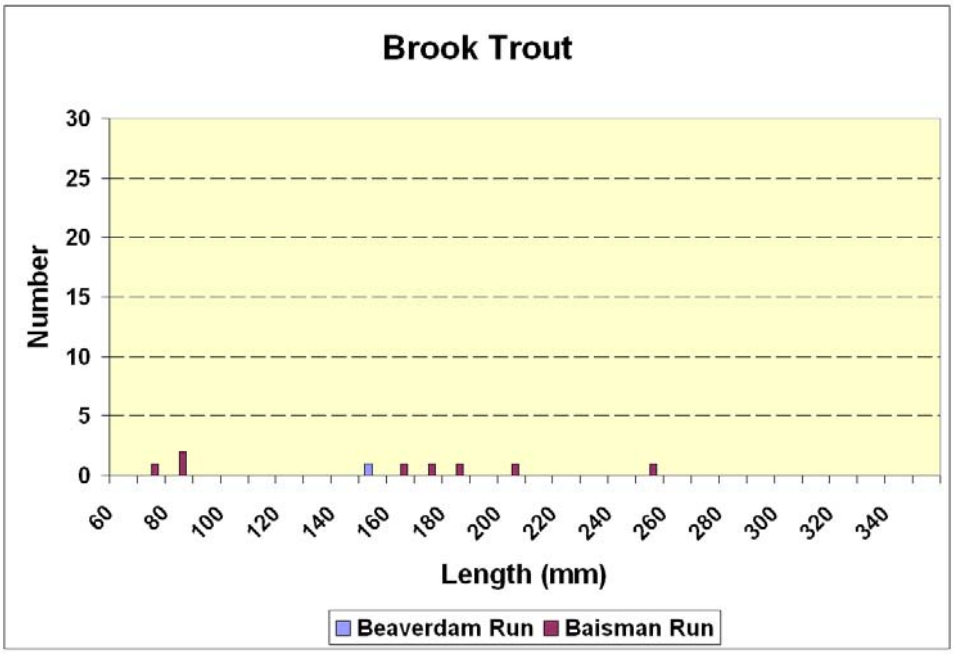
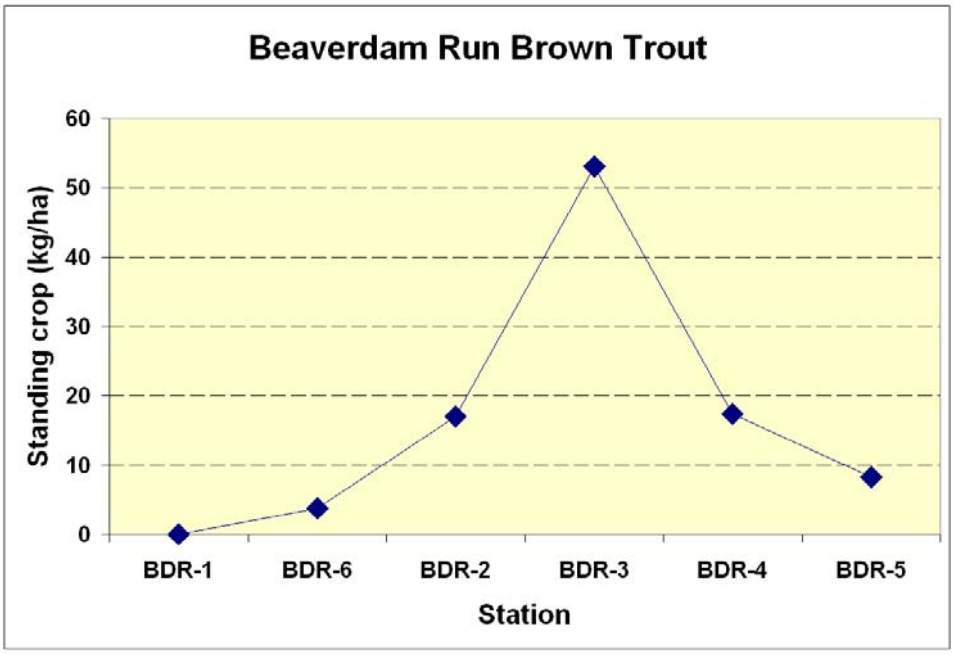
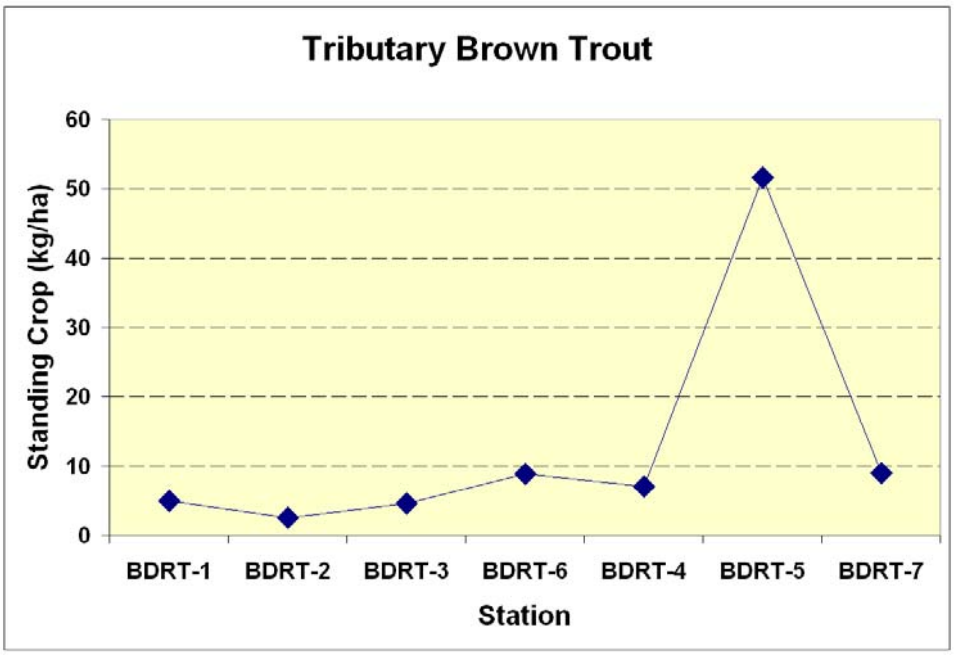


(d)

Figure 2 (cont.).



(a)



(b)

Figure 3. Standing crop estimates for brown trout in (a) mainstem Beaverdam Run stations and (b) tributary stations. Stations are arranged left to right from downstream to upstream.

Table 1. Beaverdam Run fish sampling station locations

Station	Stream	Latitude	Longitude
BDR-1	Beaverdam Run	39° 29' 2.38" N	76° 38' 51.14" W
BDR-2	Beaverdam Run	39° 28' 27.18" N	76° 41' 8.20" W
BDR-3	Beaverdam Run	39° 27' 35.34" N	76° 42' 13.07" W
BDR-4	Beaverdam Run	39° 28' 22.91" N	76° 43' 17.81" W
BDR-5	Beaverdam Run	39° 28' 28.16" N	76° 43' 20.23" W
BDR-6	Beaverdam Run	39° 28' 52.61" N	76° 39' 13.04" W
BDRT-1	Oregon Branch	39° 29' 15.82" N	76° 39' 34.61" W
BDRT-2	Oregon Branch	39° 29' 16.26" N	76° 39' 46.31" W
BDRT-3	Oregon Branch	39° 29' 42.83" N	76° 41' 3.71" W
BDRT-4	Baisman Run	39° 28' 47.81" N	76° 40' 49.29" W
BDRT-5	UNT Beaverdam Run	39° 27' 19.01" N	76° 42' 9.93" W
BDRT-6	Goodwin Run	39° 28' 29.72" N	76° 39' 24.48" W
BDRT-7	UNT Beaverdam Run	39° 28' 6.88" N	76° 43' 20.95" W

Table 2. Fish community composition in the Beaverdam Run watershed.

	Station												
	BDR-1	**BDR-2**	**BDR-3**	**BDR-4**	**BDR-5**	**BDR-6**	**BDRT-1**	**BDRT-2**	**BDRT-3**	**BDRT-4**	**BDRT-5**	**BDRT-6**	**BDRT-7**
Blacknose dace	4	10	41	70	63		11	17	46	54	26	35	22
Bluegill	9	6				5	15		1		5		4
Bluntnose minnow	4												
Brook trout					1					8			
Brown trout		20	34	10	3	1	5	7	11	3	36	2	11
Central stoneroller												1	
Common shiner		16	4								5		2
Creek chub	1	15	44	27	64		27	28	113	44	54	134	81
Cutlips minnow		8	26	2	2		7	22			10		4
Green sunfish	1												
Largemouth bass	2	7	5				6				4		1
Longnose dace	5	28	17	33	17		72	99	57	7	13	22	3
Margined madtom		6	21	1							3		
Northern hogsucker		1	4				1				4		
Pumpkinseed							3				1		
River chub		23	47								7		3
Rosyside dace		43	74	24	44			1	36	47	112	1	54
Spottail shiner												4	
Tesselated darter	5	2	4	3			1	12					5
White sucker		5	30	2	7		24	7	1		19	26	53
Yellow bullhead	3	1					1						
Weight (g)	384	1850	3618	750	1298	85	1896	718	884	1378	3875	2849	2005

Table 3. Fish IBI (FIBI) and Physical Habitat Index (PHI) scores for Beaverdam Run fish stations. FIBI Condition Categories: 4-5=Good, 3-3.99=Fair, 2-2.99-Poor, 1-1.99=Very Poor. PHI Condition Categories: 81-100=Minimally Degraded, 66-80=Partially Degraded, 51-65=Degraded, 0-50=Severely Degraded.

Station	**FIBI**	**Condition**	**PHI**	**Condition**
BDR-1	2.33	Poor	75	Partially Degraded
BDR-2	4.00	Good	85	Minimally Degraded
BDR-3	4.33	Good	83	Minimally Degraded
BDR-4	3.67	Fair	87	Minimally Degraded
BDR-5	3.33	Fair	82	Minimally Degraded
BDR-6	1.33	Very Poor	72	Partially Degraded
BDRT-1	3.67	Fair	65	Degraded
BDRT-2	3.33	Fair	65	Degraded
BDRT-3	2.33	Poor	66	Partially Degraded
BDRT-4	3.00	Fair	85	Minimally Degraded
BDRT-5	4.33	Good	81	Minimally Degraded
BDRT-6	3.00	Fair	61	Degraded
BDRT-7	4.33	Good	81	Minimally Degraded

Section 2 – Benthic Macroinvertebrates

Benthic macroinvertebrates are small, stream-dwelling organisms with no backbone which are visible to the naked eye. They are used as water quality indicators worldwide because of their ability to integrate water quality conditions over long time periods. As partial fulfillment of the requirements of the National Pollutant Discharge and Elimination System (NPDES) permit administered by DEPRM, a probabilistic benthic macroinvertebrate sampling program was initiated in 2003. Benthic macroinvertebrates are collected annually following MBSS methods and Benthic Index of Biotic Integrity (BIBI) scores are reported.

Methods

Potential sampling stations are randomly generated using a geographic information system (GIS). Where necessary, permission to enter private property is obtained. Eighty-seven stations are selected for sampling. Thirteen stations are re-sampled annually to monitor biological condition over time. These stations are referred to as "sentinel sites." A consultant collects the macroinvertebrate and habitat data, performs the macroinvertebrate identification, and provides the raw data to DEPRM. The raw data are converted to metrics, from which the BIBI is calculated. Each metric contributes unique information to the overall index value. A brief definition of each metric follows.

No. Taxa: the total number of different invertebrate taxa collected. Higher numbers indicate better water quality.

No. EPT Taxa: the total number of Ephemeroptera (mayfly), Plecoptera (stonefly), and Trichoptera (caddisfly) taxa collected. These three orders of aquatic invertebrates are considered to be the most sensitive to disturbances in stream environments. Higher numbers indicate better water quality.

No. Ephemeroptera Taxa: the number of Ephemeroptera (mayfly) taxa collected. Higher numbers indicate better water quality.

Percentage Intolerant Urban: the percentage of invertebrates considered intolerant to urbanization. Higher percentages indicate better water quality.

Percentage Chironomidae: the percentage of invertebrates composed of Chironomidae (midges). This family of two-winged flies is tolerant of a wide range of environmental stressors. Lower percentages indicate better water quality.

Percentage Clingers: the percentage of invertebrates adapted for life in flowing water. These organisms require hard, clean substrates. Higher percentages indicate better water quality.

Results and Discussion

Stations in the Beaverdam Run watershed that have been sampled since 2003 were isolated using GIS. Data were available from 2004, 2006, and 2008. Station locations are shown in Figure 4. Five stations are on Oregon Branch, one station is on Baisman Run, and the remaining six stations are on the Beaverdam Run mainstem and its unnamed tributaries.

Benthic metrics and BIBI values show that 75% of the stations had either Good or Fair water quality (BIBI >3.00, Table 4). The most impaired stream reaches were on an unnamed tributary to Goodwin Run (station 0304208) and the lower (station 0308118) and upper (station 0306156) ends of Oregon Branch. Stations with good or fair biological condition were characterized by high numbers of mayfly, stonefly, and caddisfly taxa, high percentages of organisms intolerant of urban pollution, low percentages of pollution-tolerant Chironomidae, and high percentages of clinging invertebrates.

Two sentinel sites are in the Beaverdam Run watershed, on Baisman Run (station 0304197) and the unnamed tributary to Goodwin Run (station 0304208). The benthic community at both stations has been stable over the period of record. As noted in the discussion of the fish community, Baisman Run is a well-forested tributary of Beaverdam Run that is on public land in Oregon Ridge Park. The benthic community of Baisman Run reflects this surrounding environment. High numbers of mayfly, stonefly, and caddisfly taxa are present, high percentages of organisms intolerant of urban conditions, and high percentages of clinger taxa. Clingers are invertebrates that rely on hard, clean stream substrates for attachment sites. Clingers are frequently absent from the benthic community of streams suffering from sedimentation. The unnamed tributary to Goodwin Run has shown consistently poor condition. It supports very low overall numbers of taxa, and has no mayflies, stoneflies, caddisflies, or other intolerant invertebrates. In 2006 and 2008 pollution-tolerant Chironomidae were the dominant group in the macroinvertebrate community.

Overall, the benthic and fish data show agreement in the condition of streams in the Beaverdam Run watershed. Well-forested, lightly developed stream reaches support healthy biological communities. Stream reaches with more intensive land use, particularly the commercial/industrial area near Hunt Valley, and the more heavily agricultural area in the upper end of Oregon Branch, showed impairment in both the benthic and fish communities.

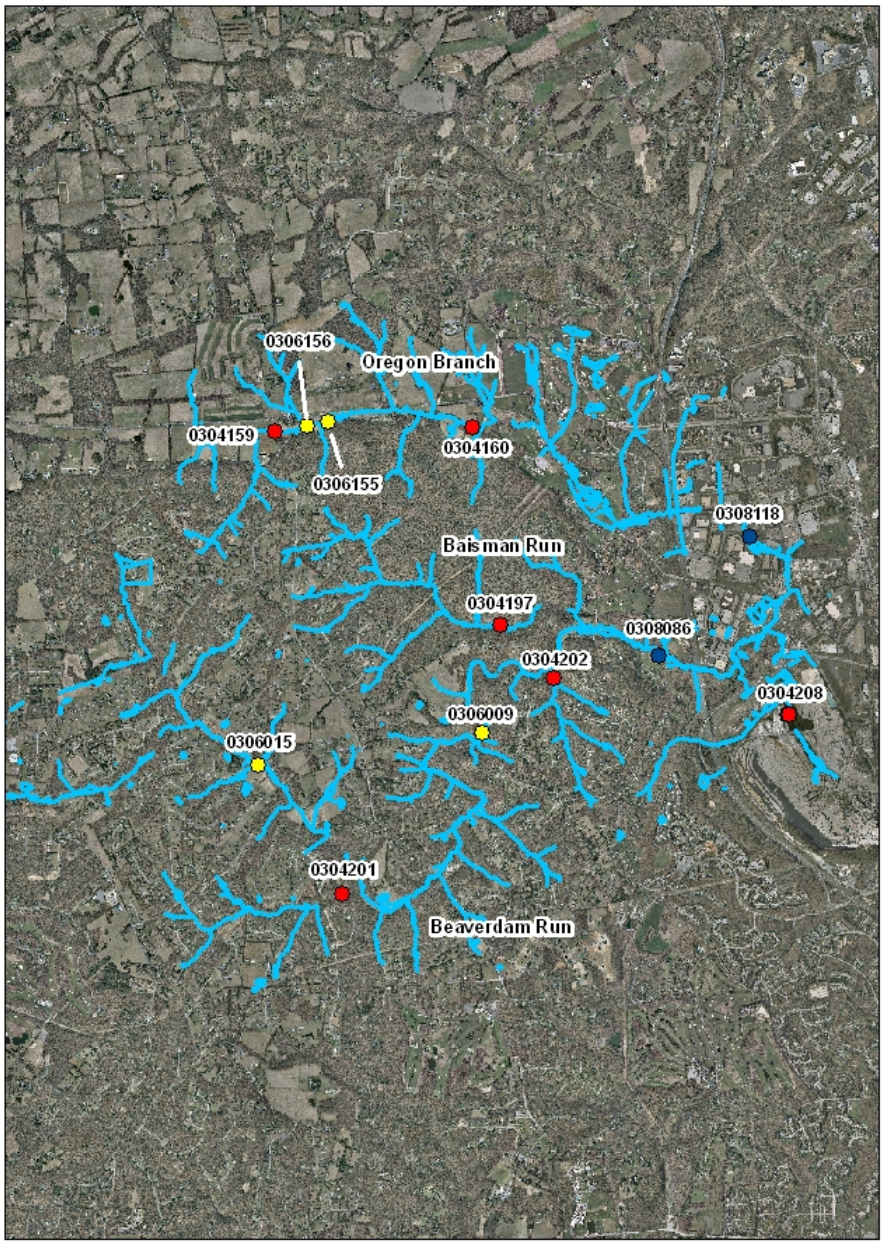


Figure 4. Beaverdam Run benthic sampling locations.

Table 4. Metric values and BIBI scores for Beaverdam Run stations sampled for benthic macroinvertebrates. BIBI Condition Categories: 4-5=Good, 3-3.99=Fair, 2-2.99-Poor, 1-1.99=Very Poor.

Station	Stream	Year	No. Taxa	No. EPT Taxa	No. Ephemeroptera Taxa	% Intolerant Urban	% Chironomidae	% Clingers	BIBI	Condition
0304159	Oregon Branch	2004	33	12	5	46	20	56	4.00	Good
0304160	Oregon Branch	2004	34	10	6	47	16	55	3.67	Fair
0304197	Baisman Run	2004	29	15	7	69	5	68	4.33	Good
0304197	Baisman Run	2006	16	10	6	92	2	91	4.33	Good
0304197	Baisman Run	2008	28	10	5	69	12	72	4.00	Good
0304201	UNT Beaverdam Run	2004	46	12	4	38	24	46	4.00	Good
0304202	UNT Beaverdam Run	2004	38	13	5	47	12	52	4.00	Good
0304208	UNT Goodwin Run	2004	2	0	0	0	5	0	1.33	Very Poor
0304208	UNT Goodwin Run	2006	10	0	0	0	55	5	1.33	Very Poor
0304208	UNT Goodwin Run	2008	10	0	0	0	92	2	1.00	Very Poor
0306009	Beaverdam Run	2006	41	11	7	39	24	60	4.00	Good
0306015	Beaverdam Run	2006	31	7	5	41	32	53	3.67	Fair
0306155	Oregon Branch	2006	20	7	2	66	13	69	3.33	Fair
0306156	Oregon Branch	2006	21	4	2	51	20	57	2.67	Poor
0308086	Beaverdam Run	2008	35	14	6	50	12	67	4.00	Good
0308118	Oregon Branch	2008	21	2	1	19	25	15	2.00	Poor

APPENDIX K:

Stream Corridor Assessment Survey Data

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Oregon Branch Subwatershed SCA Survey Sites:
Channel Alterations

Map	Site	Date Assessed	Photo Site	Type	Bottom Width	Perennial Flow	Sediment Deposition	Vegetation	Road Crossing	Channelized Length Above Road Crossing (ft)	Channelized Length Below Road Crossing (ft)	Length (ft)	Length (mi)	Severity
041B2	OR041B2-CA1	2/9/2011	1571	Channel	24	Y	Y	N	Both	150	0	131	0.02	Moderate

Baisman Run Subwatershed-SCA Survey Sites:
Channel Alterations

Map	Site	Date Assessed	Photo Site	Type	Bottom Width	Perennial Flow	Sediment Deposition	Vegetation	Road Crossing	Channelized Length Above Road Crossing (ft)	Channelized Length Below Road Crossing (ft)	Length (ft)	Length (mi)	Severity
050C1	BS050C1-CA1	12/2/2010	1656	Plastic	30	Yes	No	N	No	0	0	53.04	0.010	Low
050B1	BS050B1-CA1	1/6/2011	1737	Earth	24	Yes	N	N	Both	0	0	207.59	0.039	Minor

Beaverdam Subwatershed SCA Survey Sites:
Channel Alterations

Map	Site	Date Assessed	Photo Site	Type	Bottom Width	Perennial Flow	Sediment Deposition	Vegetation	Road Crossing	Length Above Road Crossing (ft)	Length Below Road Crossing (ft)	Length (ft)	Length (mi)	Severity
051A1	BV051A1-CA1	12/20/2010	17	Other	5	Y	N	Y	No	0	0	655.34	0.12	Low
051A2	BV051A2-CA4	12/22/2010	146	Gabion	5	N	Y	N	No	0	0	28.40	0.01	Low
050C2	BV050C2-CA1	2/9/2011	307	Other	4	N	N	Y	No	0	0	245.82	0.05	Low
050C2	BV050C2-CA2	2/9/2011	304	Other	2	N	N	Y	Both	5	5	280.09	0.05	Low
050C2	BV050C2-CA3	2/9/2011	309	Other	2	Y	Y	Y	No	0	0	249.72	0.05	Low
050B3	BV050B3-CA2	1/6/2011	213	Gabion	8	Y	N	Y	No	0	0	13.81	0.00	Minor
050C3	BV050C3-CA4	1/6/2011	238	Rip-rap	10	N	N	N	Above	50	0	92.44	0.02	Minor
050C2	BV050C2-CA0	12/22/2010	99	Gabion	3	N	Y	Y	No	0	0	107.77	0.02	Minor

Oregon Branch Subwatershed SCA Survey Sites:
Unusual Conditions

Map	Site	Date Assessed	Photo Sites	Type	Description	Notes	Potential Cause	Severity
042A2	OR042A2-UC0	2/9/2011	None	Unusual Condition	Excessive Algae	Golf course	Golf Course	Severe
041C2	OR041C2-UC1	2/9/2011	1804	Unusual Condition	Excessive Algae	Below Wetland, side trib on left bank	Unknown	Severe
041C2	OR041C2-UC9	12/20/2010	17	Unusual Condition	Other	Narrow Stream Valley with Cobble dumped on bank-looks like an old Ag. clearing of fields, Channel has downcut and is now widening on outside of bends	Unknown	Moderate
041B2	OR041B2-UC12	12/20/2010	29	Unusual Condition	Other	Collecting road drainage, upstream of Shawan road in side channel	Unknown	Low

Baisman Run Subwatershed SCA Survey Sites:
Unusual Conditions

Map	Site	Date Assessed	Photo Site	Type	Description	Notes	Potential Cause	Severity
050C1	BS050C1-UC1	1/6/2011	1745	Unusual Condition	Excessive Algae	Pond and Gas Pipeline	Unknown	Severe
041B3	BS041B3-UC3	1/6/2011	1686	Unusual Condition	Other	Gravel ATV Ford & Concrete water control structure which also may have been road crossing- (also possible minor fish barrier?)	Unknown	Moderate
041B3	BS041B3-UC4	1/6/2011	1697-1698	Unusual Condition	Excessive Algae	Deer Carcass	Unknown	Low
041C3	BS041C3-UC1	1/6/2011	1729	Unusual Condition	Other	Bamboo Grove-Could be Removed	Unknown	Low

Beaverdam Subwatershed SCA Survey Sites:
Unusual Conditions

Map	Site	Date Assessed	Photo Sites	Type	Description	Notes	Potential Cause	Severity
050B3	BV050B3-C1	1/4/2011	1674, 1675	Unusual Condition	Other	Breach Farm Pond- Non Wetland; Failed pipe may cause larger failure of berm over time	N/A	Moderate
050A2	BV050A2-UC1	1/4/2011	1578	Unusual Condition	Other	Multiple small drain pipes on both sides of field; 1" pipe inside corrugated plastic inside filter cloth; This area is upstream of last driveway on left side of Hunters Glen	May be part of old golf course; infrastructure, draining wetlands-*See example of pipes PO1	Low
050B2	BV050B2-UC3	1/4/2011	None	Unusual Condition	Excessive Algae	N/A	N/A	Minor

Baisman Run Subwatershed SCA Survey Sites:
Comments

Map	Site	Date Assessed	Photo Site	Type	Description	Notes	Potential Cause	Severity
050B1	BS050B1-C3	1/6/2011	1740	Comment	Other	Partial Flow Diversion pipe into pond; resulting channel alteration	Unknown	N/A
041B3	BS041B3-C10	1/6/2011	1715	Comment	Other	Tree tubes under tree canopy-most dead-a few big ones on open ground	Unknown	N/A
050C1	BS050C1-UC2	1/6/2011	None	Comment	Other	Wetland at pipeline-GOOD Unusual Condition	Pipeline appears to be forcing shallow flow to surface creating bog-like condition providing grade control-GOOD CONDITION	N/A
041C3	BS041C3-C1	12/2/2010	1662	Comment	Other	Utility Crossing	Unknown	N/A
041C3	BS041C3-C2	12/2/2010	1683	Comment	Other	Utility Crossing	Unknown	N/A
041C3	BS041C3-C3	12/2/2010	1701	Comment	Other	Utility Crossing	Unknown	N/A

Beaverdam Subwatershed SCA Survey Sites:
Comments

Map	Site	Date Assessed	Photo Sites	Type	Description	Notes	Potential Cause	Severity
050C3	BV050C3-C4	12/22/2010	1555	Comment	Other	On right bank-old water mill equipment and clay structures on left bank	Unknown	NA
050C3	BV050C3-C3	12/22/2010	1553	Comment	Other	Trib with frozen water/old ag. drainage ditch	Unknown	NA
050C3	BV050C3-C6	12/22/2010	1560	Comment	Other	Tributary to pond	Unknown	NA
050C3	BV050C3-C1	12/22/2010	1545	Comment	Other	Algae/Bryozones indication of good stream stability Found 10' dead trout near road	Unknown	NA
050C3	BV050C3-C7	12/22/2010	1562, 1563	Comment	Other	Old farm pond- 2 pipes (4" & 8" PVC) discharge downstream, Stable Outfall	Unknown	NA
050C3	BV050C3-C2	12/22/2010	1551	Comment	Other	Dry Trib	Unknown	NA
050C3	BV050C3-C5	12/22/2010	None	Comment	Other	Wetland Along Stream	Unknown	NA
050A1	BV050A1-C3	1/4/2011	1617	Comment	Other	SW flow from crest Noll Dr. Development is bypassing SW pond for Cory Ridge Rd. comm.-Good Retrofit site-Divert more flow into dry pond, raise overflow berm, restrict pipe orifice	Unknown	NA
050A2	BV050A2-C2	1/4/2011	1588	Comment	Other	Old irrigation pipes with large tank between ponds	Old Golf Course Irragadian	NA
050B2	BV050B2-C1	1/4/2011	164	Comment	pond	built pond	Unknown	NA
050C2	BV050C2-C2	1/4/2011	175	Comment	old culvert		Unknown	NA
050B2	BV050B2-C3	1/4/2011	180	Comment	inline ponds/bamboo	altered hydrology	humans	NA
050B3	BV050B3-C3	1/6/2011	200	Comment	old road	outfall to old road	Unknown	NA
050B3	BV050B3-C2	1/6/2011	209	Comment	damaged riser	damaged riser inside swm-	Unknown	NA
050C2	BV050C2-C3	1/6/2011	242	Comment	unstable pond	244	Unknown	NA
050C2	BV050C2-C1	12/22/2010	87	Comment	pumping to farm		Unknown	NA
051A2	BV051A2-C2	12/22/2010	134	Comment	small dam		manmade	NA

Stream Corridor Assessment: Comments

Oregon Branch Subwatershed SCA Survey Sites:
Erosion Sites

Map	Site	Date Assessed	Photo Sites	Type	Cause	Average Exposed Bank Height (ft)	Land Use (Left)	Land Use (Right)	Threat to Infrastructure	Length (ft)	Length (mi)	Severity
041B2	OR041B2-ES6	12/22/2010	1539, 1540	Downcutting	Other	2.5	Pasture	Pasture	N	621	0.12	Moderate
042A3	OR042A3-ES4	12/20/2010	6	Widening	Deposition above I-83	4	Forest	Forest	N	793	0.15	Low
041B2	OR041B2-ES1	2/9/2011	1785	Widening	Below road crossing	3	Pasture	Pasture	N	295	0.06	Low
042A3	OR042A3-ES5	12/20/2011	8	Downcutting	Below road crossing	1	Forest	Forest	N	297	0.06	Low

Baisman Run Subwatershed SCA Survey Sites:
Erosion Sites

Map	Site	Date Assessed	Photo Site	Type	Cause	Average Exposed Bank Height (ft)	Land Use (Left)	Land Use (Right)	Threat To Infrastructure	Length (ft)	Length (mi)	Severity
041B3	BS041B3-ES14	1/6/2011	1723	Downcutting	Below road crossing	5	Forest	Forest	N	2,606.13	0.49	Severe
050C1	BS050C1-ES2	12/2/2010	1666	Widening	Bend at steep slope	4	Forest	Forest	N	41.02	0.01	Moderate
050C1	BS050C1-ES7	12/2/2010	1680	Widening	Bend at steep slope	5	Forest	Forest	N	60.06	0.01	Moderate
041C3	BS041C3-ES9	12/2/2010	1692	Widening	Bend at steep slope	3	Forest	Forest	N	69.48	0.01	Moderate
041C3	BS041C3-ES10	12/2/2010	1698	Widening	Bend at steep slope	4	Forest	Forest	N	97.16	0.02	Moderate
041C3	BS041C3-ES11	12/2/2010	1704	Widening	Bend at steep slope	3	Forest	Forest	N	42.87	0.01	Moderate
041C3	BS041C3-ES12	12/2/2010	1705	Widening	Bend at steep slope	4	Forest	Forest	N	76.20	0.01	Moderate
050C1	BS050C1-ES4	1/6/2011	None	Downcutting	Land use change	3	Forest	Forest	N	653.91	0.12	Moderate
050C1	BS050C1-ES2	1/6/2011	1748	Downcutting	Headcutting	4	Forest	Forest	N	757.50	0.14	Moderate

Baisman Run Subwatershed SCA Survey Sites:
(Erosion Sites continued from page 9)

Map	Site	Date Assessed	Photo Site	Type	Cause	Average Exposed Bank Height (ft)	Land Use (Left)	Land Use (Right)	Threat To Infrastructure	Length (ft)	Length (mi)	Severity
050C1	BS050C1-ES1	1/6/2011	1743-1744	Downcutting	Headcutting	4	Shrubs and small trees	Shrubs and small trees	N	398.67	0.08	Moderate
050C1	BS050C1-ES3	1/6/2011	1749-1754	Downcutting	Other	5	Shrubs and small trees	Shrubs and small trees	N	644.73	0.12	Moderate
050B1	BS050B1-ES4	1/6/2011	None	Widening	Other	2	Forest	Forest	N	2,182.51	0.41	Moderate
041C3	BS041C3-ES2	1/6/2011	1732-1733	Widening	Other	2	Forest	Forest	N	1,006.48	0.19	Moderate
050C1	BS050C1-ES2	11/30/2010	1585	Widening	Bend at steep slope	5	Forest	Forest	N	84.44	0.02	Low
050C1	BS050C1-ES1	12/2/2010	1664	Widening	Bend at steep slope	3	Forest	Forest	N	70.71	0.01	Low
050C1	BS050C1-ES3	12/2/2010	1667	Widening	Bend at steep slope	3	Forest	Forest	N	20.25	0.00	Low
050C1	BS050C1-ES4	12/2/2010	1672	Widening	Bend at steep slope	2	Forest	Forest	N	50.71	0.01	Low
050C1	BS050C1-ES5	12/2/2010	1674	Widening	Bend at steep slope	3	Forest	Forest	N	30.62	0.01	Low
050C1	BS050C1-ES6	12/2/2010	1675	Widening	Bend at steep slope	8	Forest	Forest	N	43.27	0.01	Low
041C3	BS041C3-ES8	12/2/2010	1690	Widening	Bend at steep slope	3	Forest	Forest	N	75.83	0.01	Low
050C1	BS050C1-ES13	12/2/2010	1585	Widening	Bend at steep slope	5	Forest	Forest	N	81.78	0.02	Low
050C1	BS050C1-ES5	1/6/2011	1760	Downcutting	Land use change	4	Forest	Forest	N	380.23	0.07	Low
050C1	BS050C1-ES6	1/6/2011	1762	Downcutting	Other	2	Forest	Forest	Y	844.67	0.16	Low

Beaverdam Subwatershed SCA Survey Sites:
Erosion Sites

Map	Site	Date Assessed	Photo Site	Type	Cause	Average Exposed Bank Height (ft)	Land Use (Left)	Land Use (Right)	Threat To Infrastructure	Length (ft)	Length (mi)	Severity
050A1	BV050A1-ES12	1/4/2011	1617-1633	Downcutting	Other	9	Forest	Forest	N	852.48	0.16	Very Severe
050C2	BV050C2-ES10	12/22/2010	96	Widening	Bend at steep Slope	6	Forest	Forest	N	110.30	0.02	Severe
050B3	BV050B3-ES7	1/6/2011	226	Widening	Below road crossing	4	Shrubs and small trees	Forest	N	145.76	0.03	Severe
050B2	BV050B2-ES1	1/4/2011	1640-1643	Downcutting	Below road crossing	3	Forest	Forest	Y	1,391.12	0.26	Severe
050B2	BV050B2-ES4	1/4/2011	1663-1666	Downcutting	Below road crossing	3	Forest	Forest	N	699.09	0.13	Severe
050B3	BV050B3-ES3	1/6/2011	192	Headcutting	Below road crossing	5	Forest	Forest	N	438.49	0.08	Severe
050C2	BV050C2-ES5	12/22/2010	80	Widening	Unknown	4	Forest	Forest	N	83.68	0.02	Moderate
050C2	BV050C2-ES4	12/22/2010	78	Widening	Unknown	5	Forest	Forest	N	105.39	0.02	Moderate
050C2	BV050C2-ES1	12/22/2010	45	Widening	Bend at steep Slope	5	Forest	Forest	N	36.16	0.01	Moderate
050C3	BV050C3-ES20	12/22/2010	124	Widening	Bend at steep Slope	5	Forest	Forest	N	78.69	0.01	Moderate
050C2	BV050C2-ES17	12/22/2010	114	Widening	Unknown	4	Forest	Forest	N	95.90	0.02	Moderate
050C2	BV050C2-ES15	12/22/2010	110	Widening	Land use Change	5	Pasture	Forest	N	84.57	0.02	Moderate
050C2	BV050C2-ES12	12/22/2010	102	Widening	Unknown	5	Forest	Forest	N	64.61	0.01	Moderate
050C2	BV050C2-ES6	12/22/2010	89	Widening	Bend at steep slope	5	Forest	Forest	N	75.68	0.01	Moderate
050C2	BV050C2-ES3	12/22/2010	77	Widening	Unknown	5	Forest	Forest	N	47.68	0.01	Moderate
050C2	BV050C2-ES2	12/22/2010	76	Widening	Unknown	5	Forest	Forest	N	56.40	0.01	Moderate
050C1	BV050C1-ES12	12/20/2010	57	Widening	Bend at steep Slope	5	Forest	Forest	N	123.31	0.02	Moderate
050C2	BV050C2-ES7	12/22/2010	90	Widening	Bend at steep Slope	4	Forest	Forest	N	142.43	0.03	Moderate

Beaverdam Subwatershed SCA Survey Sites:
(Erosion Sites continued from page 11)

Map	Site	Date Assessed	Photo Site	Type	Cause	Average Exposed Bank Height (ft)	Land Use (Left)	Land Use (Right)	Threat To Infrastructure	Length (ft)	Length (mi)	Severity
051A1	BV051A1-ES8	12/20/2010	27	Widening	Unknown	6	Forest	Forest	N	75.02	0.01	Moderate
050C2	BV050C2-ES14	12/22/2010	107	Widening	Unknown	5	Forest	Forest	N	22.31	0.00	Moderate
050A3	BV050A3-ES5	1/6/2011	220	Downcutting	Pipe outfall	3	Lawn	Shrubs and small trees	N	32.21	0.01	Moderate
051A1	BV051A1-ES6	12/20/2010	18	Widening	Bend at steep Slope	6	Forest	Forest	N	106.29	0.02	Moderate
051A1	BV051A1-ES4	12/20/2010	15	Widening	Unknown	4	Forest	Forest	N	147.73	0.03	Moderate
050B3	BV050B3-ES2	1/6/2011	191	Widening	Bend at steep slope	5	Forest	Forest	N	45.42	0.01	Moderate
051A1	BV051A1-ES2	12/20/2010	13	Widening	Unknown	5	Forest	Forest	N	121.94	0.02	Moderate
050B3	BV050B3-ES5	1/6/2011	190	Widening	Bend at steep slope	45	Forest	Forest	N	71.82	0.01	Moderate
051A1	BV051A1-ES1	12/20/2010	8	Widening	Unknown	6	Forest	Forest	N	102.93	0.02	Moderate
050B3	BV050B3-ES6	1/6/2011	225	Widening	Below road crossing	4	Shrubs and small trees	Forest	N	12.31	0.00	Moderate
050B1	BV050B1-ES1	1/4/2011	159	Headcutting	Other	4	Forest	Forest	N	38.16	0.01	Moderate
050B3	BV050B3-ES2	1/4/2011	1679-1680	Downcutting	Pipe outfall	2	Shrubs and small trees	Shrubs and small trees	N	307.02	0.06	Moderate
050C2	BV050C2-ES8	12/22/2010	93	Widening	Bend at steep Slope	6	Forest	Forest	N	7.29	0.00	Moderate
051A1	BV051A1-ES9	12/20/2010	28	Widening	Below Road Crossing	4	Forest	Forest	N	76.46	0.01	Moderate
051A1	BV051A1-ES21	12/22/2010	143	Headcutting	Pipe Outfall	4	Forest	Forest	N	13.61	0.00	Moderate
050C2	BV050C2-ES19	12/22/2010	123	Widening	Bend at steep Slope	5	Forest	Forest	N	112.96	0.02	Moderate
050C2	BV050C2-ES18	12/22/2010	119	Widening	Bend at steep Slope	5	Forest	Forest	N	67.54	0.01	Moderate
050C2	BV050C2-ES16	12/22/2010	113	Widening	Landuse Change	5	Pasture	Forest	N	144.95	0.03	Moderate

Beaverdam Subwatershed SCA Survey Sites:
(Erosion Sites continued from page 12)

Map	Site	Date Assessed	Photo Site	Type	Cause	Average Exposed Bank Height (ft)	Land Use (Left)	Land Use (Right)	Threat To Infrastructure	Length (ft)	Length (mi)	Severity
050C2	BV050C2-ES13	12/22/2010	105	Widening	Unknown	5	Forest	Forest	N	33.54	0.01	Moderate
050B3	BV050B3-ES1	1/4/2011	1676	Downcutting	Other	3	Forest	Forest	N	697.12	0.13	Low
050B2	BV050B2-ES2	1/4/2011	1655, 1661	Widening	Land use change	3	Forest	Forest	N	653.12	0.12	Low
050B2	BV050B2-ES3	1/4/2011	1656-1659	Downcutting	Land use change	3	Forest	Forest	N	674.83	0.13	Low
050C2	BV050C2-ES11	12/22/2010	98	Widening	Unknown	5	Forest	Forest	N	82.25	0.02	Low
051A1	BV051A1-ES3	12/20/2010	14	Widening	Unknown	4	Forest	Forest	N	59.98	0.01	Low
050A1	BV050A1-ES2	1/4/2011	1603	Widening	Other	3	Other	Pasture	Y	693.09	0.13	Low
051A1	BV051A1-ES14	12/20/2010	67	Widening	Unknown	3	Forest	Forest	N	301.53	0.06	Low
050C2	BV050C2-ES16	12/20/2010	69	Widening	Unknown	4	Forest	Forest	N	101.06	0.02	Low
050A2	BV050A2-ES1	1/4/2011	1586	Downcutting	Other	2	Pasture	Pasture	N	697.09	0.13	Low
051A1	BV051A1-ES7	12/20/2010	21	Widening	Unknown	6	Forest	Forest	N	69.00	0.01	Low
051A1	BV051A1-ES10	12/20/2010	45	Widening	Bend at steep Slope	4	Forest	Forest	N	157.24	0.03	Low
050C2	BV050C2-ES15	12/20/2010	68	Widening	Unknown	4	Forest	Forest	N	117.24	0.02	Low
050C1	BV050C1-ES11	12/20/2010	56	Widening	Bend at steep Slope	4	Forest	Forest	N	86.50	0.02	Moderate
050C2	BV050C2-ES9	12/22/2010	95	Widening	Unknown	5	Forest	Forest	N	53.98	0.01	Moderate
050C1	BV050C1-ES13	12/20/2010	63	Widening	Unknown	4	Forest	Forest	N	112.82	0.02	Moderate
051A1	BV051A1-ES5	12/20/2010	16	Widening	Unknown	4	Forest	Forest	N	145.18	0.03	Low

Oregon Branch Subwatershed SCA Survey Sites:
Fish Barriers

Map	Site	Date Assessed	Photo Sites	Blockage Type	Barrier Type	Reason	Water Drop (in)	Water Depth (in)	Severity
041B2	OR041B2-FB11	12/20/2010	28	Total	Road Crossing	Too Shallow and Too High	1	2	Severe
042A3	OR042A3-FB1	12/21/2010	None	Partial	Road Crossing	Too Shallow	NA	3	Low
041C2	OR041C2-FB8	12/20/2010	6667	Partial	Road Crossing	Too Shallow and Too Fast	NA	2	Minor

Baisman Run Subwatershed SCA Survey Sites:
Fish Barriers

Map	Site	Date Assessed	Photo Sites	Blockage Type	Barrier Type	Reason	Water Drop (in)	Water Depth (in)	Severity
051A1	BS051A1-FB1	11/30/2010	1581	Total	Dam	Too High	16	1	Severe
051A1	BS051A1-FB2	12/20/2010	34	Total	Dam	Too High	12	2	Moderate
050C1	BS050C1-FB1	12/2/2010	1657	Total	Instream Pond	Too High	100	1	Moderate

Oregon Branch Subwatershed SCA Survey Sites:
Pipe Outfalls

Map	Site	Date Assessed	Photo Sites	Type of Outfall	Type of Pipe	Location	Pipe Diameter (in)	Channel Width (ft)	Discharge	Color	Odor	Severity
042A3	OR042A3-PO2	12/20/2010	4	Stormwater	Concrete Channel	Right Bank	Same as Channel	5	N	NA	NA	Minor
042A3	OR042A3-PO3	12/20/2010	5	Stormwater	Earth Channel	Left Bank	Same as Channel	5	N	NA	NA	Minor
041B3	OR041B3-PO2	2/9/2011	1791	Stormwater	Concrete Pipe	Head of Stream	36	0	N	NA	NA	Minor
041C2	OR041C2-PO1	2/9/2011	1808	Stormwater	Concrete Pipe	Left Bank	18	5	Y	Clear	None	Minor

Baisman Run Subwatershed- SCA Survey Sites:
Pipe Outfalls

Map	Site	Date Assessed	Photo Sites	Type of Outfall	Type of Pipe	Location	Pipe Diameter (in)	Channel Width (ft)	Discharge	Color	Odor	Severity
050C1	BS050C1-PO3	1/6/2011	1761-1762	Stormwater	Corrugated Metal Pipe	Head of Stream	24	5	Y	NA	NA	Low
041B3	BS041B3-PO13	1/6/2011	1707-1711	Stormwater	Concrete Pipe	Head of Stream	24	2	N	NA	NA	Low
041B3	BS041B3-PO11	1/6/2011	1721	Stormwater	Corrugated Metal Pipe	Head of Stream	30	4	N	NA	NA	Low
041B3	BS041B3-PO12	1/6/2011	1712	Agricultural	Smooth Metal Pipe	Right Bank	6	3	N	NA	NA	Minor

Beaverdam Subwatershed SCA Survey Sites:
Pipe Outfalls

Map	Site	Date Assessed	Photo Sites	Type of Outfall	Type of Pipe	Location	Pipe Diameter (in)	Channel Width (ft)	Discharge	Color	Odor	Severity
050B3	BV050B3-PO2	1/4/2011	1681	Stormwater	Concrete Pipe	Head of Stream	12	3	N	NA	NA	Moderate
050B1	BV050B1-PO1	1/4/2011	152	Stormwater	Corrugated Metal	Head of Stream	48	2	Y	Clear	None	Moderate
050C2	BV050C2-PO3	1/4/2011	171	Other	Corrugated Metal	Right Bank	36	2	Y	Clear	None	Moderate
050B3	BV050B3-PO0	1/6/2011	195	Stormwater	Concrete Pipe	Head of Stream	36	5	Y	Clear	None	Moderate
050A2	BV050A2-PO1	1/4/2011	1578	Agricultural	Plastic	Both	1	1	N	NA	NA	Moderate
050C2	BV050C2-PO19	1/6/2011	245	Stormwater	Concrete Pipe	Head of Stream	12	0	Y	Clear	None	Moderate
050C2	BV050C2-PO1	12/22/2010	100	Stormwater	Concrete Pipe	Right Bank	18	3	Y	Other	None	Moderate
050A2	BV050A2-PO0	12/22/2010	128	Stormwater	Concrete Pipe	Left Bank	24	4	Y	Clear	None	Moderate
051A1	BV051A1-PO8	12/22/2010	142	Stormwater	Concrete Pipe	Left Bank	24	3	Y	Clear	None	Moderate
050B3	BV050B3-PO12	1/6/2011	232	Other	Plastic	Left Bank	24	3	Y	Clear	None	Moderate
050B3	BV050B3-PO11	1/6/2011	227	Stormwater	Concrete Pipe	Left Bank	18	3	Y	Clear	None	Moderate
050C2	BV050C2-PO18	1/6/2011	241	Stormwater	Concrete Pipe	Head of Stream	18	0	Y	Clear	None	Low
050B1	BV050B1-PO2	1/4/2011	156	Other	Plastic	Right Bank	8	2	N	NA	None	Low
050A2	BV050A2-PO2	1/4/2011	1583	Residential	Plastic	Right Bank	8	1	N	NA	NA	Low
050C2	BV050C2-PO4	1/4/2011	176	Stormwater	Concrete Channel	Head of Stream	60	6	Y	Clear	None	Low
051A1	BV051A1-PO5	1/4/2011	184	Stormwater	Concrete Pipe	Left Bank	48	0	Y	Clear	None	Low
051A1	BV051A1-PO6	1/4/2011	185	Stormwater	Concrete Pipe	Right Bank	36	0	Y	Clear	None	Low
051A1	BV051A1-PO7	1/4/2011	186	Stormwater	Concrete Pipe	Head of Stream	12	0	Y	Medium Brown	Musky	Low

Beaverdam Subwatershed SCA Survey Sites:
(Pipe Outfalls continued from page 16)

Map	Site	Date Assessed	Photo Sites	Type of Outfall	Type of Pipe	Location	Pipe Diameter (in)	Channel Width (ft)	Discharge	Color	Odor	Severity
050B3	BV050B3-PO14	1/6/2011	201	Stormwater	Concrete Pipe	Above Stream	24	5	Y	Clear	None	Low
050B3	BV050B3-PO3	1/6/2011	202	Stormwater	Plastic	Above Stream	10	0	Y	Clear	None	Low
050B3	BV050B3-PO4	1/6/2011	203	Stormwater	Plastic	Above Stream	12	0	Y	Clear	None	Low
050B3	BV050B3-PO5	1/6/2011	204	Stormwater	Concrete Pipe	Above Stream	36	0	Y	Clear	None	Low
050B3	BV050B3-PO6	1/6/2011	207	Stormwater	Concrete Pipe	Above Stream	36	4	Y	Clear	None	Low
050B3	BV050B3-PO7	1/6/2011	210	Stormwater	Concrete Pipe	Above Stream	24	4	Y	Clear	None	Low
050A3	BV050A3-PO8	1/6/2011	217	Stormwater	Concrete Pipe	Above Stream	36	4	Y	Clear	None	Low
050B3	BV050A3-PO9	1/6/2011	224	Stormwater	Concrete Pipe	Left Bank	24	6	Y	Clear	None	Low
050B3	BV050B3-PO10	1/6/2011	224	Stormwater	Concrete Pipe	Right Bank	18	6	Y	Clear	None	Low
050B3	BV050B3-PO13	1/6/2011	233	Stormwater	Plastic	Head of Stream	48	3	Y	Clear	None	Low
050C3	BV050C3-PO14	1/6/2011	236	Stormwater	Concrete Pipe	Head of Stream	24	3	Y	Clear	None	Low
050C3	BV050C3-PO15	1/6/2011	236	Stormwater	Concrete Pipe	Head of Stream	24	3	Y	Clear	None	Low
050C3	BV050C3-PO16	1/6/2011	237	Stormwater	Concrete Pipe	Head of Stream	24	3	Y	Clear	None	Low
050C3	BV050C3-PO17	1/6/2011	239	Stormwater	Plastic	Head of Stream	18	0	N	Clear	None	Low
050A2	BV050A2-PO3	12/22/2010	129	Stormwater	Concrete Pipe	Left Bank	24	3	Y	Clear	None	Low
051A2	BV051A2-PO5	12/22/2010	137	Stormwater	Concrete Pipe	Head of Stream	24	3	Y	Other	None	Low
051A2	BV051A2-PO6	12/22/2010	139	Stormwater	Concrete Pipe	Head of Stream	30	3	Y	Other	None	Low
051A2	BV051A2-PO7	12/22/2010	141	Stormwater	Corrugated Metal	Head of Stream	24	3	Y	Clear	None	Low
050C2	BV050C2-PO20	2/9/2011	302	Stormwater	Plastic	Head of Stream	36	4	Y	Clear	None	Low
050C2	BV050C2-PO2	2/9/2011	303	Stormwater	Plastic	Head of Stream	36	4	Y	Clear	None	Low

Beaverdam Subwatershed SCA Survey Sites:
(Pipe Outfalls continued from page 17)

Map	Site	Date Assessed	Photo Sites	Type of Outfall	Type of Pipe	Location	Pipe Diameter (in)	Channel Width (ft)	Discharge	Color	Odor	Severity
050C2	BV050C2-PO2	2/9/2011	303	Stormwater	Plastic	Head of Stream	36	4	Y	Clear	None	Low
050A1	BV050A1-PO1	1/4/2011	1603	Road Crossing	Corrugated Metal Pipe	Left Bank	18	6	Y	Clear	None	Minor
051A2	BV051A2-PO4	12/22/2010	138	Stormwater	Concrete Pipe	Head of Stream	16	1	N	Clear	None	Minor
050C3	BV050C3-PO1	12/22/2010	1561	Utility Road	Corrugated Metal Pipe	Mid Channel	18	Unknown	Y	Clear	None	Minor
050B3	BV050B3-PO1	1/4/2011	1677	Road Culverts	Corrugated Metal Pipe	Across Stream	48	8	Y	Clear	None	Minor

Oregon Branch Subwatershed SCA Survey Sites:
Exposed Pipes

Map	Site	Date Assessed	Photo Sites	Pipe Is	Type of Pipe	Pipe Diameter (in)	Length Exposed (ft)	Purpose of Pipe	Evidence of Discharge	Color	Odor	Severity
041C2	OR041C2-EP10	12/20/2010	21	Exposed along stream bank	Smooth Metal	6	5	Spring House in Park off Kurtz Road	N	NA	NA	Minor

Baisman Run Subwatershed-SCA Survey Sites:
Exposed Pipes

Map	Site	Date Assessed	Photo Sites	Pipe Is	Type of Pipe	Pipe Diameter (in)	Length Exposed (ft)	Purpose of Pipe	Evidence of Discharge	Color	Odor	Severity
041C3	BS041C3-EP15	1/6/2011	1725-1726	Exposed across bottom of stream	Smooth Metal	48	15	Gas Line	N	NA	NA	Severe
041C3	BS041C3-EP1	12/2/2010	1684	Exposed across bottom of stream	Smooth Metal	24	10	Other	N	NA	NA	Moderate

Oregon Branch Subwatershed SCA Survey Sites:
Inadequate Buffers

Map	Site	Date Assessed	Photo Sites	Buffer Inadequate On	Stream Unshaded On	Buffer Width Left (ft)	Buffer Length Left (ft)	Buffer Width Right (ft)	Buffer Length Right (ft)	Land Use (Left)	Land Use (Right)	Buffer Recently Established	Livestock Present	Type	Length (ft)	Length (mi)	Severity
041B2	OR041B2-IB5	12/22/2010	1539	Both	Right	10	0	10	0	Pasture	Pasture	N	N	NA	620	0.12	Severe
042A3	OR042A3-IB6	12/20/2010	9,10	Both	Neither	10	0	10	0	Lawn	Lawn	N	N	NA	1367	0.26	Severe
042A3	OR042A3-IB7	12/20/2010	12,13	Both	Both	8	0	8	0	Lawn	Lawn	N	N	NA	1021	0.19	Severe
042A2	OR042A2-IB1	2/9/2011	1810	Both	Both	5	0	5	0	Lawn	Lawn	N	N	NA	1601	0.30	Severe
041B3	OR041B3-IB1	12/22/2010	None	Right	Neither	25	0	10	0	Lawn	Shrubs Small Trees	N	N	NA	1117	0.21	Moderate
041B2	OR041B2-IB1	12/22/2010	1565	Right	Neither	25	0	10	0	Lawn	Shrubs Small Trees	N	N	NA	517	0.10	Moderate
041B2	OR041B2-IB2	12/22/2010	1568	Left	Neither	7	0	15	0	Lawn	Shrubs Small Trees	N	Y	Horses	1345	0.25	Moderate
041C2	OR041C2-IB1	2/9/2011	1803	Both	Neither	15	0	15	0	Pasture	Pasture	Y	N	NA	1063	0.20	Low
041B2	OR041B2-IB7	2/9/2011	1790	Both	Neither	15	0	15	0	Pasture	Pasture	N	Y	Horses	505	0.10	Low
042A2	OR042A2-IB3	2/9/2011	401	Both	Neither	15	0	15	0	Lawn	Lawn	N	N	NA	880	0.17	Low
042A2	OR042A2-IB2	2/9/2011	403	Both	Neither	10	0	10	0	Other	Other	N	N	NA	1442	0.27	Low
041B2	OR041B2-IB6	2/9/2011	1787	Both	Neither	15	0	15	0	Pasture	Pasture	N	Y	Horses	637	0.12	Low
041C2	OR041C2-IB10	12/20/2010	24	Left	Neither	25	0	37	0	Shrubs Small Trees	Shrubs Small Trees	N	N	NA	963	0.18	Minor
041C2	OR041C2-IB9	12/20/2010	22	Left	Neither	25	0	37	0	Shrubs Small Trees	Shrubs Small Trees	N	N	NA	539	0.10	Minor

Stream Corridor Assessment: Inadequate Buffers

Baisman Run Subwatershed SCA Survey Sites:
Inadequate Buffers

Map	Site	Date Assessed	Photo Site	Buffer Inadequate On	Stream Unshaded On	Buffer Width Left (ft)	Buffer Length Left (ft)	Buffer Width Right (ft)	Buffer Length Right (ft)	Land Use Left	Land Use Right	Recent Buffer	Livestock Present	Severity	Shape Length (ft)	Shape Length (mi)
041B3	BS041B3-IB5	1/6/2011	1700	Right	Neither	0	0	10	0	Lawn	Lawn	N	N	Moderate	751	0.14
051A1	BS051A1-IB2	12/20/2010	33	Both	Both	0	1000	0	1000	Lawn	Lawn	N	N	Low	403	0.08
051A1	BS051A1-IB3	12/20/2010	36	Both	Both	0	1000	0	1000	Lawn	Lawn	N	N	Low	269	0.05
050B1	BS050B1-IB1	1/6/2011	1735-1737	Left	Both	30	0	0	0	Shrubs Small Trees	Other	N	N	Low	208	0.04
042A3	BS042A3-IB1	1/6/2011	1772	Left	Left	15	0	0	0	Lawn	Forest	N	N	Low	638	0.12
051A1	BS051A1-IB1	1/6/2011	1769-1770	Both	Both	10	0	10	0	Multiflora	Shrubs Small Trees	N	N	Low	504	0.10

Beaverdam Subwatershed SCA Survey Sites:
Inadequate Buffers

Map	Site	Date Assessed	Photo Sites	Buffer Inadequate On	Stream Unshaded On	Buffer Width Left (ft)	Buffer Length Left (ft)	Buffer Width Right (ft)	Buffer Length Right (ft)	Land Use Left	Land Use Right	Buffer Recently Established	Livestock Present	Length (ft)	Length (mi)	Severity
050A2	BV050A2-IB3	1/4/2011	1586	Both	Both	0	0	0	0	Pasture	Pasture	N	N	2,397.07	0.45	Severe
050C3	BV050C3-IB3	12/22/2010	125	Left	Left	0	750	250	0	Lawn	Forest	N	N	485.59	0.09	Moderate
050C2	BV050C2-IB2	12/22/2010	108	Left	Left	5	1000	250	0	Pasture	Forest	N	N	685.21	0.13	Moderate
050B1	BV050B1-IB1	1/4/2011	155	Both	Both	155	250	0	250	Lawn	Lawn	N	N	317.19	0.06	Moderate
050B2	BV050B2-IB2	1/4/2011	1650	Both	Both	0	0	0	0	Shrubs Small Trees	Shrubs Small Trees	N	N	431.57	0.08	Moderate
050C2	BV050C2-IB3	1/4/2011	174	Both	Both	0	350	0	350	Forest	Lawn	N	N	240.59	0.05	Moderate
050B3	BV050B3-IB1	1/6/2011	223	Right	Neither	100	0	10	150	Forest	Lawn	N	N	307.13	0.06	Low
051A1	BV051A1-IB5	12/20/2010	40	Left	Left	0	250	100	0	Forest	Forest	N	N	309.42	0.06	Low
050B1	BV050B1-IB2	1/4/2011	161	Right	Neither	161	0	35	100	Forest	Lawn	N	N	196.93	0.04	Low
051A1	BV051A1-IB1	12/20/2010	31	Right	Right	150	0	0	100	Forest	Lawn	N	N	139.95	0.03	Low
051A1	BV051A1-IB4	12/20/2010	38	Right	Right	50	0	0	500	Forest	Lawn	N	N	364.56	0.07	Low
050C1	BV050C1-IB6	12/20/2010	59	Right	Right	250	1	0	750	Lawn	Forest	N	N	507.63	0.10	Low

Stream Corridor Assessment: Inadequate Buffers

Beaverdam Subwatershed SCA Survey Sites:
(Inadequate Buffers continued from page 22)

Map	Site	Date Assessed	Photo Sites	Buffer Inadequate On	Stream Unshaded On	Buffer Width Left (ft)	Buffer Length Left (ft)	Buffer Width Right (ft)	Buffer Length Right (ft)	Land Use Left	Land Use Right	Buffer Recently Established	Livestock Present	Length (ft)	Length (mi)	Severity
050C3	BV050C3-IB2	12/22/2010	1554	Right	Neither	0	0	10-025	0	Shrubs Small Trees	Shrubs Small Trees	N	N	910.06	0.17	Low
050C3	BV050C3-IB1	12/22/2010	1546-1548	Left	Neither	15-20	0	50-100	0	Shrubs Small Trees	Forest	N	N	1,276.49	0.24	Low
050A1	BV050A1-IB3	1/4/2011	1603	Both	Both	0	0	0	0	Pasture	Pasture	Y	N	762.89	0.14	Minor

Oregon Branch Subwatershed SCA Survey Sites:
Stream Stability Assessments

Reach ID	Date Assessed	Photo Sites	Stability Stage	Dominant Bed Condition	Secondary Bed Condition	Planform	Length (ft)	Length (mi)
12/20/2010	8	OR042A3-SA3	Stage I Incision	Gravel	Sand	Straight	299.93	0.06
2/9/2011	1789	OR041B2-SA9	Stage II Widening	Gravel	Sand	Meandering	520.05	0.10
12/22/2010	1539	OR041B2-SA5	Stage II Widening	Gravel	Sand	Meandering	620.16	0.12
12/20/2010	17	OR041C2-SA9	Stage II Widening	Cobble	Sand	Meandering	640.85	0.12
12/20/2010	6	OR042A3-SA1	Stage II Widening	Cobble	Gravel	Meandering	793.04	0.15
1/20/2010	15	OR042A2-SA8	Stage II Widening	Sand	Gravel	Meandering	867.25	0.16
12/20/2010	7	OR042A3-SA2	Stage II Widening	Gravel	Sand	Meandering	1694.47	0.32
12/22/2010	1572	OR041B2-SA3	Stage III Deposition	Gravel	Sand	Straight	656.77	0.12
2/9/2011	1796	OR041B3-SA3	Stage IV Recovery and Reconstruction	Gravel	Sand	Meandering	259.81	0.05
2/9/2011	1795	OR041B3-SA2	Stage IV Recovery and Reconstruction	Cobble	Gravel	Meandering	300.11	0.06
12/22/2010	1569	OR041B2-SA2	Stage IV Recovery and Reconstruction	Cobble	Bedrock	Straight	403.02	0.08
2/9/2011	1799	OR041C1-SA1	Stage IV Recovery and Reconstruction	Cobble	Gravel	Meandering	436.44	0.08
2/9/2011	1806	OR041C2-SA3	Stage IV Recovery and Reconstruction	Gravel	Silt/Clay	Braided	506.18	0.10
12/20/2010	22	OR041C2-SA12	Stage IV Recovery and Reconstruction	Cobble	Gravel	Straight	539.32	0.10
2/9/2011	1800	OR041C1-SA2	Stage IV Recovery and Reconstruction	Cobble	Gravel	Meandering	595.12	0.11
2/9/2011	1784	OR041B2-SA7	Stage IV Recovery and Reconstruction	Cobble	Gravel	Meandering	634.66	0.12
12/20/2010	26	OR041C2-SA14	Stage IV Recovery and Reconstruction	Bedrock	Cobble	Straight	660.48	0.13
12/20/2010	18	OR041C2-SA10	Stage IV Recovery and Reconstruction	Bedrock	Cobble	Meandering	749.17	0.14
12/22/2010	1544	OR041B2-SA6	Stage IV Recovery and Reconstruction	Cobble	Gravel	Meandering	877.18	0.17
2/9/2011	400	OR042A2-SA3	Stage IV Recovery and Reconstruction	Gravel	Silt/Clay	Meandering	955.64	0.18
12/22/2010	1575	OR041B2-SA4	Stage IV Recovery and Reconstruction	Gravel	Cobble	Meandering	957.70	0.18
12/20/2010	12,13	OR042A3-SA6	Stage IV Recovery and Reconstruction	Gravel	Cobble	Meandering	1021.28	0.19
2/9/2011	1807	OR041C2-SA4	Stage IV Recovery and Reconstruction	Sand	Gravel	Straight	1021.35	0.19
12/20/2010	11	OR042A3-SA5	Stage IV Recovery and Reconstruction	Gravel	Cobble	Meandering	1043.05	0.20
12/22/2010	1566	OR041B2-SA1	Stage IV Recovery and Reconstruction	Cobble	Bedrock	Straight	1116.77	0.21

Oregon Branch Subwatershed SCA Survey Sites:
(Stream Stability Assessments continued from page 24)

Reach ID	Date Assessed	Photo Sites	Stability Stage	Dominant Bed Condition	Secondary Bed Condition	Planform	Length (ft)	Length (mi)
12/20/2010	None	OR042A2-SA7	Stage IV Recovery and Reconstruction	Sand	Gravel	Meandering	1205.18	0.23
12/20/2010	9,10	OR042A3-SA4	Stage IV Recovery and Reconstruction	Sand	Cobble	Meandering	1366.81	0.26
2/9/2011	1793	OR041B3-SA1	Stage IV Recovery and Reconstruction	Cobble	Gravel	Meandering	1397.81	0.26
2/9/2011	404	OR042A2-SA2	Stage IV Recovery and Reconstruction	Gravel	Silt/Clay	Meandering	1442.04	0.27
12/20/2010	19	OR041C2-SA11	Stage IV Recovery and Reconstruction	Cobble	Gravel	Meandering	1495.21	0.28
2/9/2011	1809	OR042A2-SA1	Stage IV Recovery and Reconstruction	Gravel	Sand	Straight	1601.27	0.30
12/20/2010	24	OR041C2-SA13	Stage IV Recovery and Reconstruction	Cobble	Gravel	Meandering	1609.42	0.30
2/9/2011	1786	OR041B2-SA8	Stage IV Recovery and Reconstruction	Cobble	Gravel	Meandering	1628.98	0.31
12/20/2010	27	OR041C2-SA15	Stage IV Recovery and Reconstruction	Cobble	Gravel	Straight	1718.29	0.33
2/9/2011	1801	OR041C1-SA3	Stage IV Recovery and Reconstruction	Cobble	Gravel	Meandering	1718.83	0.33
2/9/2011	1802	OR041C2-SA2	Stage IV Recovery and Reconstruction	Silt/Clay	Gravel	Straight	1833.88	0.35
2/9/2011	1798	OR041C2-SA1	Stage IV Recovery and Reconstruction	Cobble	Gravel	Meandering	1862.99	0.35

Baisman Run Subwatershed SCA Survey Sites:
Stream Stability Assessments

Reach ID	Date Assessed	Photo Sites	Stability Stage	Dominant Bed Condition	Secondary Bed Condition	Planform	Length (ft)	Length (mi)
BS050C1-SA19	12/2/2010	1665	Stage I Incision	Gravel	Sand	Straight	159.67	0.03
BS050C1-SA0	12/22/2010	1658	Stage I Incision	Boulder	Cobble	Straight	177.09	0.03
BS050C1-SA5	1/6/2011	1760	Stage I Incision	Cobble	Gravel	Straight	383.07	0.07
BS041B3-SA1	1/6/2011	1685	Stage I Incision	Boulder	Cobble	Straight	619.41	0.12
BS050C1-SA1	1/6/2011	1743-1744	Stage I Incision	Gravel	Cobble	Straight	619.86	0.12
BS050C1-SA3	1/6/2011	1749-1754	Stage I Incision	Cobble	Gravel	Straight	644.73	0.12
BS050C1-SA4	1/6/2011	None	Stage I Incision	Cobble	Gravel	Meandering	654.55	0.12
BS050C1-SA2	1/6/2011	1748	Stage I Incision	Cobble	Gravel	Straight	757.50	0.14
BS041B3-SA6	1/6/2011	1714, 1716, 1717	Stage I Incision	Cobble	Gravel	Straight	774.53	0.15
BS050C1-SA10	12/2/2010	1673	Stage II Widening	Cobble	Sand	Meandering	77.89	0.01
BS041C3-SA10	12/2/2010	1694	Stage II Widening	Sand	Silt/Clay	Meandering	155.33	0.03
BS041C3-SA8	12/2/2010	1691	Stage II Widening	Sand	Cobble	Straight	258.85	0.05
BS050C1-SA20	12/2/2010	1668	Stage II Widening	Sand	Cobble	Meandering	341.85	0.06
BS041C3-SA12	12/2/2010	1706	Stage II Widening	Sand	Cobble	Meandering	367.46	0.07
BS041C3-SA1	1/6/2011	1730-1731	Stage II Widening	Cobble	Gravel	Meandering	1006.48	0.19
BS041C3-SA11	12/2/2010	1702	Stage II Widening	Sand	Cobble	Meandering	1590.85	0.30
BS041B3-SA7	1/6/2011	1713, 1722	Stage II Widening	Cobble	Boulder	Meandering	2156.45	0.41

Baisman Run Subwatershed SCA Survey Sites:
(Stream Stability Assessments continued from page 26)

Reach ID	Date Assessed	Photo Sites	Stability Stage	Dominant Bed Condition	Secondary Bed Condition	Planform	Length (ft)	Length (mi)
BS050B1-SA1	1/6/2011	None	Stage II Widening	Cobble	Gravel	Meandering	2182.51	0.41
BS051A1-SA2	11/30/2010	1583	Stage III Deposition	Sand	Gravel	Meandering	290.19	0.05
BS050C1-SA15	12/2/2010	1677	Stage IV Recovery and Reconstruction	Cobble	Sand	Meandering	113.15	0.02
BS050C1-SA22	11/30/2010	1587	Stage IV Recovery and Reconstruction	Gravel	Cobble	Meandering	156.85	0.03
BS050C1-SA9	12/2/2010	1671	Stage IV Recovery and Reconstruction	Cobble	Sand	Meandering	227.99	0.04
BS050C1-SA8	12/2/2010	1670	Stage IV Recovery and Reconstruction	Bedrock	Sand	Meandering	232.89	0.04
BS041C3-SA13	12/2/2010	1707	Stage IV Recovery and Reconstruction	Sand	Boulder	Meandering	235.80	0.04
BS050C1-SA17	11/30/2010	1584	Stage IV Recovery and Reconstruction	Cobble	Gravel	Meandering	272.09	0.05
BS050C1-SA11	12/2/2010	1679	Stage IV Recovery and Reconstruction	Sand	Silt/Clay	Straight	278.42	0.05
BS050C1-SA12	12/2/2010	1682	Stage IV Recovery and Reconstruction	Cobble	Sand	Meandering	310.22	0.06
BS041B3-SA3	1/6/2011	None	Stage IV Recovery and Reconstruction	Boulder	Cobble	Meandering	321.68	0.06
BS041C3-SA5	12/2/2010	1685	Stage IV Recovery and Reconstruction	Sand	Cobble	Meandering	361.07	0.07
BS050C1-SA21	12/2/2010	1669	Stage IV Recovery and Reconstruction	Sand	Cobble	Meandering	379.33	0.07
BS050C1-SA13	11/30/2010	1588	Stage IV Recovery and Reconstruction	Cobble	Gravel	Meandering	432.45	0.08
BS050C1-SA18	11/30/2010	1586	Stage IV Recovery and Reconstruction	Gravel	Sand	Meandering	497.90	0.09
BS050B1-SA2	1/6/2011	1735	Stage IV Recovery and Reconstruction	Cobble	Gravel	Straight	502.02	0.10
BS050C1-SA16	12/2/2010	1659	Stage IV Recovery and Reconstruction	Sand	Cobble	Meandering	512.90	0.10
BS041C3-SA4	12/2/2010	1663	Stage IV Recovery and Reconstruction	Sand	Silt/Clay	Meandering	518.46	0.10
BS041B3-SA2	1/6/2011	1694, 1695, 1696	Stage IV Recovery and Reconstruction	Cobble	Gravel	Meandering	534.75	0.10

Baisman Run Subwatershed SCA Survey Sites:
(Stream Stability Assessments continued from page 27)

Reach ID	Date Assessed	Photo Sites	Stability Stage	Dominant Bed Condition	Secondary Bed Condition	Planform	Length (ft)	Length (mi)
BS041C3-SA7	12/2/2010	1689	Stage IV Recovery and Reconstruction	Sand	Cobble	Meandering	623.15	0.12
BS041C3-SA9	12/2/2010	1693	Stage IV Recovery and Reconstruction	Sand	Gravel	Straight	659.61	0.12
BS041C3-SA2	12/2/2010	1660	Stage IV Recovery and Reconstruction	Boulder	Cobble	Meandering	660.21	0.13
BS051A1-SA4	12/20/2010	37	Stage IV Recovery and Reconstruction	Cobble	Sand	Meandering	695.10	0.13
BS051A1-SA1	1/6/2011	1769-1770	Stage IV Recovery and Reconstruction	Cobble	Gravel	Straight	797.22	0.15
BS041B3-SA5	1/6/2011	1698, 1700, 1701	Stage IV Recovery and Reconstruction	Gravel	Cobble	Straight	802.41	0.15
BS041C3-SA3	12/2/2010	1661	Stage IV Recovery and Reconstruction	Sand	Cobble	Meandering	805.53	0.15
BS051A1-SA3	11/30/2010	1582	Stage IV Recovery and Reconstruction	Gravel	Cobble	Meandering	881.04	0.17
BS041C3-SA6	12/2/2010	1686	Stage IV Recovery and Reconstruction	Sand	Silt/Clay	Meandering	1003.01	0.19
BS050C1-SA6	1/6/2011	1759, 1763, 1764	Stage IV Recovery and Reconstruction	Cobble	Gravel	Straight	1030.48	0.20
BS041B3-SA4	1/6/2011	1694-1696	Stage IV Recovery and Reconstruction	Cobble	Gravel	Meandering	1171.29	0.22
BS050C1-SA14	11/30/2010	1588	Stage IV Recovery and Reconstruction	Sand	Cobble	Meandering	1278.05	0.24
BS042A3-SA2	1/6/2011	1778	Stage IV Recovery and Reconstruction	Cobble	Gravel	Meandering	1653.23	0.31
BS042A3-SA1	1/6/2011	1775-1776	Stage IV Recovery and Reconstruction	Cobble	Gravel	Meandering	1735.99	0.33
BS050C1-SA7	1/6/2011	1765-1766	Stage IV Recovery and Reconstruction	Cobble	Gravel	Meandering	2301.81	0.44

Beaverdam Subwatershed SCA Survey Sites:
Stream Stability Assessments

Reach ID	Date Assessed	Photo Sites	Stability Stage	Dominant Bed Condition	Secondary Bed Condition	Planform	Length (ft)	Length (mi)
BV050B3-SA11	1/6/2011	228	Stage I Incision	Gravel	Silt/Clay	Straight	76.67	0.01
BV050B3-SA15	1/6/2011	194	Stage I Incision	Silt/Clay	Sand	Straight	101.52	0.02
BV051A1-SA12	1/4/2011	188	Stage I Incision	Silt/Clay	Sand	Meandering	185.55	0.04
BV050C2-SA15	1/6/2011	246	Stage I Incision	Bedrock	Cobble	Meandering	207.00	0.04
BV050A2-SA4	1/4/2011	1586-1593	Stage I Incision	Sand	Gravel	Straight	229.92	0.04
BV050C2-SA18	2/9/2011	301	Stage I Incision	Cobble	Silt/Clay	Meandering	257.23	0.05
BV050B3- SA5	1/4/2011	1679-1680	Stage I Incision	Gravel	Cobble	Straight	313.25	0.06
BV050A2-SA2	1/4/2011	1586-1593	Stage I Incision	Sand	Gravel	Straight	376.53	0.07
BV050B3-SA8	1/6/2011	216	Stage I Incision	Sand	Cobble	Meandering	392.46	0.07
BV050B3-SA18	1/6/2011	205	Stage I Incision	Silt/Clay	Cobble	Meandering	393.51	0.07
BV050C3-SA7	1/4/2011	182	Stage I Incision	Silt/Clay	Sand	Meandering	532.28	0.10
BV050A2-SA5	1/4/2011	1586-1593	Stage I Incision	Sand	Gravel	Straight	674.67	0.13
BV050B2-SA7	1/4/2011	1663-1665	Stage I Incision	Sand	Gravel	Straight	715.08	0.14
BV050B1-SA4	1/4/2011	160	Stage I Incision	Sand	Gravel	Meandering	806.29	0.15
BV050A1-SA3	1/4/2011	1607-1608	Stage I Incision	Cobble	Gravel	Straight	977.23	0.19
BV050B2-SA1	1/4/2011	1640-1645	Stage I Incision	Sand	Cobble	Meandering	1391.12	0.26
BV050A1-SA11	1/4/2011	1617-1633	Stage I Incision	Sand	Silt/Clay	Straight	1479.69	0.28
BV050C2-SA10	12/10/2010	112	Stage II Widening	Sand	Cobble	Meandering	84.56	0.02
BV050C1-SA2	12/20/2010	54	Stage II Widening	Boulder	Cobble	Straight	242.81	0.05
BV050B3-SA3	1/4/2011	1676	Stage II Widening	Cobble	Gravel	Straight	258.88	0.05
BV051A2-SA1	12/22/2010	131	Stage II Widening	Cobble	Gravel	Meandering	314.80	0.06

Beaverdam Subwatershed SCA Survey Sites:
(Stream Stability Assessments continued from page 29)

Reach ID	Date Assessed	Photo Sites	Stability Stage	Dominant Bed Condition	Secondary Bed Condition	Planform	Length (ft)	Length (mi)
BV051A1-SA4	12/20/2010	20	Stage II Widening	Gravel	Cobble	Straight	349.61	0.07
BV050C1-SA4	12/20/2010	65	Stage II Widening	Gravel	Sand	Straight	355.43	0.07
BV051A1-SA9	12/20/2010	46	Stage II Widening	Cobble	Gravel	Straight	361.44	0.07
BV050B3-SA9	1/6/2011	193	Stage II Widening	Cobble	Silt/Clay	Meandering	381.59	0.07
BV051A2-SA3	12/22/2010	145	Stage II Widening	Silt/Clay	Gravel	Meandering	389.38	0.07
BV051A1-SA2	12/20/2010	11	Stage II Widening	Cobble	Gravel	Meandering	435.27	0.08
BV050B3-SA12	1/6/2011	229	Stage II Widening	Silt/Clay	Gravel	Meandering	488.10	0.09
BV050C3-SA2	12/22/2010	1552	Stage II Widening	Cobble	Sand	Meandering	516.95	0.10
BV050C2-SA6	12/22/2010	95	Stage II Widening	Sand	Cobble	Meandering	551.81	0.10
BV050B3-SA13	1/6/2011	230	Stage II Widening	Silt/Clay	Gravel	Meandering	636.72	0.12
BV050C1-SA7	12/20/2010	58	Stage II Widening	Cobble	Gravel	Straight	674.24	0.13
BV050B2-SA5	1/4/2011	1655	Stage II Widening	Gravel	Cobble	Meandering	691.20	0.13
BV051A1-SA7	12/20/2010	41	Stage II Widening	Cobble	Sand	Straight	704.46	0.13
BV050C2-SA17	12/20/2010	70	Stage II Widening	Sand	Gravel	Straight	727.96	0.14
BV050C2-SA9	12/22/2010	111	Stage II Widening	Gravel	Sand	Meandering	763.91	0.14
BV050C2-SA11	12/22/2010	116	Stage II Widening	Sand	Gravel	Meandering	811.69	0.15
BV050A1-SA1	1/4/2011	1604	Stage II Widening	Gravel	Cobble	Straight	956.78	0.18
BV050B2-SA10	1/4/2011	168	Stage II Widening	Cobble	Silt/Clay	Meandering	1075.03	0.20
BV051A1-SA5	12/20/2010	32	Stage II Widening	Cobble	Sand	Meandering	1192.17	0.23
BV050C2-SA2	12/22/2010	82	Stage II Widening	Gravel	Cobble	Straight	1289.91	0.24
BV050C2-SA14	12/22/2010	126	Stage II Widening	Sand	Cobble	Straight	1596.64	0.30
BV051A1-SA3	12/20/2010	19	Stage II Widening	Sand	Cobble	Meandering	2024.16	0.38
BV050C2-SA7	12/22/2010	103	Stage II Widening	Sand	Cobble	Straight	2462.49	0.47

Beaverdam Subwatershed SCA Survey Sites:
(Stream Stability Assessments continued from page 30)

Reach ID	Date Assessed	Photo Sites	Stability Stage	Dominant Bed Condition	Secondary Bed Condition	Planform	Length (ft)	Length (mi)
BV050B3-SA16	1/6/2011	198	Stage III Deposition	Silt/Clay	Sand	Straight	146.74	0.03
BV050C2-SA13	2/9/2011	85	Stage III Deposition	Sand	Cobble	Meandering	161.73	0.03
BV050C2-SA3	12/22/2010	83	Stage III Deposition	Sand	Gravel	Meandering	163.64	0.03
BV050B1-SA2	1/4/2011	1638	Stage III Deposition	Sand	Cobble	Straight	329.85	0.06
BV050C2-SA8	12/22/2010	106	Stage III Deposition	Sand	Cobble	Meandering	345.38	0.07
BV050C2-SA5	12/22/2010	86	Stage III Deposition	Sand	Cobble	Straight	662.41	0.13
BV050B1-SA5	1/4/2011	162	Stage III Deposition	Silt/Clay	Sand	Straight	719.75	0.14
BV050C2-SA22	1/4/2011	173	Stage IV Recovery and Reconstruction	Silt/Clay	Cobble	Straight	82.46	0.02
BV050C2-SA1	2/9/2011	300	Stage IV Recovery and Reconstruction	Cobble	Silt/Clay	Meandering	127.08	0.02
BV050B1-SA1	1/4/2011	1636-1638	Stage IV Recovery and Reconstruction	Sand	Gravel	Braided	144.57	0.03
BV050A1-SA0	1/4/2011	None	Stage IV Recovery and Reconstruction	Silt/Clay	Sand	Meandering	155.90	0.03
BV050C2-SA12	12/22/2010	117	Stage IV Recovery and Reconstruction	Sand	Gravel	Meandering	206.13	0.04
BV050C2-SA0	12/22/2010	73	Stage IV Recovery and Reconstruction	Gravel	Cobble	Meandering	222.37	0.04
BV050B3-SA6	1/6/2011	212	Stage IV Recovery and Reconstruction	Silt/Clay	Cobble	Meandering	227.56	0.04
BV050C1-SA6	12/20/2010	55	Stage IV Recovery and Reconstruction	Boulder	Gravel	Meandering	265.92	0.05
BV050B3-SA4	1/4/2011	1678	Stage IV Recovery and Reconstruction	Cobble	Gravel	Meandering	310.96	0.06
BV050B2-SA11	1/4/2011	172	Stage IV Recovery and Reconstruction	Silt/Clay	Cobble	Meandering	331.57	0.06
BV050C2-SA16	1/6/2011	247	Stage IV Recovery and Reconstruction	Cobble	Gravel	Meandering	337.53	0.06
BV050B3-SA14	1/6/2011	234	Stage IV Recovery and Reconstruction	Silt/Clay	Sand	Meandering	346.78	0.07
BV050B2-SA2	1/4/2011	1646-1649	Stage IV Recovery and Reconstruction	Sand	Gravel	Straight	380.64	0.07

Beaverdam Subwatershed SCA Survey Sites:
(Stream Stability Assessments continued from page 31)

Reach ID	Date Assessed	Photo Sites	Stability Stage	Dominant Bed Condition	Secondary Bed Condition	Planform	Length (ft)	Length (mi)
BV051A1-SA8	12/20/2010	42	Stage IV Recovery and Reconstruction	Cobble	Boulder	Straight	421.11	0.08
BV050B3-SA2	1/4/2011	None	Stage IV Recovery and Reconstruction	Sand	Gravel	Braided	432.34	0.08
BV051A1-SA1	12/20/2010	12	Stage IV Recovery and Reconstruction	Sand	Cobble	Straight	433.85	0.08
BV050C3-SA4	12/22/2010	1558	Stage IV Recovery and Reconstruction	Bedrock	Cobble	Straight	440.30	0.08
BV050B2-SA4	1/4/2011	1652-1653	Stage IV Recovery and Reconstruction	Sand	Cobble	Meandering	442.92	0.08
BV050B3-SA10	1/6/2011	222	Stage IV Recovery and Reconstruction	Sand	Gravel	Meandering	448.57	0.08
BV050C2-SA19	2/9/2011	305	Stage IV Recovery and Reconstruction	Cobble	Silt/Clay	Straight	497.60	0.09
BV050C2-SA20	2/9/2011	308	Stage IV Recovery and Reconstruction	Cobble	Silt/Clay	Meandering	502.58	0.10
BV050C2-SA21	1/4/2011	None	Stage IV Recovery and Reconstruction	Silt/Clay	Cobble	Straight	515.97	0.10
BV041A3-SA1	1/4/2011	148	Stage IV Recovery and Reconstruction	Silt/Clay	Sand	Meandering	517.26	0.10
BV050C3-SA3	12/22/2010	1559	Stage IV Recovery and Reconstruction	Sand	Gravel	Straight	541.57	0.10
BV050C1-SA5	12/20/2010	66	Stage IV Recovery and Reconstruction	Gravel	Cobble	Meandering	575.21	0.11
BV050A3-SA1	1/6/2011	219	Stage IV Recovery and Reconstruction	Sand	Gravel	Meandering	613.19	0.12
BV051A1-SA0	12/20/2010	None	Stage IV Recovery and Reconstruction	Silt/Clay	Sand	Straight	655.37	0.12
BV050B2-SA6	1/4/2011	1656	Stage IV Recovery and Reconstruction	Cobble	Gravel	Meandering	674.83	0.13
BV050B2-SA9	1/4/2011	167	Stage IV Recovery and Reconstruction	Silt/Clay	Cobble	Meandering	683.90	0.13
BV050B3-SA1	1/4/2011	1671-1672	Stage IV Recovery and Reconstruction	Gravel	Cobble	Straight	687.13	0.13
BV050A2-SA1	1/4/2011	1576-1585	Stage IV Recovery and Reconstruction	Sand	Silt/Clay	Straight	697.09	0.13
BV050B3-SA7	1/6/2011	215	Stage IV Recovery and Reconstruction	Silt/Clay	Cobble	Meandering	729.90	0.14
BV050B3-SA17	1/6/2011	199	Stage IV Recovery and Reconstruction	Sand	Cobble	Meandering	738.26	0.14

Beaverdam Subwatershed SCA Survey Sites:
(Stream Stability Assessments continued from page 32)

Reach ID	Date Assessed	Photo Sites	Stability Stage	Dominant Bed Condition	Secondary Bed Condition	Planform	Length (ft)	Length (mi)
BV050B2-SA3	1/4/2011	1649	Stage IV Recovery and Reconstruction	Gravel	Cobble	Straight	803.14	0.15
BV051A1-SA10	12/20/2010	48	Stage IV Recovery and Reconstruction	Cobble	Gravel	Straight	827.37	0.16
BV050A1-SA4	1/4/2011	1614	Stage IV Recovery and Reconstruction	Sand	Silt/Clay	Meandering	918.05	0.17
BV050C1-SA3	12/20/2010	61	Stage IV Recovery and Reconstruction	Cobble	Gravel	Straight	929.50	0.18
BV050A2-SA3	1/4/2011	1597	Stage IV Recovery and Reconstruction	Gravel	Cobble	Meandering	973.80	0.18
BV050B2-SA8	1/4/2011	1669-1670	Stage IV Recovery and Reconstruction	Cobble	Gravel	Meandering	1148.79	0.22
BV050A1-SA2	1/4/2011	1612	Stage IV Recovery and Reconstruction	Gravel	Cobble	Meandering	1250.03	0.24
BV050C2-SA4	2/9/2011	306	Stage IV Recovery and Reconstruction	Cobble	Silt/Clay	Straight	1256.29	0.24
BV051A1-SA6	12/22/2010	144	Stage IV Recovery and Reconstruction	Cobble	Silt/Clay	Meandering	1322.59	0.25
BV050B1-SA3	1/4/2011	158	Stage IV Recovery and Reconstruction	Silt/Clay	Cobble	Meandering	1416.72	0.27
BV051A2-SA2	12/22/2010	135	Stage IV Recovery and Reconstruction	Silt/Clay	Gravel	Meandering	1439.24	0.27
BV050C3-SA6	1/6/2011	235	Stage IV Recovery and Reconstruction	Silt/Clay	Sand	Meandering	1525.95	0.29
BV051A1-SA11	1/4/2011	187	Stage IV Recovery and Reconstruction	Cobble	Boulder	Meandering	1557.09	0.29
BV050C1-SA1	12/20/2010	53	Stage IV Recovery and Reconstruction	Boulder	Cobble	Meandering	2256.78	0.43
BV050C3-SA5	12/22/2010	1562	Stage IV Recovery and Reconstruction	Gravel	Sand	Meandering	2456.02	0.47
BV050C3-SA1	12/22/2010	1547	Stage IV Recovery and Reconstruction	Cobble	Boulder	Meandering	3094.98	0.59

APPENDIX L:

Uplands Survey Data

NSA Data

NSA ID	Subwatershed	Neighborhood Name	PSI	ROI	NSA Acres	Imperv Acres	% Imperv
NSA_I_100	Baisman Run/Oregon Branch	Jonathans's Delight/Oregon Gate	Moderate	High	93.2	8.6	9%
NSA_I_101	Baisman Run/Beaverdam Run	Spring Hill Farms/Dellwood/FoxRidge Estates	High	Moderate	247.4	21.7	9%
NSA_I_102	Baisman Run/ Beaverdam Run /Oregon Branch	Shawan Valley/Hunt Club Hills/Falls Estates/Gent Farms	Moderate	Moderate	283.8	25.4	9%
NSA_I_200	Beaverdam Run/Oregon Branch	Medford/Shaneybrook Farms/Long Farm	Moderate	Moderate	237.3	23.6	10%
NSA_I_200B	Beaverdam Run/ Oregon Branch	Briarwood Farms	Moderate	Moderate	33.5	3.1	9%
NSA_I_201	Beaverdam Run /Oregon Branch	Broadmor,Laurelford	Moderate	Moderate	336.7	32.8	10%
NSA_I_202	Oregon Branch	Ivy Hill	Moderate	Moderate	135.9	10.9	8%
NSA_I_204	Beaverdam Run	Tufton Springs	Moderate	Moderate	92.6	6.4	7%
NSA_I_205	Beaverdam Run	Knoll Crest Manor	High	Moderate	55.5	7.5	14%
NSA_I_207	Beaverdam Run	Beaverbrook/Akeley Property	Moderate	Moderate	372.8	29.1	8%
NSA_I_208	Beaverdam Run	Green Valley North/Autumn Wind/Belfair	Moderate	Moderate	77.4	9.4	12%
NSA_I_209	Beaverdam Run	The Woods, Green Valley North	Moderate	Moderate	174.0	17.1	10%
NSA_I_211	Beaverdam Run	Broadridge	Moderate	Moderate	63.3	5.1	8%
NSA_I_212	Beaverdam Run	Momsville/Alec Bullock Farm	Moderate	Moderate	166.9	12.8	8%
NSA_I_214	Beaverdam Run	Sugarvale Estates	Moderate	Moderate	36.0	4.2	12%

NSA ID	Subwatershed	Neighborhood Name	PSI	ROI	NSA Acres	Imperv Acres	% Imperv
NSA_I_215	Beaverdam Run	Heather Hill	Moderate	Moderate	56.7	7.2	13%
NSA_I_216	Beaverdam Run	Hickory Meadow	Moderate	Moderate	55.8	5.9	10%
NSA_I_217	Beaverdam Run	Burns Property	Moderate	Moderate	32.7	4.9	15%
NSA_I_218	Beaverdam Run	Boxer Hill, Greenway, Justa	Moderate	Low	163.3	14.1	9%
NSA_I_220	Beaverdam Run	Worthington Estates	High	High	106.9	5.0	5%
NSA_I_221	Beaverdam Run	Baublitz, Valley Pines, Fellowship, Worthington Ridge	Moderate	Moderate	148.3	13.8	9%
NSA_I_222	Beaverdam Run	Stanson	Moderate	Moderate	24.3	1.0	4%
NSA_I_223	Beaverdam Run	Greenspring	Moderate	Moderate	37.7	2.4	6%
NSA_I_224	Beaverdam Run	Ridgemont, Broadway, S. Myleston	Moderate	Low	106.5	11.6	11%
NSA_I_225	Beaverdam Run	Ivey Trace, Ivy Reach, Hillsyde	Moderate	Moderate	153.1	13.7	9%
NSA_I_226	Beaverdam Run	Happy Hollow, Padonia Manor	Moderate	Low	148.4	8.2	6%
NSA_I_301	Oregon Branch	Shawan at Hunt Valley	Moderate	Moderate	107.4	7.4	7%

NSA Recommendations

NSA ID	Downspout Redirect	% Connected Downspouts	Rain Barrel	Raingarden	Stencil	BayScape	Lot Canopy	Fertilizer Reduction	Pct Lawns High	Pet Waste	Buffer Impact	Stormwater Retrofit
NSA_I_100	x	50	x	x	x	x	x	x	95		x	
NSA_I_101	x	50		x	x	x	x	x	100			
NSA_I_102	x	50		x	x	x	x	x	100			
NSA_I_200		20	x	x	x	x	x	x	90	x		
NSA_I_200B		20	x	x	x	x	x	x	90			
NSA_I_201		10	x	x	x	x		x	90			
NSA_I_202		10		x	x	x		x	65			
NSA_I_204	x	25		x	x	x	x	x	90			
NSA_I_205	x	25		x	x	x	x	x	50			
NSA_I_207	x	25		x	x	x	x	x	100			x
NSA_I_208	x	25		x	x	x	x	x	70			
NSA_I_209	x	25		x	x	x	x	x	90			x
NSA_I_211	x	25		x	x	x	x	x	100			
NSA_I_212	x	25		x	x	x	x	x	100			
NSA_I_214	x	25		x	x	x	x	x	100			
NSA_I_215	x	25		x		x	x	x	100			
NSA_I_216	x	25		x	x	x	x	x	50			
NSA_I_217	x	25		x	x	x	x	x	100			
NSA_I_218	x	25		x	x			x	25			
NSA_I_220	x	50		x	x	x	x	x	100		x	x
NSA_I_221		20	x	x	x	x	x	x	90			x
NSA_I_222	x	25	x	x		x	x	x	80			x
NSA_I_223	x	25	x	x					0			
NSA_I_224	x	25	x	x				x	40			x
NSA_I_225	x	25	x	x	x	x	x	x	70			
NSA_I_226	x	25	x	x	x				15			
NSA_I_301		20		x	x	x	x	x	100			x

HSI Data

Category				
HSI ID	**Description**	**Commercial or Industrial**	**Transport Related**	**Other**
HSI_I_300	Coffee Shop / Restaurant	x		
HSI_I_301	Restaurant	x		

Hotspot Status				
HSI ID	**Not a Hotspot**	**Potential**	**Confirmed**	**Severe**
HSI_I_300	x			
HSI_I_301	x			

Pollution Sources						
HSI ID	**Vehicle Operations**	**Outdoor Materials**	**Waste Mgmt**	**Physical Plant**	**Turf / Land-scaping**	**Storm Water**
HSI_I_300			X	X		
HSI_I_301			X	X	X	X

ISI Data

ISI ID	Subwatershed	Name	Type	Ownership	Nutrient Mgmt Plan Required	Tree Planting	Stormwater Retrofit	Downspout Disconnection	Comments
ISI_I_200	Beaverdam Run	Hunt Valley Presbyterian Church	Faith-Based	Private	N	120			Tree Planting behind the church
ISI_I_201	Baisman Run	Baltimore Chinese Baptist Church	Faith-Based	Private	N	0		x	Rainbarrels for downspouts flowing into parking
ISI_I_300	Oregon Branch	Catholic Community of St. Francis Xavier	Faith-Based	Private	N	520	x	x	Tree planting in open areas
ISI_I_301	Oregon Branch	Hayfield Golf Course	Golf Course	Private	Y	600	x		Tree planting in open areas

PAA Data

ISI ID	Subwatershed	Ownership	Area (Acres)	Site Prep	% Turf	Comments
PAA_I_300	Oregon Branch	Private	2.6	Minimal	100	Tree planting in open areas (Same site as ISI_I_300)