





Appendix

July 2013

10 Mile Creek Area Limited Amendment

Clarksburg Master Plan and Hyattstown Special Study Area

Montgomery County Planning Department
M-NCPPC
MongomeryPlanning.org

Appendix

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Ten Mile Creek Amendment
Appendix 1

1994 Clarksburg Master Plan Excerpts

Land Use Plan Recommendations by Geographic Area

Town Center District (635 acres)

The historic center of Clarksburg is located at MD 355 and MD 121. Buildings dating to the early 1800s still remain and newer uses, such as the Clarksburg Post Office and a bank, have continued the role of Clarksburg as a community center.

This Plan creates a Town Center, which includes the historic district as a focal point. Surrounding the historic district are mixed-use neighborhoods, office, and residential opportunities. A strong interrelationship between the historic district and new development is proposed to help blend the "old" with the "new."

As noted in the Environmental Plan chapter, portions of the Town Center are located in the headwaters of Ten Mile Creek. This environmental concern was considered during the Plan process and less constrained locations for the Town Center were evaluated. However, the advantages of locating the Town Center near the historic district in terms of fostering community identity and reinforcing the traditional center of Clarksburg are equally important Plan objectives. To help address environmental concerns, the Plan shows reduced densities for parcels closest to the headwaters of Ten Mile Creek.

An important feature of the Town Center is a transit stop located along a new proposed road west of the historic district. This stop is envisioned as the focal point of a small, medium density, mixed-use neighborhood. The Plan includes detailed guidelines regarding building heights near the historic district to help assure compatibility.

Plan Objectives:

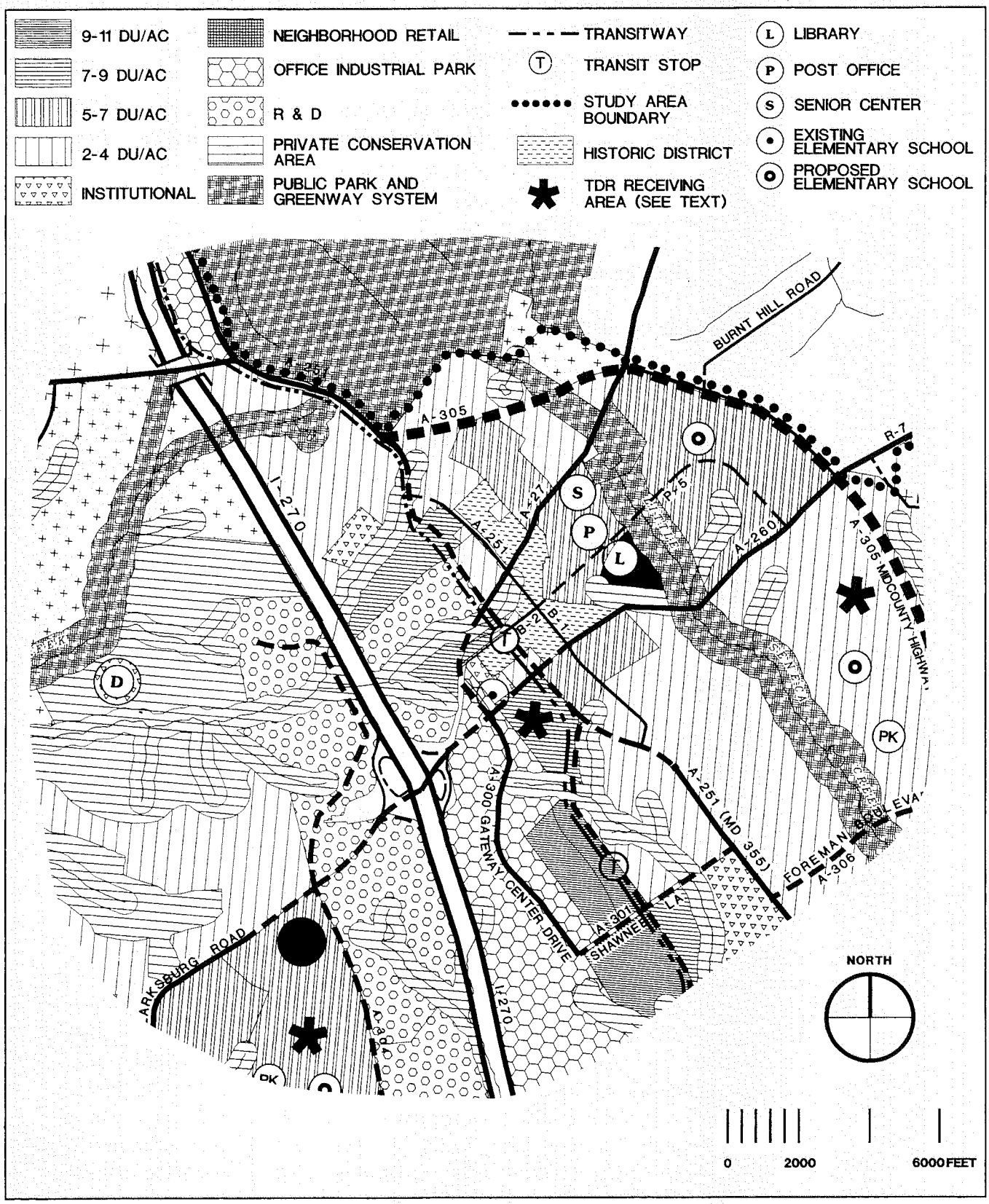
- **Create a Town Center which will be a strong central focus for the entire Study Area.**

  The Land Use Plan for the Town Center is shown in Figure 19, page 43; the Town Center Concept Diagram is shown in Figure 12, page 27. This Plan proposes residential, retail, and office uses within the Town Center. Of equal importance is that the Plan recommends civic and public uses also be concentrated here.

  An Illustrative Sketch has been prepared to provide one example of the pattern of development envisioned for the Town Center (see Figure 20, page 45). This Illustrative Plan is intended to provide only one example and not a prescription of future development. The important features shown in the Illustrative Plan include the patterns of small blocks, the use of an interconnected system of streets which avoids the use of dead-end streets and provides access to transit, the preservation and enhance-

Town Center District Land Use Plan

Figure 19



ment through selective infill of the existing historic district, the street-orientation of buildings, and the provision of a variety of open spaces.

- **Reinforce the concept of I-270 as a high tech employment corridor by designating a suitable site near I-270 for employment use.**

  The Land Use Plan recommends an employment site for up to 470,000 square feet in the Town Center District. The proposed site has the following characteristics:

  - It is visible from I-270.
  - It adjoins a future proposed transit stop.
  - It has excellent access from the I-270/MD 121 interchange.

  In accord with the Plan intent to foster a mix of uses and to promote an interrelated land use pattern, a zoning option which encourages the joint development of residential and employment uses is proposed. This approach is also intended to promote a more integrated overall Town Center concept and a better relationship between this property and portions of Town Center east of MD 355.

  This zoning option (the MXPD Zone — see Zoning Plan chapter, page 95) would apply to all the acreage shown in Figure 38, page 97.

- **Encourage a mixed-use development pattern in the Town Center to help create a lively and diverse place.**

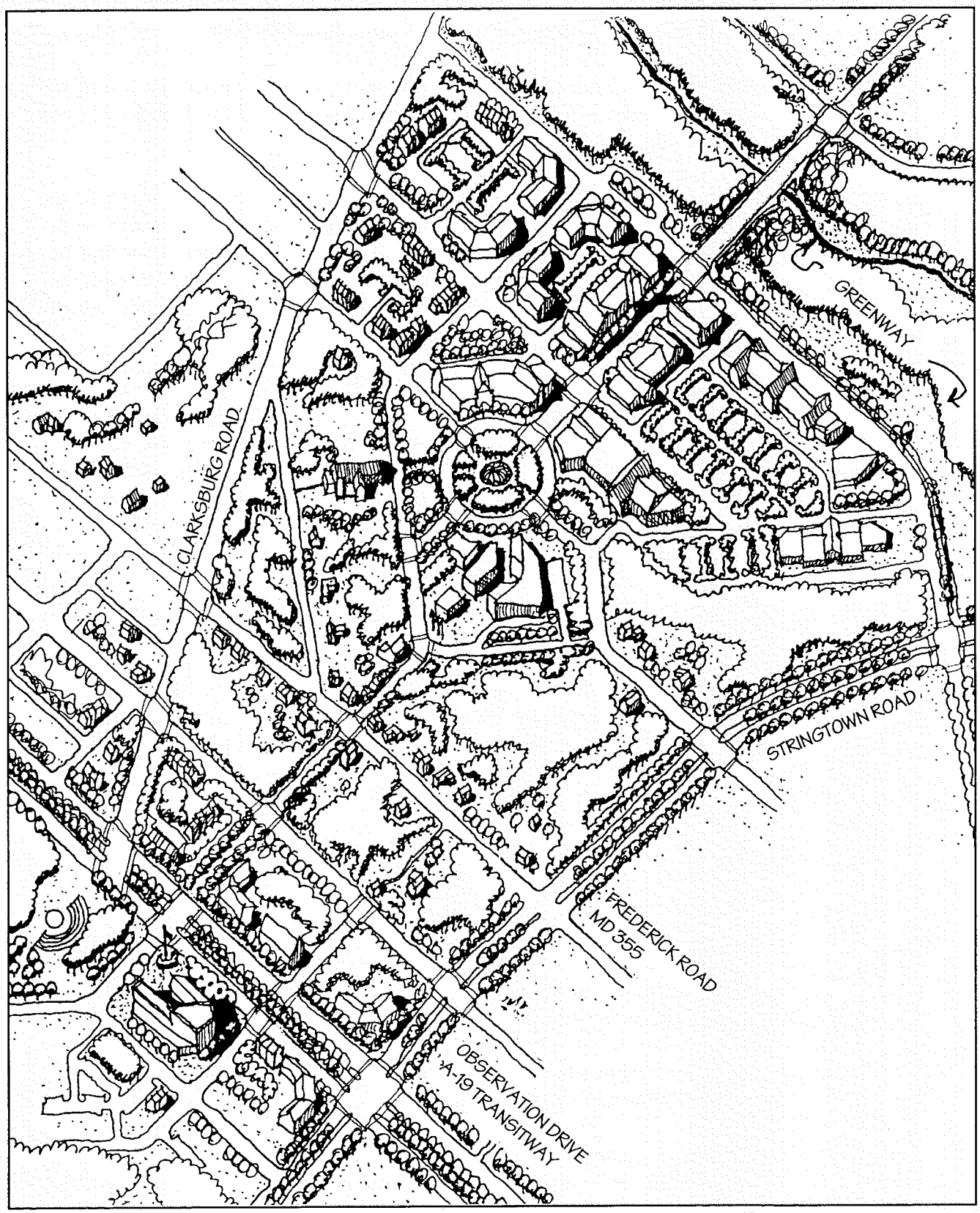
  In terms of **residential uses,** the Plan assumes an ultimate build out of approximately 2,600 units in the Town Center. The recommended guidelines in terms of mix of units are as follows:

Multi-Family	–	25 to 45%
Attached	–	30 to 50%
Detached	–	10 to 20%

  The total number of units in Town Center may be increased in the PD and RMX Zones up to 20 percent if carriage homes are accessory to a primary dwelling unit or they are a primary dwelling on a lot; however, the final determination regarding this increased number of units, their design, and placement (so as not to result in an adverse concentration and impact) will be made by the Planning Board at the time of Project Plan or Development Plan approval. These units will not count as Moderately-Priced Dwelling Units. The Planning Staff should continue to explore whether a text amendment allowing separate ownership of a carriage house or changes to the Montgomery County Code is necessary.

Town Center Illustrative Sketch

Figure 20



All apartment buildings in the future Town Center will be four stories or less except within walking distance of the transit stop, where a building height of six to eight stories may be allowed if Master Plan recommendations concerning compatibility with the historic district can be achieved.

The Town Center District boundary bisects some properties; portions of the properties within Town Center are recommended for densities of two to four units per acre.

If density is clustered from the portions of the properties outside the Town Center, then a density of five to seven units per acre for the portions inside Town Center would be appropriate. Approval of this density would be dependent upon a proposed development achieving compatibility with the scale and intensity of neighboring uses and meeting Plan objectives regarding compatibility with the historic district.

In terms of **commercial uses,** up to 300,000 square feet are proposed. This recommendation exceeds the findings of the Planning Board retail studies (see Technical Appendix) that up to 153,000 square feet of neighborhood retail uses can be supported in the Town Center. Additional square footage would be desirable and would be consistent with the Plan if provided at a pedestrian scale and developed in accord with Plan policies regarding a mix of uses at the neighborhood level (see Policy 7: Transit- and Pedestrian-Oriented Neighborhoods).

This Plan recognizes that retail uses are critical to the vitality of the Town Center. A grocery store is particularly important since this type of use can serve as a magnet for other commercial operations (dry cleaners and banks, for example). One of the concerns about a retail center in the Town Center is how to integrate what has traditionally been an auto-oriented use in an area envisioned to be transit- and pedestrian-oriented.

This Plan addresses that concern as follows:

- A retail center designation is proposed east of the historic district as part of a large-scale mixed-use neighborhood (see Figure 19, page 43). By incorporating the retail center proposal into a larger planned development, there will be a greater opportunity to assure a strong integration of the retail center to adjoining residential and public uses and to assure a compatible relationship to the Clarksburg Historic District.

- A maximum square footage of the retail center is proposed (up to approximately 150,000 square feet).

- Design guidelines are included in this chapter to help assure that the location, size, and scale of the retail center are compatible with the Plan's vision for the Town Center.

The balance of proposed retail and office uses (70,000 to 105,000 square feet) is proposed to be located throughout the Town Center District and consists of infill retail within the historic district (in accord with historic preservation guidelines).

- **Encourage infill within the historic district in accord with the historic development patterns.**

  The following design guidelines are recommended to help assure that infill development within the Clarksburg Historic District is supportive of historical development patterns.

  - Orient buildings to the streets, with parking behind to assure consistency with the character of the historic district.

  - Preserve and enhance the existing rural character of streets by retaining existing pavement widths, locating street trees close to the edge of pavement, and providing sidewalks, lighting, and signage that are of a rural village character.

  - Assure that all road improvements, including both changes to existing roads and creation of new roads, are sensitive to the historic character of the Clarksburg Historic District.

  - Reaffirm and strengthen current historic building patterns, e.g., the pattern of houses built close to the road with long backyards and expanses of green space behind them — in particular, retain the deep backyards of the structures on the west side of Frederick Road as part of a green buffer between the historic district and the transit stop area.

  - Encourage the renovation of existing buildings in the Clarksburg Historic District for both residential and compatible light commercial uses; e.g., professional offices, antique stores, tea rooms, small restaurants, bed-and-breakfasts, and small grocery stores.

  - Encourage a limited amount of new construction, as long as the new buildings are compatible with the historic ones in terms of size, scale, rhythm, percentage of lot coverage, relationship to the street, and relationship to open space.

  - Moving of historic structures is a "last resort" decision; however, if the Clarksburg Elementary School must be relocated due to the construction at the transit stop, the building must be retained within the historic district and should be situated in an appropriate, prominent location. If any other structures in the historic district must be relocated due to road construction or other capital improvements, they must be retained within the district and should be situated in appropriate, prominent locations.

- Assure that particularly prominent resources in the historic district (e.g., Hammer Hill and the Clarksburg Methodist Episcopal Church) are highlighted as focal points.

- Encourage the maintenance of existing trees and major landscaping features in the historic district, while also planting new street trees in an informal pattern (not rigidly spaced, leaving room for views of historically or architecturally significant houses, and maintaining the rural character of the town).

- Encourage the installation of historically appropriate sidewalks along both sides of Frederick Road.

- Encourage appropriate lighting and street furniture, which will enhance Clarksburg's village character.

- Encourage the creation of gateways at both the north and south entrances to the Clarksburg Historic District which will enhance the identity of the community and will help to interpret Clarksburg's history.

- Encourage the continuation of open space in front of the Clarksburg United Methodist Church.

- **Assure that future development around the Historic District complements the District's scale and character.**

  The relationship between the Clarksburg Historic District and the new Town Center is a sensitive one. The historic district must retain its integrity and identity while still blending smoothly with the new neighborhoods which will be created.

  The idea of isolating the historic district from the new Town Center is unrealistic and defeats the purpose of having "new" Clarksburg grow naturally out of "old" Clarksburg. It is equally important, however, that the historic district not be subsumed by the new Town Center and that the character and identity of the district be preserved, while allowing for appropriate growth and change.

  Figure 21, page 50, graphically represents the following Plan guidelines which will help assure a sympathetic relationship between "old" and "new."

  1. An area between existing MD 355 and Relocated MD 355 to the west (an area of approximately 550 feet) is identified as a buffer zone, appropriate only for single-family detached housing with a maximum height of two stories. The maximum density of development should be two units per acre.

2. The area between Relocated MD 355 and the transitway (an area of approximately 550 feet) is shown as appropriate for housing with a maximum height of three stories. All structures greater in height than three stories should be identified as being west of the transitway (over 1,100 feet from the center of the historic district).

3. On the east side of the historic district, all development 400 feet east of existing MD 355 and/or on land which is within the historic district should be single-family detached structures which are no higher than two stories.

4. New development immediately to the west of the district should be low-rise to provide compatibility. New development near the church on Spire Street should be smaller in scale and sufficiently set back from the church.

5. Pedestrian and bicycle linkages to and through the district should be appropriate in scale and character. Redgrave Place should serve as a direct link between the transit stop and the greenway. Where it traverses the district it should have minimum pavement widths, appropriate street trees, street furniture, lighting, and signage.

- **Make the Town Center a focal point for community services (such as libraries and postal services) as well as informal community activities.**

  The Clarksburg Town Center should function as the "civic" center of the Study Area. To achieve this end, community and government related services should be located here. This Plan recommends that a high degree of public interaction be provided in the Town Center, in close proximity to the retail center, to encourage a post office, library, and community center. At the time of development, Planning Staff will identify the amenity required under the RMX Zone. A civic use may be an appropriate amenity for this area. Public functions that serve the community but which do not require day-to-day public access (such as fire stations and maintenance depots) should be located outside of the Town Center. Areas of the Town Center where civic and public spaces are encouraged include:

  - The transit stop (a small civic space, approximately one-half acre in size is recommended).

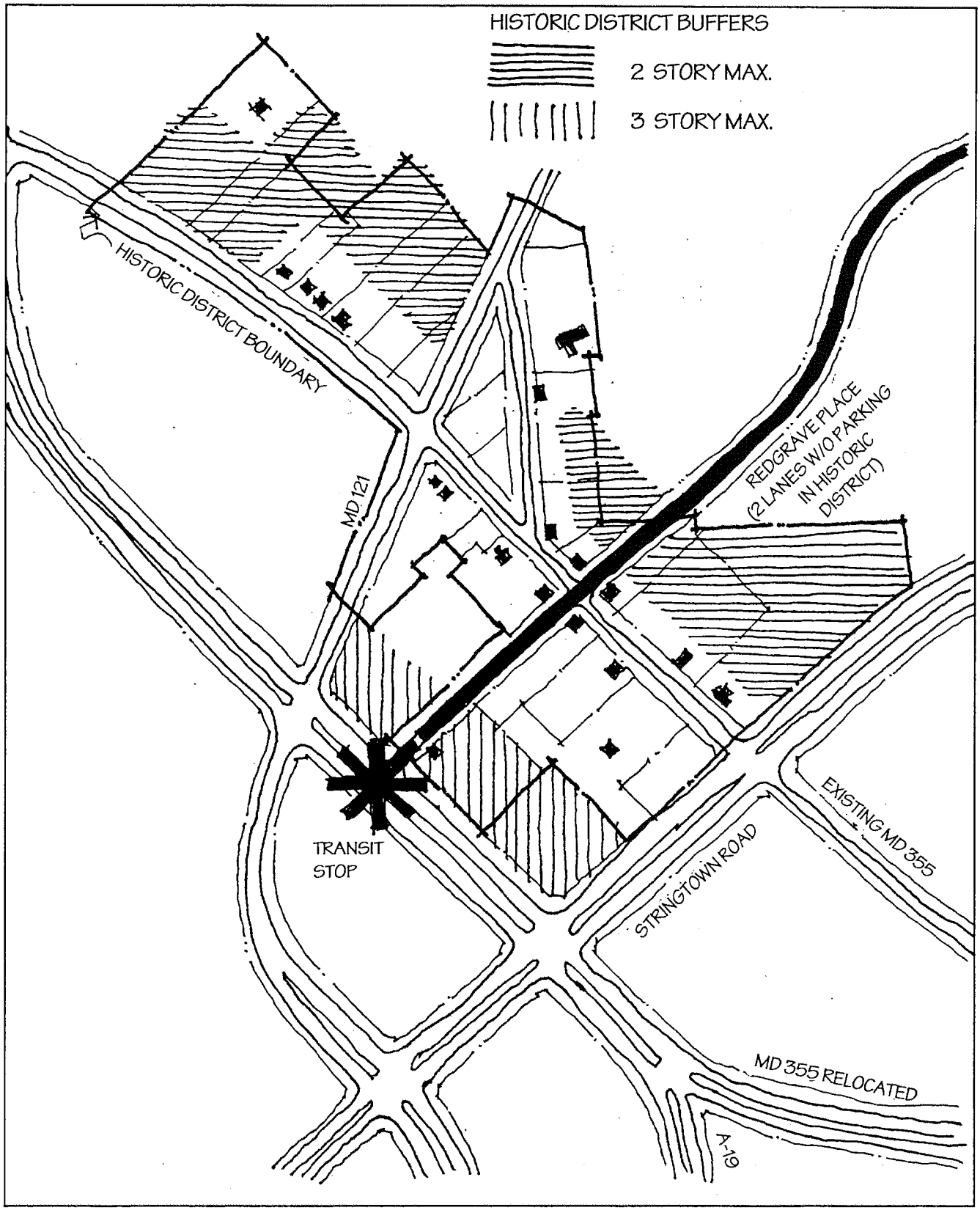
  - Redgrave Place.

  - The open space element in the triangle formed by the intersection of Old Frederick Road, Clarksburg Road, and Spire Street.

  The location, design, and size of community services and community facilities should reflect the more concentrated development pattern proposed for the Town Center. Facilities should be planned in this context and be

Clarksburg Historic District Buffers

Figure 21



land intensive and pedestrian-oriented; the same Plan principles which guide private development should also guide public uses.

- **Create a transit-oriented land use pattern within the Town Center and link all portions of the Town Center with transitways, bus loops, bikeways, and pedestrian-oriented streets.**

  This Plan seeks to achieve a balance between transit-oriented densities and a town scale of development.

  A **transit stop** is proposed in the Town Center west of the historic district on Redgrave Place and A-19. Clarksburg Elementary School is located here. Although this Plan endorses the long-term future replacement of this school at another location, the continued operation of the school is anticipated for many years to come (see Public Facilities chapter). Clustering residential uses close to the transit stop will allow residents to walk to transit. A portion of the historic district as well as the mixed-use neighborhood proposed east of the district will also be within walking distance.

  In the balance of the Town Center, development will be oriented to streets which function as "neighborhood bus loops" so that residents in these areas will be within walking distance of bus stops. Buildings that allow access and frontage to be oriented to the street system should be provided.

  Recreational bikeways should be provided along the Little Seneca Creek greenway. Additional bikeways should be provided along Stringtown Road, MD 121, and Observation Drive to provide access to the transit stop.

- **Create a land use pattern that is responsive to environmental concerns relating to traffic noise and protective of headwaters.**

  The Land Use Plan for the Town Center balances community-building objectives with environmental concerns.

  The key environmental constraints are located between MD 355 and I-270 and include noise affected areas along I-270 as well as the headwaters of the Ten Mile Creek (see Environmental Plan chapter). The land use and density pattern focuses development in a relatively small area around a proposed transit stop and proposes substantially reduced densities (2-4 units per acre) elsewhere in the headwaters area of Ten Mile Creek.

- **Encourage an interconnected street system as typically found in older towns.**

  An important planning concern within the Town Center relates to the **roadway system.** The Town Center is a very large geographic area (about 635 acres; for purposes of comparison, the Germantown Town Center is about 350 acres). Roadways will be critical to the efficient movement of traffic through and within the Town Center. If too many of these roadways are

characterized by cross-sections which discourage pedestrian crossing, then the creation of a unified Town Center will be difficult. For this reason, the Land Use Plan Concept for the Town Center recommends a "high density" network of smaller roads. This strategy will foster an interconnected street system, so important to transit serviceability, and so essential to a "pedestrian-friendly" Town Center.

The Illustrative Sketch shows the pattern of small blocks and interconnected street systems that provide access for pedestrians, bicyclists, and vehicles to all areas of the Town Center including the transit facilities (see Figure 20, page 45).

Roadways designed to carry heavy volumes of traffic will still be needed and the Land Use Plan designates Observation Drive (A-19) and Midcounty Highway (A-305) to serve that function through the Town Center. I-270, which lies on the western edge, is envisioned as the major carrier of regional through traffic.

It is essential that the **character of the roadway network** is supportive of the Plan's vision for the Town Center. The guidelines below will help assure that streets and highways are built in a manner that is compatible with land use and urban design objectives for the Town Center.

- **Arterials** — Because the arterials of Stringtown Road and Clarksburg Road serve as entrances to the Town Center, extensive landscaping, including medians, bikeways, and bus transit access facilities, must be provided. Setbacks from the Midcounty Highway (A-305) should be provided within the Town Center to establish a "parkway like" character.

- **Connecting Streets** — Observation Drive Extended and MD 355 serve as special streets in the Town Center. Figure 11 shows the character of Observation Drive. MD 355 should be located away from the existing historic resources to reduce the impact on the historic district. Revisions to the Road Code will be necessary to meet these guidelines.

- **Local Streets** — The local streets must provide a system of interconnected streets which allow on-street parking, close spacing of intersections, and enhancement of the areas outside the traffic lanes. Revisions to the Road Code will be necessary to meet this guideline. Two key local streets that require revisions to the Road Code include Old Frederick Road to maintain a narrow open section street appropriate in scale to the historic district, and the narrow Redgrave Place that provides access to the transit stop from the districts in the Town Center.

- **Create a special character for Redgrave Place as it traverses the Clarksburg Historic District.**

Redgrave Place will provide needed east-west movement through the historic district and help integrate the district into the larger Town Center.

However, it is essential that the scale, character, and location of this connection is developed appropriately.

The road should be a maximum of two lanes or 24 feet in width. It should have no parking lanes along the portions of the road which are in the historic district. The radius of the intersection corners should match the existing corners located on the west side of MD 355. Efforts should be made to design the road and the intersection as a low volume, local road which will not detract from the character of the historic district (see Figure 21, page 50).

Redgrave Place will provide access from a proposed mixed-use neighborhood east of the historic district to a future transit stop. This Plan supports this connection but emphasizes that auto access to the stop should be secondary to the Plan objective that Redgrave Place be a low-volume, local road. Redgrave Place should not provide through access beyond MD 355 to A-19.

- **Provide a variety of open space features.**

The Town Center is traversed by a portion of the Little Seneca greenway. This greenway will be a major open space feature in the Town Center, making it important that the greenway be visible and accessible to the public. Sidewalks and bikeways should be located outside the stream buffer along the greenway. A strong connection between the transit stop and the greenway is particularly critical to enhance pedestrian and bicycle access between the greenway and the transit stop. The width of the greenway should be the minimum width needed to provide a trail system, but should not be any wider than necessary in Town Center.

While the greenway is the dominant open space feature, other smaller open space areas are also proposed. These include:

- Forested conservation areas along streams.

- Green space within the historic district in front of the Clarksburg United Methodist Church, a highly visible entry point at the intersection of Clarksburg Road and MD 355.

A park is already located in the Town Center (Kings Pond Local Park) which will provide active recreation opportunities.

Ten Mile Creek Area (3,590 Acres)

As noted in the Environmental Plan chapter, the 3,590-acre Ten Mile Creek Area has characteristics which make it environmentally sensitive, including extensive woodlands, fragile stream banks, and steep slopes.

The Land Use Plan proposed for this area is shown in Figure 34, page 88.

Plan Objectives:

- **Recommend a land use pattern west of Ten Mile Creek which is supportive of the larger Agricultural Reserve.**

  The Ten Mile Creek Area adjoins a portion of the County-wide Agricultural Reserve described in the *Functional Master Plan for the Preservation of Agriculture and Rural Open Space in Montgomery County* as the "Central Sector." The central sector is described in the *Functional Master Plan for Agriculture and Open Space* as follows:

  > This 36,000-acre sector is the pivotal point in Montgomery County's agricultural and rural open space preservation program . . . Pressure to develop this area is expected to increase because of its natural beauty and as employment opportunities move northward along the I-270 corridor. An aggressive preservation program should be focused on this area.

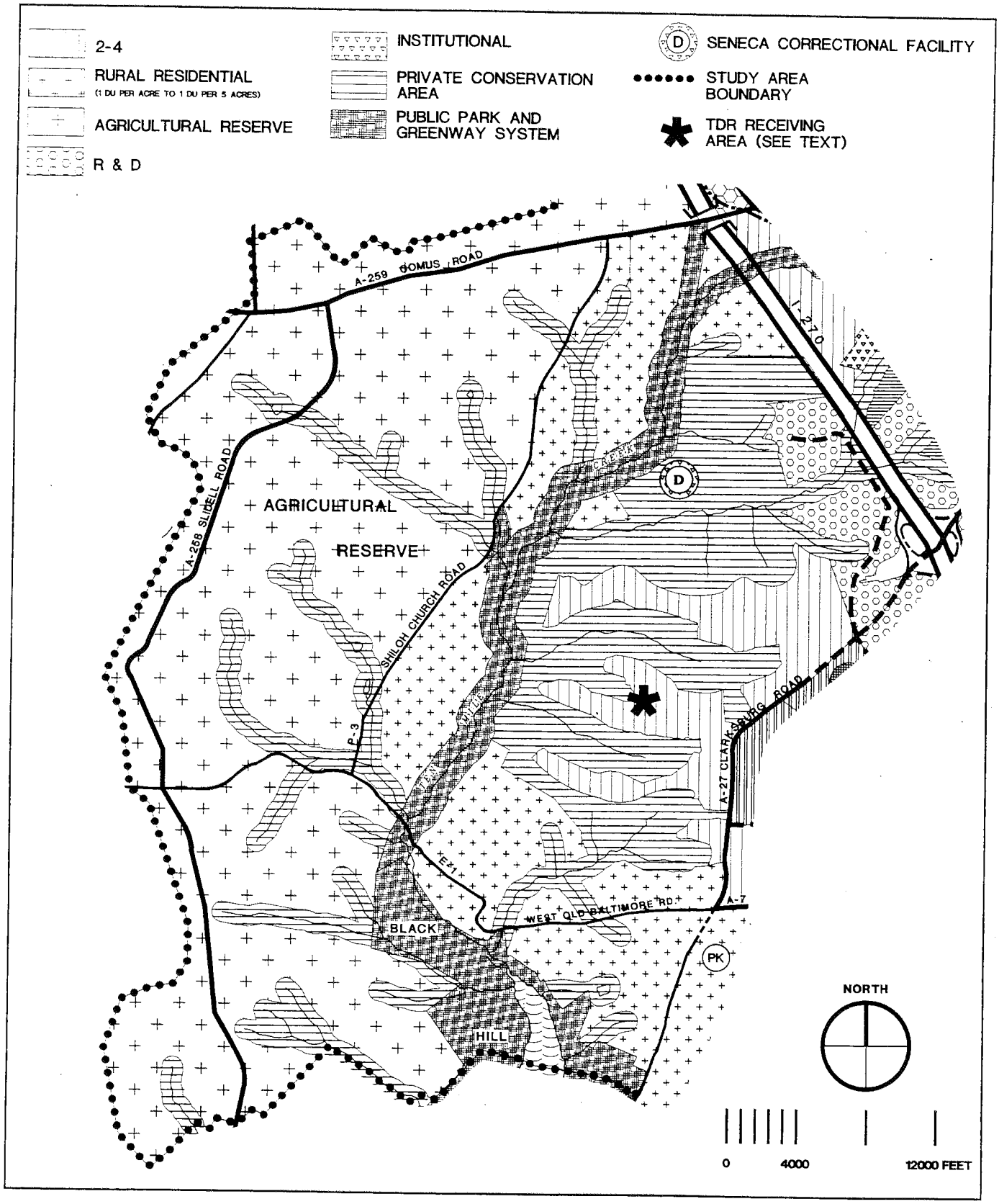
  The Functional Master Plan for Agriculture and Open Space concludes that a new Master Plan for the Clarksburg Study Area should be prepared that "examines Clarksburg's potential for agricultural preservation."

  This Plan focuses on the area west of Ten Mile Creek as the most critical in terms of helping to preserve the larger Agricultural Reserve. The existing land use pattern is dominated by very large parcels and has traditionally been a farming community. Although the suitability of soils for farming varies from poor to good (see Figure 35, page 90), the importance of this area to County-wide agricultural preservation is significant because it forms a critical transition from the I-270 Corridor to the very productive farmland of western Montgomery County. For this reason, this Plan recommends approximately 1,800 acres west of Ten Mile Creek be added to the County's Agricultural Reserve area.

  Alternative rural land use patterns were considered in this area but rejected as being inconsistent with farmland preservation objectives.

Ten Mile Creek Area Land Use Plan

Figure 34



- **Recommend a land use pattern east of Ten Mile Creek which balances environmental concerns, County housing needs, and the importance of I-270 as a high-technology employment corridor.**

  Because this area is separated from the larger Agricultural Reserve by Ten Mile Creek, agricultural preservation is not the primary objective. The key land use objective in this area is to provide housing and job opportunities while mitigating water quality impacts in Ten Mile Creek. An open space pattern extensive enough to help protect the many natural attributes of the larger watershed is recommended by this Plan.

  A more detailed discussion of the environmental characteristics and concerns in this area is included in the Environmental Plan chapter. During the Master Plan process, the importance of protecting these environmental resources was weighed against competing County needs, in particular, the long term County-wide need for additional areas for single-family detached housing and the future of I-270 as a significant employment corridor.

  This Plan recommends an extensive level of environmental mitigation because all of the environmental studies done as part of this Master Plan process have identified Ten Mile Creek as a fragile stream due to its delicate ecosystem, low base flow, and highly erodible stream banks. In this respect, Ten Mile Creek differs from other streams in the Study Area and merits special consideration.

- **Recommend employment sites along I-270 and include development criteria to help address environmental concerns.**

  Two employment sites are recommended in this area; both front I-270 and are in close proximity and have good access to the I-270/MD 121 interchange.

  The character of development at these sites is very important given their location in the Ten Mile Creek Sub-basin. (See Environmental Plan chapter, page 137.) The following guidelines are intended to foster environmentally sensitive site plans when these sites develop:

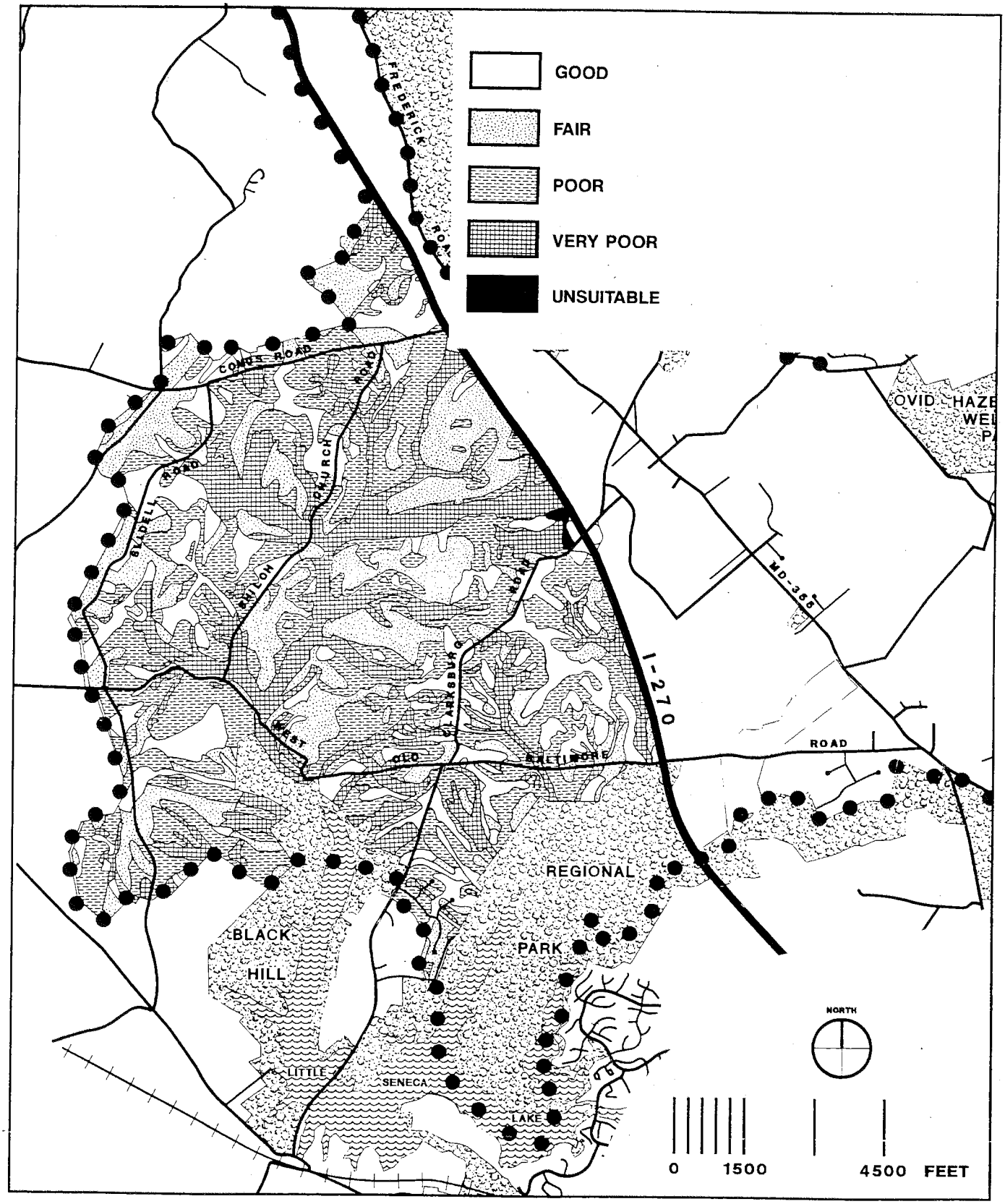
  - Each site shall have no more than 400,000 square feet of floor area.

  - An imperviousness limit of 15 percent shall apply to the entirety of each site (this coverage shall be calculated over the entire property — not just the portion which is zoned for industrial, see Figure 36, page 93).

  - Development plans should include tightly clustered buildings close to I-270 to promote transit serviceability.

Soil Suitabilities for Agriculture West of I-270

Figure 35



- Both sites will require improved access from MD 121 once development occurs and I-270 improvements require relocation of Whelan Lane (the current access). The Master Plan recommends relocated Whelan Lane to be kept as close to the existing alignment as possible to minimize new stream crossings.

- **Recommend residential land uses west of MD 121 and include development guidelines to help address environmental concerns and to assure a predominance of single-family detached units.**

  This Plan recommends that approximately 600 acres be designated RE-1/TDR with a base density of one unit per acre — the density recommended by the 1968 Clarksburg Master Plan but never implemented.

  Up to 900 dwelling units would be appropriate through the purchase of TDR's if the following environmental and housing mix guidelines can be achieved.

  - Development should achieve a minimum of 70 percent single-family detached units. The Montgomery County Office of Planning Implementation has documented the need for single-family detached lots to meet projected future market demand. Master Plan guidelines will help assure this type of development occurs in this area.

  - The open space and conservation areas along Ten Mile Creek's mainstem and tributaries shown on the Master Plan should remain undeveloped and should be afforested.

  - Dedication to M-NCPPC will be required for the open space and conservation areas along Ten Mile Creek's mainstem. At the time of subdivision, M-NCPPC will decide whether the open space along the tributaries will also be required for dedication to parkland or will become homeowners associations' common land.

  - There may be a need for future study of possible water reservoir sites and Ten Mile Creek is identified as a potential study site. Therefore, this development should be able to accommodate a possible future reservoir within the open space shown on the Master Plan.

- **Provide general guidance in terms of future potential uses of County-owned land (Site 30).**

  Montgomery County owns a 300-acre site known as Site 30.

  This Plan recommends the following land use pattern for this site:

  - The portion of the property fronting I-270 is recommended for office or R&D uses, not to exceed 400,000 square feet of floor area.

- A publicly owned facility could be accommodated elsewhere on the property. A detention center for minimum to medium security inmates (the Seneca Correctional Facility) is presently planned for Site 30. If the detention center is located elsewhere, then an alternative public use of similar scale and intensity may be appropriate.

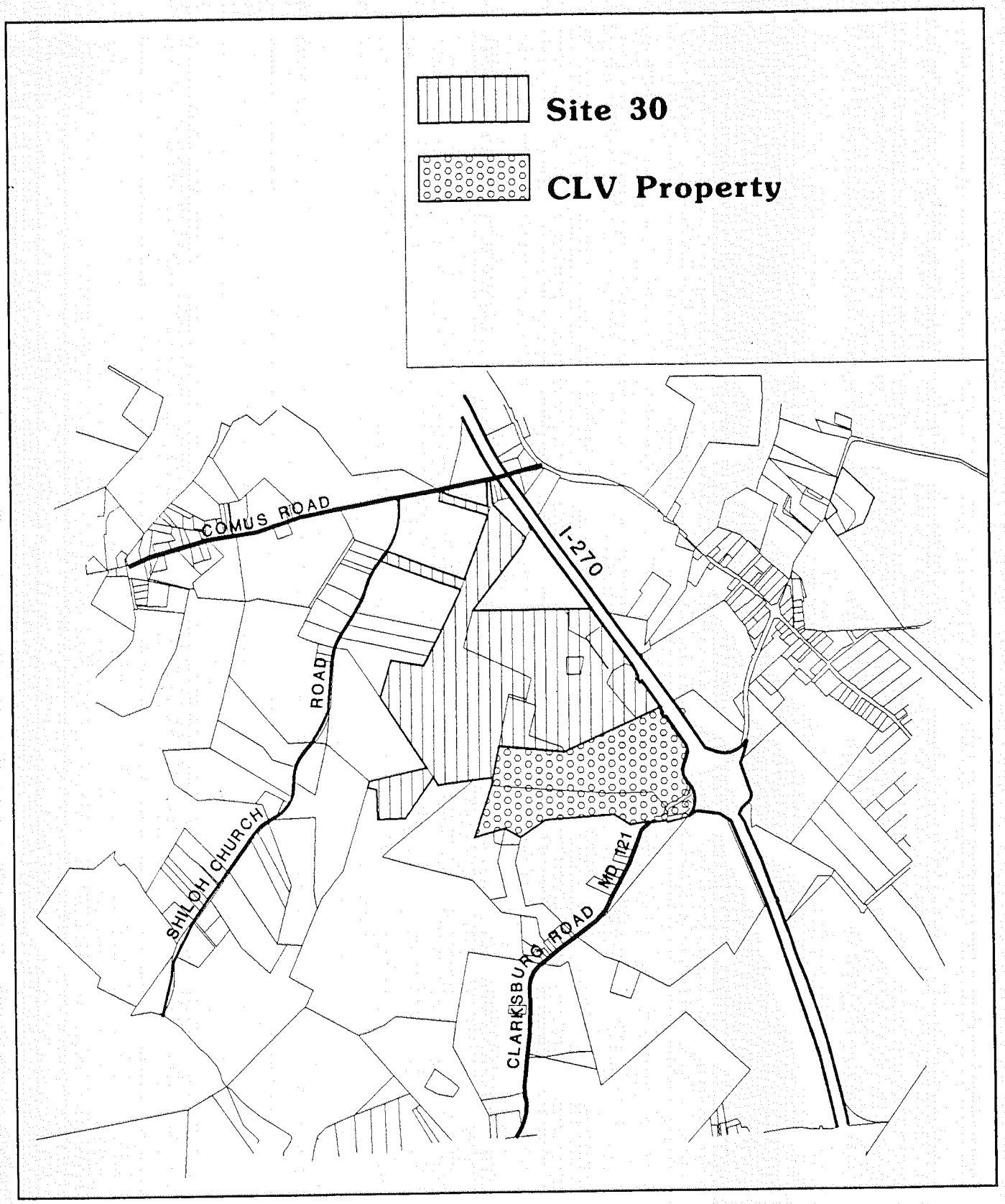
This Plan recommends that the ultimate development of Site 30 include the following elements:

- The greenway proposed along Ten Mile Creek.
- Preservation of the Moneysworth Farm historic site on the property (adaptive re-use of the building is encouraged).
- A compatible transition to surrounding rural and open space uses.
- No access to Shiloh Church because a significant stream crossing would be required.
- Designation of a significant portion of Site 30 as open space.
- Impervious surfaces shall not exceed 15 percent for the entirety of Site 30 (including public and private uses).

Because of the many environmental constraints on Site 30, its location in a sensitive watershed, and the rural/agricultural character of surrounding land uses, evaluating whether a particular public facility is suitable at Site 30 must occur as part of a well defined planning process. Such a process should include citizen participation and involve other governmental review agencies as early in the process as possible.

Areas Affected by Master Plan Recommended 15% Impervious Limits

Figure 36



- **All the Master Plan's environmental studies agree that Ten Mile Creek exhibits characteristics that make it most prone to environmental degradation from development.**

  In addition to the consultant studies, the Montgomery County Department of Parks produced its own assessment of the quality of natural resources in the Little Seneca Lake sub-watershed, based on existing data and some field work. The study found that the three sub-watersheds have markedly different characteristics in terms of tree cover, steep slopes, and habitat for birds and aquatic life. Overall, Ten Mile Creek was ranked as the most important watershed because it had the best or most extensive natural resources and the highest potential for undesirable development effects. Little Seneca Creek was ranked slightly behind Ten Mile Creek, and Cabin Branch was ranked third. This data reinforces the consultant study findings that this area is sensitive to degradation.

- **Certain environmental features in this Study Area pose development constraints.**

  The map shown as Figure 45 ranks environmental constraints such as steep slopes, floodplains, and poor soils in terms of their effect on development potential.

  The greatest constraints are in the stream valleys. The least constrained areas are located east of I-270. The Study Area west of I-270 with the exception of the Cabin Branch Neighborhood, displays a pattern of moderate to severe constraints. The Hyattstown Special Study Area is also highly constrained.

  The sensitive areas required to be protected under the 1992 Maryland Planning Act (streams and their buffers, floodplains, steep slopes, and known habitats of threatened or endangered species or species in need of conservation) are included in the areas shown in Figure 46.

Plan Recommendations Relating to Watershed and Sensitive Areas Protection

To protect and enhance the Little Seneca Lake watershed and its sensitive environmental areas, this Plan:

- **Considers the special qualities of Ten Mile Creek Area.**

  About 64 percent of the Ten Mile Creek watershed is designated for farmland preservation or rural uses. This recommendation supports the environmental objectives which emphasize that low-density land use patterns and appropriate Best Management Practices (BMPs) are the most effective strategies for maintaining water quality. Elsewhere in the watershed, the

land use plan objectives make environmental mitigation the main focus. The following mitigation strategies are recommended in these areas:

1. In the Town Center District, residential densities beyond transit stop walking distances are lowered, and a limit is imposed on employment uses.

2. West of I-270, a 15 percent imperviousness cap and a square footage cap are placed on employment uses.

3. Extensive green space beyond standard stream buffers is recommended for the area bounded by Ten Mile Creek and MD 121 where substantial development is proposed. This expanded green space, as shown in the Land Use Plan, will become part of the undisturbed stream buffer and should be afforested/reforested by the developers during the subdivision process, if not earlier.

4. Public parkland dedication will be required for the Ten Mile Creek mainstem stream buffers and possibly for buffers for the first and second order tributaries.

5. Public uses on Site 30 are limited to a size and intensity similar to the County detention center now under consideration. Site 30 will be subject to the same environmental requirements and constraints as comparable development west of I-270 in Ten Mile Creek, including the employment limits and imperviousness cap mentioned above.

- **Designates a forested buffer along all streams.**

  All development in the County is required to protect stream buffers along perennial and intermittent streams as part of the Planning Board approval of subdivisions. The Plan endorses public acquisition of key stream valleys along their mainstems. In Clarksburg, it is essential that these buffers be forested for the environmental reasons described earlier. The Master Plan strongly encourages landowners to allow stream buffer areas within 175 feet of the stream to remain undisturbed and to permit trees to regenerate if the area is not presently wooded.

- **Protects environmentally sensitive areas such as mature hardwood forests, wetlands, areas of unique vegetation, and prime wildlife habitat.**

  Trees in the natural landscape filter groundwater, reduce surface runoff, help alleviate flooding, and supply necessary habitat for wildlife. Trees improve the quality of life within communities by providing for recreation, aesthetics, climate control, and beautification. They can reduce the cost of home cooling and heating, and also protect a temperature sensitive ecosystem by shading. The Master Plan's environmental analysis underscores the importance of tree cover to water quality in the form of continuous forested buffers along stream valleys. The Master Plan responds to the importance of

preserving large contiguous areas of trees by keeping the most heavily wooded areas, which are west of I-270, in low density rural and agricultural uses.

Recently adopted state and County legislation require that forest and tree conservation be a part of future development projects in the County and Clarksburg. Forest conservation measures include avoiding tree clearing, minimizing the amount of trees lost, and replacing trees that are unavoidably cleared. A major goal of the forest conservation program is to ensure that tree saving and tree planting (reforestation and afforestation) occur in priority areas on the developing properties. When this is not possible, the required planting can be done off-site within the same watershed, and as a last resort, payment of a fee to a tree fund in lieu of planting is acceptable. The tree fund would be used by the County for reforestation projects.

- **Supports a "no net loss of wetlands" policy.**

  The Master Plan recognizes the critical role of wetlands by recommending a "no net loss" objective and endorsing the preparation of a Nontidal Wetlands Functional Assessment (NWFA). Montgomery County Planning Department staff and staff of the Nontidal Wetlands Division of the Maryland State Department of Natural Resources are working together to produce an NWFA for Clarksburg. The NWFA will identify the locations of existing wetlands and potential mitigation sites, and assess the functions and values of the wetlands. The NWFA will comprehensively consider potential impact areas and possible alternatives throughout Clarksburg prior to the piecemeal regulatory process with an emphasis on preserving the highest quality wetland resources.

- **Recommends modifications to the M-NCPPC "Environmental Guidelines" for the review of subdivisions to assure that existing high water quality standards can be maintained.**

  The Master Plan strives to meet the state's goals of maintaining or improving existing water quality by first minimizing new development as much as possible in the most sensitive watersheds. Where environmental impacts from significant development and/or major roads are expected, the Plan designates "Special Protection Areas" (SPA). The M-NCPPC "Guidelines for Environmental Management of Development in Montgomery County" should be amended to include additional objectives in Special Protection Areas. This will promote environmentally sensitive design and construction of development and infrastructure in Clarksburg. Water quality monitoring may also be a requirement for certain developments, as specified in the proposed Water Quality Review Process.

  The type of amendments needed for the Guidelines for Environmental Management to implement this recommendation are discussed in the Implementation chapter.

- **Maintains the environmental qualities of headwater streams to prevent increases in water pollution, flooding, and stream erosion and sedimentation.**

  Headwaters are the principal source of watercourses that can be defined as first and second order streams. They often originate from springs, seeps or other wetlands and they are found throughout the Study Area at the most upstream end of each stream segment. The result is that most sites are fairly close to a headwater area, which makes complete avoidance very difficult. These tiny streams are vulnerable to land use changes within their drainage basins because of their size and small dilution capacity, especially when the natural baseflow is overwhelmed by a much larger quantity of storm runoff. Degradation of a headwater area can adversely affect the water quality and aquatic habitat of the immediate area. It can also harm downstream reaches, especially if the effects occur near the top of the watershed. Headwaters that drain to the middle or bottom of a watershed can be buffered to a certain extent by the greater baseflow of the stream's mainstem. For these reasons, headwaters near the top of the watershed should receive the highest degree of protection possible.

  Sensitive headwaters are affected in Ten Mile Creek by the development of the west side of Town Center and between I-270 and the Creek as well as a small portion of the Transit Corridor Area. Headwaters in Wildcat Branch in the Great Seneca Creek watershed are affected by M-83. These areas are included in the Special Protection Area (SPA) designation. (See Implemen-tation Strategies chapter.)

- **Endorses agricultural BMPs in strict accord with the practices prescribed by the Maryland Department of Agriculture and Montgomery Soil Conservation District.**

  One of the current sources of stream pollution in the Study Area is agricultural runoff. Although agricultural conservation practices are encouraged, speculative land ownership in the watershed has made the establishment of such practices very difficult. This arrangement maintains the landowner's agricultural assessment by making short term or annual farm leases until the land value proves profitable for development. The result is a resistance from farmers to spend time or money developing BMPs on land that they may not be using in the near future. In recent years, with the development of the Little Seneca Lake area, the number of speculative land holders has increased. Establishing a land use pattern with clearly defined agricultural areas will remove some of the incentive for speculative use of the land.

  The Montgomery Soil Conservation District offers free technical assistance with the development and implementation of a soil conservation and water quality plan. This voluntary program relies on the renter/landowner to contact District staff, who visit the property to determine which BMPs might reduce agricultural non-point source pollution.

Popular practices such as conservation tillage, grass waterways, nutrient management systems, animal waste control structures, and planting of stream buffers are often used. If farming increases in the Clarksburg area, it will be even more important to stream quality that as many agricultural BMPs as possible are implemented.

Maryland is currently designing bay-wide tributary protection strategies as part of the initiatives for implementing nutrient reduction goals for the Chesapeake Bay. The Master Plan supports efforts by state and local agencies to offer more assistance in providing agricultural BMPs throughout the County and encourages farmers to participate in the many programs available. These agencies have shown that conservation and water quality plans can be significant cost-savers to farmers as well as very effective environmental management tools.

A summary of the key protection strategies for the watersheds is contained in Table 11.

Relation of Environmental Plan to 1992 Maryland Planning Act

The 1992 Maryland Planning Act mandates that local plans include a "sensitive areas" element. The intent of the sensitive areas designation is to protect streams and their buffers, 100-year floodplains, habitats of threatened and endangered species, steep slopes, and any other areas identified as sensitive by a local plan. A generalized identification of these areas is shown in Figure 46.

Little Bennett Creek will be further protected because of the limited development proposed by this Plan. Due to its moderate land use density, most of the Cabin Branch watershed is expected to maintain existing conditions with use of fully forested stream buffers and appropriate stormwater management.

In those areas where substantial development is recommended, the Plan uses the Special Protection Area designation to buffer the function of sensitive areas from the effects of that development. This approach is discussed in more detail in the Implementation Strategies chapter and involves amending the M-NCPPC "Environmental Guidelines" for the review of subdivisions.

Plan Recommendations Relating to Area-Wide Environmental Concerns

Groundwater

This Plan:

- **Supports protecting the sole source aquifer from groundwater contamina-**

Ten Mile Creek Amendment
Appendix 2

Description of Modeling Scenarios and Assumptions

Description of Scenarios for Environmental Testing (Scenario 1 was a previous test of the 1994 plan that was discarded due to changed methodologies):

2. **1994 Plan** - The 1994 Clarksburg Master Plan recommendations for density and land use in Stage 4, assuming full Environmental Site Design for the developable and redevelopable properties. The full length and width of the 355 Bypass is included, assuming that minimal bridging will be required.

3. **1994 Plan-Reduced Footprint, Same Yield** - The same as Scenario 1 with a reduced footprint for the Pulte properties. Assumes a different unit mix that would allow approximately the same number of units permitted by the 1994 plan. In addition, the 355 Bypass is shortened, reducing the impact on one stream crossing and adding more developable area to the Miles/Coppola and Egan properties. Imperviousness assumed on the County property is reduced from 15% to 8%.

4. **1994 Plan-Reduced Footprint Lower Yield** - The same as Scenario 3 with the same unit mix as recommended in the 1994 Plan for the Pulte property, resulting in fewer potential units on the Pulte property.

5. **7% Watershed Imperviousness** – The same as Scenario 4 with reduced yield on Miles/Coppola, Egan, Pulte, and the County property is assumed as undeveloped beyond that planned for the Detention Center minor expansion.

All Scenarios include the following assumptions:

- Typical Environmental Site Design as prescribed by County regulations and the Maryland Stormwater Design Manual. For purposes of hydrologic modeling a single type of bioretention practice was chosen as representative of ESD with the following characteristics:
    - Ponding above media – 9”
    - Media depth - 3.5’
    - Maximum infiltration rate = 2”/hr.
    - Minimum infiltration rate = 0.25”/hr.
    - Continuous infiltration rate = 0.05”/hr.
    - Underdrains above stone reservoir with overflow to surface waters reduce potential for infiltration to native soil
    - Gravel bedding – 3” required

- Soil Decompaction per County regulations for all areas disturbed and not covered by buildings, paving or stormwater management. This assumes soils are compacted to represent the next most compacted soil group, then decompacted to be halfway between that and the original soil group.

- Reforestation of unforested stream buffers, with any unforested areas between the stream buffer and the limit of disturbance as meadow in good condition. This was assumed because, while the stream buffer is required to be planted to a high standard and managed to achieve a closed canopy as soon as possible, other unforested areas are more likely to be either managed as meadow or allowed to naturally reforest, taking substantially longer to achieve a closed canopy.

- ESD for all properties along 355 and that are likely to redevelop and for vacant properties.
- ESD is used for the Bypass, but the new lanes on I-270 would use traditional stormwater management due to the ROW constraints and topography.

Scenario Imperviousness Assumptions

Scenario 2 1994 Plan Updated

Development Name	Land Use	Density	Imperviousness Percentage of Disturbed Area	Acres of Disturbed Area	Property Acreage (per GIS polygon)	Imp acres	Gross imp %
Egan/Brookfield	Residential	4 units/ac	50.15%	56.78	100.06	28.47	28.5%
Miles Coppola/Peterson	Office/Residential	50%office 50% res	60.03%	42.46	98.64	25.49	25.8%
County Site	Office	Office	41.56%	45.72	124.77	19.00	15.2%
Pulte	Residential	2 units/ac	33.02%	198.28	523.44	65.48	12.5%
Fire Station	Institutional	NA	37.00%	4.08	4.08	1.51	37.0%
Hammer Hill	Commercial	commercial	30.00%	2.93	2.93	0.88	30.0%
Historic District Commercial	Commercial	NA	80.00%	0.71	0.71	0.57	80.0%
Historic District Residential	Residential	2 units/ac	15.40%	4.46	4.46	0.69	15.4%
Historic District Residential	Residential	2 units/ac	15.40%	7.40	7.40	1.14	15.4%
355 Bypass	Roadway/Transitway	NA	30.40%	38.43	38.43	11.68	30.4%
I-270 widening	Roadway/Transitway	NA	100.00%	3.57	3.57	3.57	99.9%
Rural Properties	Residential	1 unit/5 acres	43.00%	30.93	223.39	13.30	6.0%
Total						171.78	

Approximate Watershed Imperviousness 9.3%

Scenario 3 Reduced Footprints/1994 Unit Mix

Development Name	Land Use	Density	Imperviousness Percentage of Disturbed Area	Acres of Disturbed Area	Property Acreage (per GIS polygon)	Imp acres	Gross imp %
Egan/Brookfield	Residential	4 units/ac	50.15%	61.33	100.06	30.76	30.7%
Miles Coppola/Peterson	Office/Residential	50%office 50% res	60.03%	48.91	98.64	29.36	29.8%
County Site	Office	Office	41.56%	24.67	124.77	10.25	8.2%
Pulte	Residential	2 units/ac	40.00%	119.10	523.44	47.64	9.1%
Fire Station	Institutional	NA	37.00%	4.08	4.08	1.51	37.0%
Hammer Hill	Commercial	commercial	30.00%	2.93	2.93	0.88	30.0%
Historic District Commercial	Commercial	NA	80.00%	0.71	0.71	0.57	80.0%
Historic District Residential	Residential	2 units/ac	15.40%	4.84	4.84	0.75	15.4%
Historic District Residential	Residential	2 units/ac	15.40%	7.40	7.40	1.14	15.4%
355 Bypass	Roadway/Transitway	NA	63.06%	12.40	12.40	7.82	63.1%
I-270 widening	Roadway/Transitway	NA	100.00%	3.57	3.57	3.57	99.9%
Rural Properties	Residential	1 unit/5 acres	43.00%	30.93	223.39	13.30	6.0%
Total Imperviousness						147.54	

Approximate Watershed Imperviousness 8.5%

Scenario 4 Reduced Imperviousness/1994 Unit Mix

Development Name	Land Use	Density	Imperviousness Percentage of Disturbed Area	Acres of Disturbed Area	Property Acreage (per GIS polygon)	Imp acres	Gross imp %
Egan/Brookfield	Residential	4 units/ac	50.15%	61.34	100.06	30.76	30.7%
Miles Coppola/Peterson	Office/Residential	50%office 50% res	60.03%	48.91	98.64	29.36	29.8%
County Site	Office	Office	41.56%	24.62	124.77	10.23	8.2%
Pulte	Residential	1 unit/ac	33.02%	119.00	523.44	39.29	7.5%
Fire Station	Institutional	NA	37.00%	4.08	4.08	1.51	37.0%
Hammer Hill	Commercial	commercial	30.00%	2.93	2.93	0.88	30.0%
Historic District Residential	Residential	2 units/ac	15.40%	4.84	4.84	0.75	15.4%
Historic District Residential	Residential	2 units/ac	15.40%	7.40	7.40	1.14	15.4%
Historic District Commercial	Commercial	NA	80.00%	0.71	0.71	0.57	80.0%
355 Bypass	Roadway/Transitway	NA	63.06%	12.40	12.40	7.82	63.1%
I-270 widening	Roadway/Transitway	NA	100.00%	3.57	3.57	3.57	99.9%
Rural Properties	Residential	1 unit/5 acres	43.00%	30.93	223.39	13.30	6.0%
Total						139.18	

Approximate Watershed Imperviousness 8.4%

Scenario 5 Seven Percent Overall Imperviousness

Development Name	Land Use	Density	Imperviousness Percentage of Disturbed Area	Acres of Disturbed Area	Property Acreage (per GIS polygon)	Imp acres	Gross imp %
Egan/Brookfield	Residential	2 units/ac	32.60%	61.34	100.06	20.00	20.0%
Miles Coppola/Peterson	Office/Residential	50%office 50% res	40.90%	49.82	98.64	20.00	20.3%
County Site	Office	Office	0.00%	24.62	124.77	0.00	0.0%
Pulte	Residential	1 unit/ac	31.00%	119.00	523.44	36.89	7.0%
Fire Station	Institutional	NA	37.00%	4.08	4.08	1.51	37.0%
Hammer Hill	Commercial	commercial	30.00%	2.93	2.93	0.88	30.0%
Historic District Residential	Residential	2 units/ac	15.40%	4.84	4.84	0.75	15.4%
Historic District Residential	Residential	2 units/ac	15.40%	7.40	7.40	1.14	15.4%
Historic District Commercial	Commercial	NA	80.00%	0.71	0.71	0.57	80.0%
355 Bypass	Roadway/Transitway	NA	57.3%	10.47	10.47	6.00	57.3%
I-270 widening	Roadway/Transitway	NA	100.00%	3.57	3.57	3.57	99.9%
Rural Properties	Residential	1 unit/5 acres	43.00%	19		8.00	6.4%
Total						99.31	

Approximate Watershed Imperviousness 7.0%

Description of Scenarios for Transportation Testing

A. 2040 No-Bypass – This projects traffic assuming growth according to the Round 8.1 forecast based on existing and planned zoning from the 1994 Clarksburg Master Plan. While it assumes an improved interchange at I-270 and 121 and two additional lanes on I-270 north of the interchange, it does not include a bypass of 355.

B. 2040 – This is the same as above, assuming the four-lane bypass is built.

C. 2040 High No-Bypass – This projects traffic the same as Scenario A, but substitutes retail uses as proposed by developers on the Miles/Coppola property and in Cabin Branch for the office uses in A and B.

D. 2040 High – This is the same as C, but with the bypass of 355.

Ten Mile Creek Amendment
Appendix 3

Ten Mile Creek Watershed Environmental Analysis

Ten Mile Creek Watershed Environmental Analysis

In Support of the Limited Amendment to the Clarksburg Master Plan

Prepared for:

Maryland-National Capital Park & Planning Commission
Montgomery County Planning Department

Prepared by:

Biohabitats
Brown AND Caldwell
A Joint Venture

July 3, 2013

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Attachment B. Existing Conditions in the Ten Mile Creek Study Area
Attachment C. Trend Analysis of Little Seneca Creek Benthic and Habitat Assessment Data
Attachment D. Environmental Site Design Literature Review
Attachment E. Spatial Watershed Analysis
Attachment F. Pollutant Load Modeling Assumptions
Attachment G. Pollutant Load Modeling Results
Attachment H. Hydrology and Hydraulics Analysis – Computations and Model Output for Existing Conditions and Four Development Scenarios

1.0 Objectives

The Ten Mile Creek watershed in northwestern Montgomery County is the focus of an environmental analysis study in support of the Limited Amendment to the Clarksburg Master Plan, being undertaken by the Maryland-National Capital Park and Planning Commission (M-NCPPC) Montgomery County Planning Department. This environmental analysis is being conducted for the Planning Department by Biohabitats and Brown and Caldwell, a Joint Venture, with support from the Center for Watershed Protection. It is being done in collaboration with Montgomery County Department of Environmental Protection (DEP) and Montgomery County Department of Permitting Services (DPS).

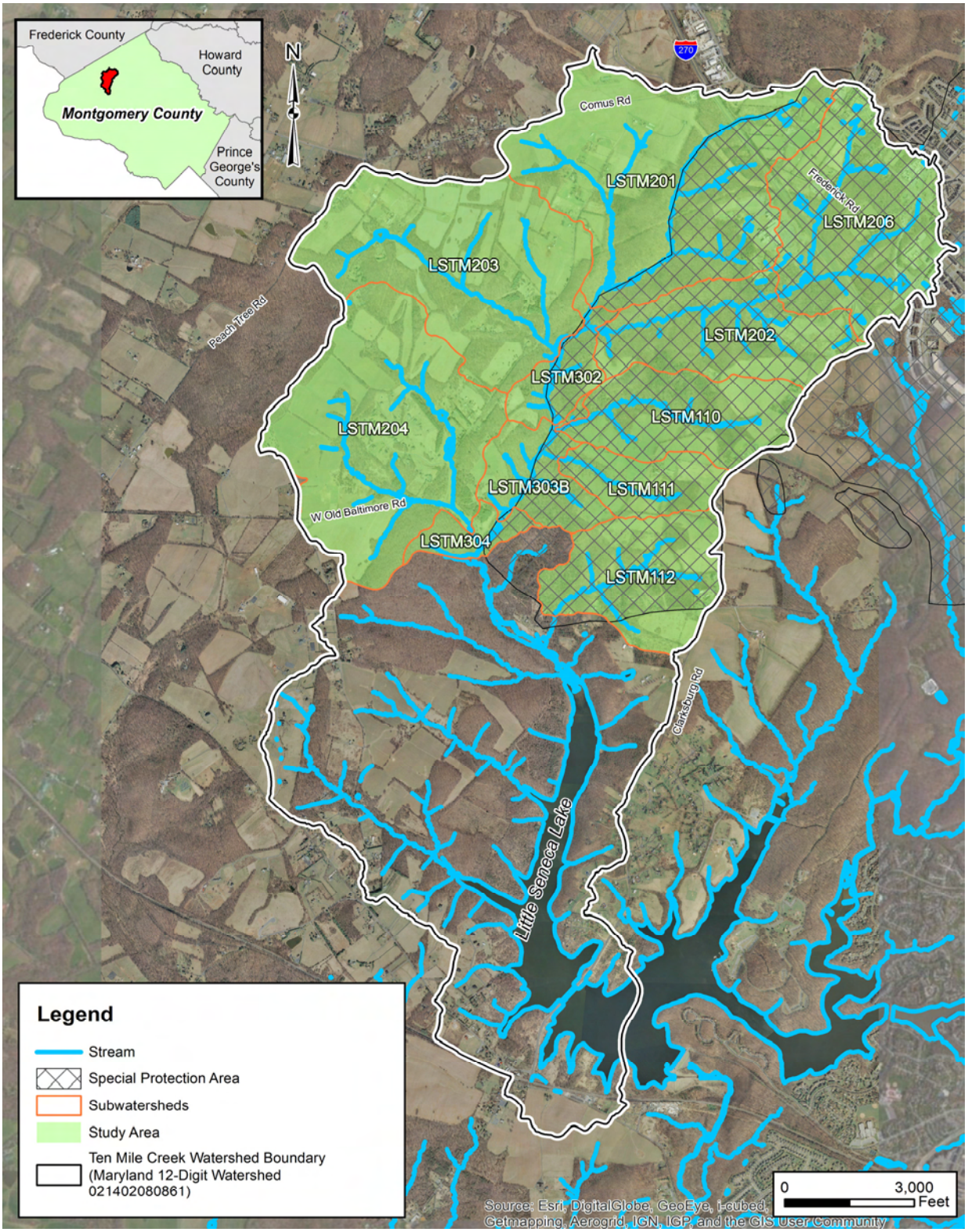
The purpose of this study is to document existing conditions and to evaluate potential watershed response to development within the Ten Mile Creek watershed. As such, analyses focus only on subwatersheds upstream of the existing USGS gage station and those that have the potential to be directly affected by development. These subwatersheds are referred to as the Ten Mile Creek "study area." The Ten Mile Creek study area drains approximately 4.8 square miles of primarily rural and forested lands in Montgomery County, flowing from its headwaters just north of Frederick Road to Little Seneca Lake.

The Planning Department crafted four scenarios for future development within the watershed. Five watershed scenarios were analyzed, including:

- Scenario 1: Existing Conditions – The baseline for these analyses is existing conditions within the watershed. This includes current land use, land cover and watershed infrastructure.
- Scenario 2: 1994 Plan – The 1994 Clarksburg Master Plan recommendations for density and land use in Stage 4, assuming full Environmental Site Design for the developable and redevelopable properties.
- Scenario 3: Reduced Footprint, Same Yield – The same as Scenario 2 with a reduced footprint for the Pulte properties. Assumes a different unit mix that would allow approximately the same number of units permitted by the 1994 Plan.
- Scenario 4: Reduced Footprint Lower Yield – The same as Scenario 3 with the same unit mix as recommended in the 1994 Plan for the Pulte property, resulting in fewer potential units on Pulte.
- Scenario 5: 7% Watershed Imperviousness – The same as Scenario 3 with reduced yield on Miles/Coppola, Egan, and the County properties.

This document sets forth the findings of these analyses and recommendations for the Planning Department to consider in formulating the Limited Amendment. Summaries of analyses results for subwatersheds are provided at the end of this memorandum. More detail on analysis methods and results is provided in documents previously produced for this study. These are included as attachments:

- Attachment A. Ten Mile Creek Subwatershed Profiles (Report)
- Attachment B. Existing Conditions in the Ten Mile Creek Study Area (Technical Memorandum)
- Attachment C. Trend Analysis of Little Seneca Creek Benthic and Habitat Assessment Data (Technical Memorandum)
- Attachment D. Environmental Site Design Literature Review (Technical Memorandum)
- Attachment E. Spatial Watershed Analysis (Technical Memorandum)
- Attachment F. Pollutant Load Modeling Assumptions (Technical Memorandum)
- Attachment G. Pollutant Load Modeling Results (Technical Memorandum)
- Attachment H. Hydrology and Hydraulics Analysis – Computations and Model Output for Existing Conditions and Four Development Scenarios (Technical Memorandum)



Ten Mile Creek Watershed and Subwatersheds

2.0 Approach to Analyses



The effects of development and land use change on watershed health and stream quality cannot be measured by any single factor. Five factors are generally considered when evaluating watersheds:

- Geomorphology, or stream channel form and stability
- Water quality
- Hydrology, or stream flow
- Habitat, both within the stream and its contributing upland drainage area
- Biology

Development and land use change have the potential to both directly and indirectly impact any of these five watershed factors. In addition, these factors are interdependent whereby impacts to one will influence the other four. For instance, increasing development within a watershed will increase the volume of stormwater runoff to a stream. This change in ***hydrology*** will result in higher and faster stream flows, which will increase channel erosion and change the stream's form, or ***geomorphology***. Sediment from eroded stream channels will be transported downstream, decreasing ***water quality***. In addition, the change in channel form will adversely affect ***habitat*** needed by fish and other aquatic organisms that live in the stream, resulting in an impact on stream ***biology***. The health of a watershed is also influenced by upland ecologies and overall biodiversity. Attributes such as interior forest and ecological hubs and corridors contribute to enhanced biodiversity and as a result system resiliency, providing degrees of protection against watershed adjustments, such as land use change.

Due to the complexity of natural systems, no single model or analytical tool can reliably predict the impacts of development on watershed conditions or the resulting changes in the biological communities which provide indicators of overall stream conditions. Therefore, several analytical methods were used evaluate potential watershed response to different development scenarios, as illustrated below. A Spatial Watershed Analysis identified potential direct impacts to areas of high natural value that provide habitat and support stream quality and watershed health. Pollutant load modeling assessed changes in pollutant loads as a result of development. Hydrologic modeling predicted potential change in stormwater runoff volumes and stream flows. All analyses used existing conditions as the baseline for comparison. These analyses were supplemented by a detailed review of existing watershed conditions and a literature review of the most recent research related to the impacts of development on watersheds and the effectiveness of sediment and stormwater control practices. The findings from these analyses are described in the following section.

Analysis Tool	Watershed Health Indicator				
	Hydrology	Geomorphology	Water Quality	Habitat	Biology
Natural Resource Impacts	O	X	O	X	O
Spatial Watershed Analysis				X	O
Pollutant Load Modeling			X	O	O
Hydrologic Modeling	X	O		O	O

X = Analysis tool projects potential impacts
O = Analysis results allow us to infer potential impacts

3.0 Findings

3.1 Existing Conditions within the Ten Mile Creek Study Area

The Ten Mile Creek watershed is located in the Clarksburg area of northwestern Montgomery County. Ten Mile Creek originates just north of MD 335 (Frederick Road) and flows into Little Seneca Lake, which flows into the Potomac River. Little Seneca Lake serves as a reservoir providing additional flow to the Potomac River, a public raw water supply, during drought periods (Montgomery County Department of Park and Planning, 1994). Ten Mile Creek and its tributaries are designated as a Use I-P stream – protection of water contact recreation, aquatic life and drinking water supply (Montgomery County Department of Park and Planning, 1994).

A portion of the study area, east of Ten Mile Creek mainstem and north of West Old Baltimore Road, is located within the Clarksburg Master Plan Special Protection Area (SPA). The area west of Ten Mile Creek is within the county-wide Agricultural Reserve. A basic profile of the study area is provided in the table below. The study area within Ten Mile Creek includes 11 subwatersheds.

Existing conditions in the Ten Mile Creek were evaluated through review of GIS data and numerous reports and studies of the watershed, as documented in the report *Existing Conditions in the Ten Mile Creek Study Area* (Biohabitats and Brown & Caldwell, 2013). Key watershed characteristics, summarized below, provide context for the development scenario analyses described later in this section.

- Ten Mile Creek is a reference stream in Montgomery County. Long-term monitoring indicates overall biological condition is healthy and diverse. Sensitive 'indicator' organisms that occur in few other areas within the County are found here. It is part of a small group of high quality watersheds still remaining within the County (e.g., many Patuxent River tributaries, Bennett Creek, and Little Bennett Creek).
- The majority of the streams within the watershed are small and spring fed with cool, clean groundwater. The mainstem is characterized by high concentrations of interior forest and wetlands.
- There is no evidence of widespread, long-term channel instability and flood flows still access the floodplain. In addition, the stream bed material is ideal to support a benthic macroinvertebrate community.
- The dominant land use/land cover is forest, followed by agriculture, with approximately 4% imperviousness.
- Slopes are steep and soils are generally rocky, with shallow to moderate depth to bedrock.

Profile of the Current Ten Mile Creek Study Area

Area in Montgomery County	• 3,046 acres (4.8 square miles)
Stream Length	• Approximately 22 miles (including Ten Mile Creek and its tributaries)
Land Use	• 46% Forest, 38% Rural, 7% Low Density Residential
Land Cover	• 4% Impervious Cover, 46% Forest Cover • Remaining land cover predominantly a mix of non-forested pervious area, including pasture, cropland, and turf
Water Quality	• Use I-P Stream
Major Transportation Routes	• Dwight D. Eisenhower Memorial Highway (I-270), Frederick Road (MD 355)
Significant Natural and Historical Features	• Rustic roads, Old Baltimore Road stream ford, Cemeteries • (Clarksburg School, Moneysworth Farm, and Cephas Summers House • Clarksburg Historical District

3.2 Natural Resources and Spatial Analysis

A Spatial Watershed Analysis of existing conditions within the Ten Mile Creek watershed was conducted with the intent of identifying areas with high resource value that support stream quality and watershed health. Natural resource attributes evaluated include steep slopes, erodible soils; hydric soils, forest, interior forest, 100-year floodplain, perennial & intermittent streams, ephemeral channels, wetlands, and springs, seeps & seasonal ponds.

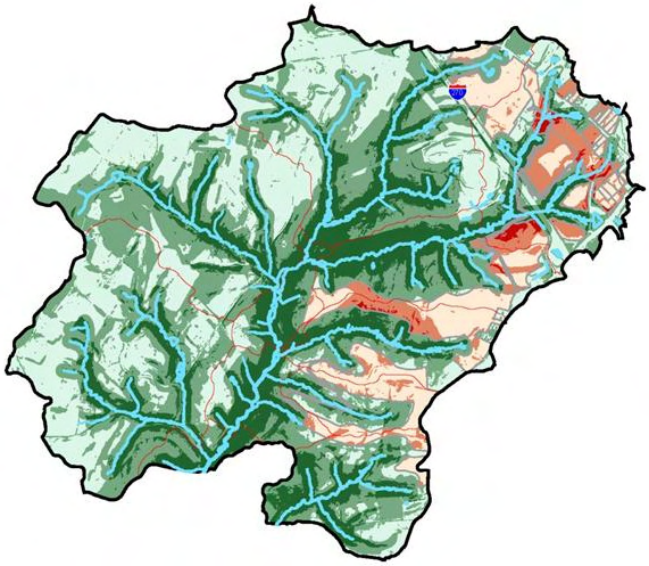
Areas of high resource value within the watershed are generally concentrated near the streams, particularly the mainstem, where wetlands, floodplains, forest, springs, seeps and the streams themselves provide critical watershed functions such as rainfall capture and runoff reduction, pollutant filtering, nutrient cycling, overbank flow attenuation and reduction, and aquatic and upland habitat.

Areas of high resource value are also associated with forest interior, largely concentrated along and east of the mainstem, west of I-270, extending onto the County and Pulte properties. In response to a request for information related to rare, threatened and endangered species within the study area, the Maryland Department of Natural Resources stated that "analysis of the information provided suggests that the forested area on the project site contains Forest Interior Dwelling Bird habitat. Populations of many Forest Interior Dwelling Bird species (FIDS) are declining in Maryland and throughout the eastern United States. The conservation of FIDS habitat is strongly encouraged by the Department of Natural Resources." (MD DNR, 2013).

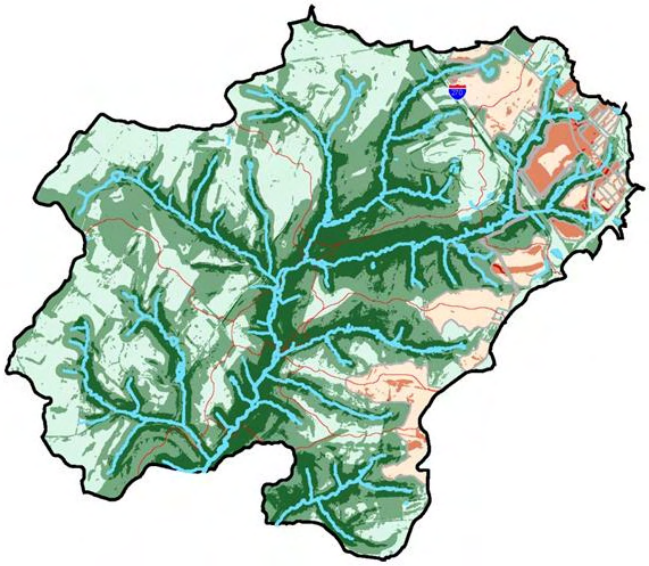
The projected limits of disturbance for Scenario 2 and Scenarios 3&4 were overlaid on the existing conditions Spatial Watershed Analysis to identify the extent of potential impacts to natural resources. Scenarios 3&4 have the same projected limits of disturbance, so this analysis applies to both. The limits of disturbance for Scenario 5 are very similar to Scenario 3, so a separate analysis was not conducted as similar results can be expected. Natural resources throughout the study area will be directly impacted by build-out of the 1994 Master Plan (Scenario 2). A significant decrease in impacts is seen in Scenarios 3&4.

- Of the 22 miles of streams in the area of the watershed studied, about a half of a mile has the potential to be impacted by build-out of the 1994 Master Plan (Scenario 2). The majority of these impacts would be to small headwater tributaries east of I-270, as a result of construction of the MD 355 Bypass. Construction of the MD 355 Bypass may also impact an acre of wetlands and nine of the watershed's 149 springs, seeps and seasonal pools (as identified by Montgomery County Department of Environmental Protection).
- Build-out of the 1994 Master Plan has the potential to impact up to 9% of the watershed's forest – about 120 acres out of 1,389 acres. The largest impacts are associated with the Pulte property, followed by the Miles Coppola; the MD 355 Bypass; and the County property.
- Build-out of the 1994 Master Plan would also result in the loss of over 60 acres of interior forest, 16% of interior forest within the study area. About 18 of these acres may be directly impacted by development, namely on the County and Pulte properties. The remaining loss would be attributed to overall reduction in forest cover, reducing the size and buffer of contiguous forest.
- Approximately 57 acres on lands with a slope greater than 15% would be developed under the 1994 Master Plan, with 6 of these acres on lands with a slope greater than 25%. These include the Pulte, County, and Miles Coppola properties, as well as the MD 355 Bypass.
- Scenarios 3&4 show a significant decrease in impacts areas with high natural resource value. Forest impacts are reduced from 120 acres to approximately 60 acres, and forest interior impacts are reduced from over 60 acres to approximately 14 acres. Direct stream and wetland impacts are reduced by half, largely due to the proposed realignment of the MD 355 Bypass.

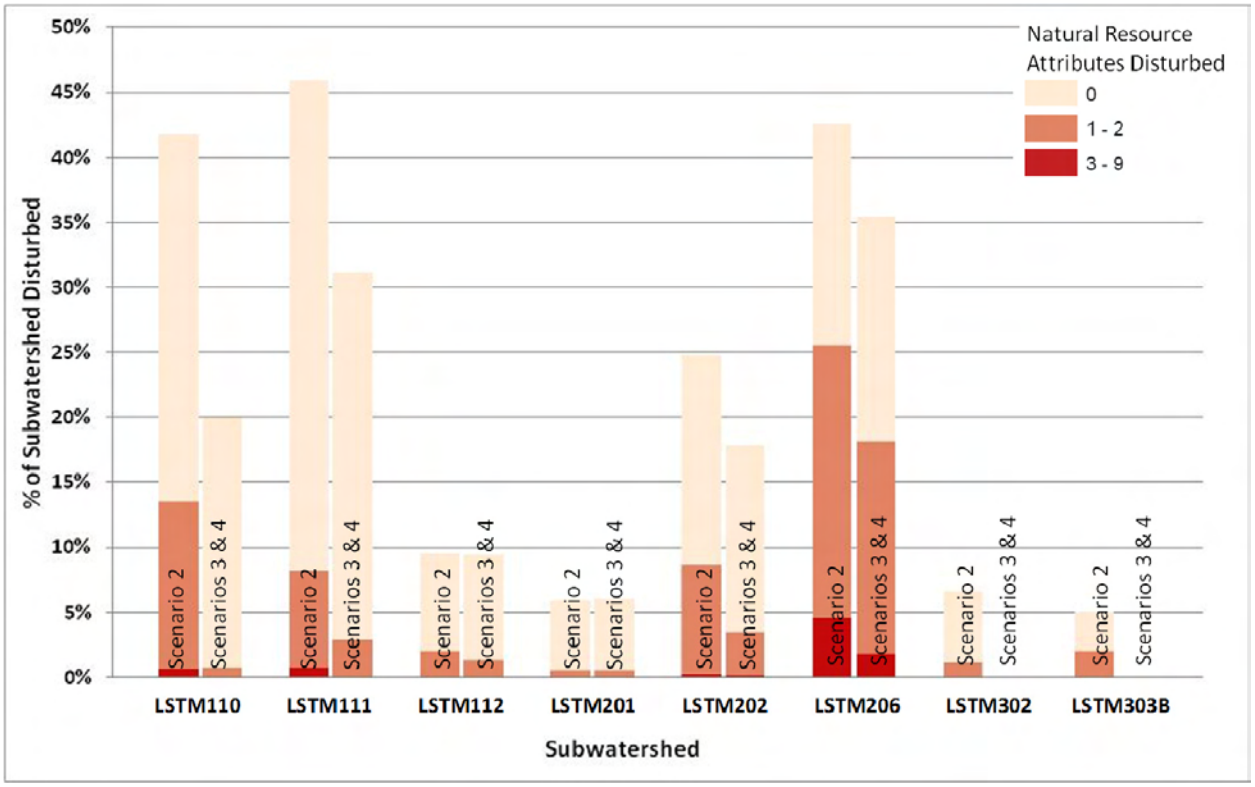
Natural resource attributes overlain with development scenarios within the Ten Mile Creek study area.
Dark green indicates areas with the highest natural resource value, and are generally associated with the presence of the stream system and its buffer areas, forested areas, and wetlands. Medium green indicates areas with fewer, but still valuable, natural resource attributes, such as interior forest and steep slopes. Dark red indicates areas with high ecological value that fall within proposed limits of disturbance and will be directly impacted by development.



Scenario 2



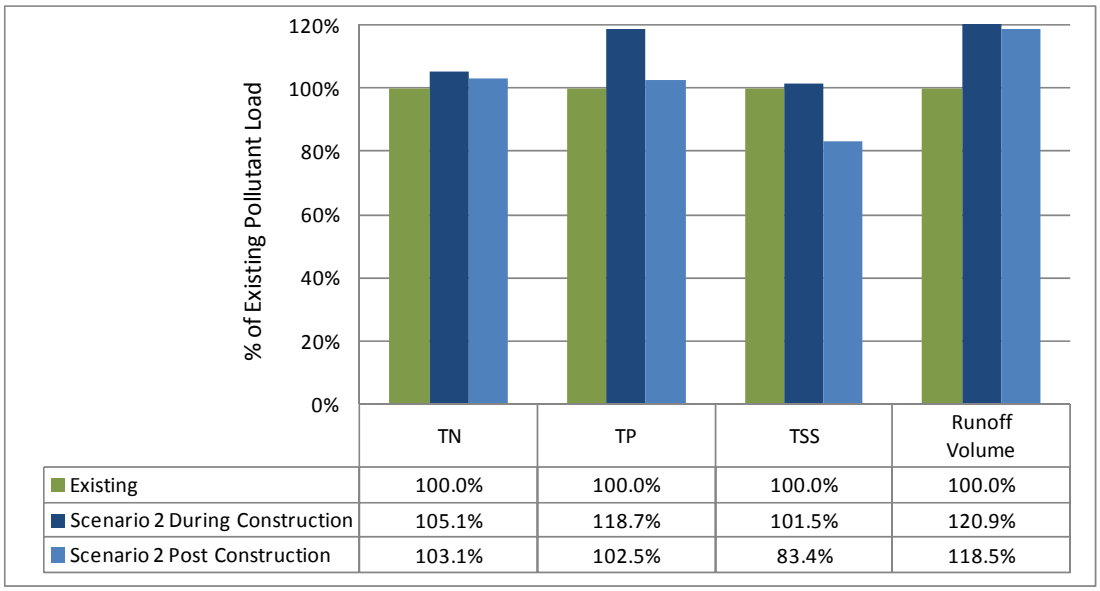
Scenarios 3&4



3.3 Pollutant Loading

Annual pollutant loading was assessed using the Watershed Treatment Model (CWP, 2010), a spreadsheet model that calculates annual runoff volume as well as pollutant loads for Nitrogen (TN), Phosphorus (TP) and Sediment (TSS). Three scenarios were analyzed: existing conditions; the 1994 Master Plan (Scenario 2); and the construction phase (with state of the practices BMPs). The construction phase is similar to Scenario 2, but assumes that construction occurs over ten construction seasons, so that 10% of the developable land is in active construction, and additional fertilizer is applied to establish new lawns. The pollutant load modeling also reflects conversion of 36 septic systems to sewer. Scenarios 3, 4 and 5 were not modeled as it may be assumed that pollutant loads will be reduced from what is seen for Scenario 2, given reduced limits of disturbance and impervious cover. Major findings include:

- Sediment loads decrease uniformly after construction, except in undisturbed watersheds. This is because sediment loads from urban land are much lower than those from most pre-developed land uses, with the exception of forest. However, modeled sediment loads do not include channel erosion. Therefore, this modeling underestimates anticipated sediment loads in streams. Sediment loads are higher during construction.
- Some subwatersheds experience an increase in sediment loads during construction, and at the same time have a decrease after construction. For example, subwatershed LSTM 206 has a 76% increase during construction, but a 35% decrease after construction. This result occurs because sediment loads from construction are much higher than any rural land, while loads from developed land are much lower. Consequently, subwatersheds with a large area of disturbance will experience an increase during construction, followed by a much lower post-construction load.
- Annual runoff volume increases during and after construction. This result may seem counterintuitive, since the goal of ESD is to generate hydrology equivalent to "woods in good condition," which should result in less annual runoff volume than the rural land currently present in much of the land to be developed. However, the WTM assumes that practices that qualify as "ESD Practices" do not actually achieve 100% runoff reduction, due to the likelihood that there will be impacts from soil compaction during construction and that some practices may be undersized due to sizing methodology and site constraints during construction.
- Watershed-wide, pollutant loads for nutrients (Nitrogen and Phosphorus) increase during construction, and decrease to slightly above Existing Condition rates in the Scenario 2 condition.



	TN	TP	TSS	Runoff Volume
Existing	100.0%	100.0%	100.0%	100.0%
Scenario 2 During Construction	105.1%	118.7%	101.5%	120.9%
Scenario 2 Post Construction	103.1%	102.5%	83.4%	118.5%

Comparative Annual Pollutant Loads (as a multiple of loads from forest) throughout the Development Process

3.4 Hydrology

Hydrologic analysis was conducted using XP-SWMM 2012, with the following modeling assumptions developed in conjunction with the Planning Department, DEP, and DPS:

- Compaction of soils will occur as a result of development, and the County's topsoiling requirements will be implemented.
- With the exception of the proposed I-270 widening, developed areas will be treated with micro-bioretention, which was modeled with 9 inches of ponding depth, 3.5 feet of media depth, a decaying infiltration rate from 2" per hour to 0.25" per hour, a constant infiltration rate of 0.05" per hour into underlying soils, and underdrains above stone reservoirs with overflow to surface water.
- New impervious surfaces related to I-270 widening will be treated with conventional stormwater management.
- Redevelopment areas will be treated to ESD volume requirements for 100% of impervious surfaces

The model provided estimates of relative changes in total streamflow volume, peak streamflow, and streamflow velocity predicted to occur as a result of the differences between existing land cover compared to each development scenario. Major findings include:

- For all development scenarios, the modeling results indicate that the development proposed for the Ten Mile Creek study area will impact hydrology in all of the modeled subwatersheds to a varying degree, with the exception of LSTM204, which was not predicted to be impacted. Streamflow changes shown in the modeling results will occur in some tributaries directly as a result of land cover changes within the subwatershed, or in some downstream locations indirectly as a result of flow changes from upstream development.
- The subwatersheds predicted to be most impacted from the 1994 Master Plan development modeled in Scenario 2 include LSTM110, LSTM111 and LSTM206, with increased streamflow volumes and peak flows also noted at downstream points LSTM202, LSTM302, LSTM303B and the study outlet point at LSTM304.
- The subwatersheds which showed most improvement from the reduced footprints modeled in Scenario 3 (compared to Scenario 2) were LSTM110 and LSTM111. Improvements were also seen at downstream points LSTM303B and the study area outlet at LSTM304.
- In most subwatersheds, the differences between the development proposed under Scenario 3 versus Scenario 4 were too small to result in any significant model response. However, additional improvements were seen as a result of the reduced imperviousness modeled in Scenario 5, with the greatest benefits predicted in LSTM110, LSTM111 and LSTM206. Improvements were also seen in LSTM201 and at the downstream modeling points at LSTM202, LSTM203, LSTM302, LSTM303B and the study outlet point at LSTM304.

4.0 Conclusions and Recommendations

Ten Mile Creek is a reference stream in Montgomery County, whose biological condition is healthy and diverse. Sensitive 'indicator' organisms that occur in few other areas within the County are found here. It is part of a small group of high quality watersheds still remaining within the County.

Of the four development scenarios evaluated, Scenario 2 (1994 Master Plan) has the greatest development footprint and consequently the greatest direct impact to the Ten Mile Creek watershed. These impacts include loss of forest, forest interior, streams and wetlands. Development will disturb approximately 420 acres of land. Four subwatersheds will see the greatest disturbance – approximately 46% of LSTM 111, 42% of LSTM 110, 43% of LSTM 206 and 25% of LSTM 202. Of these, LSTM 206 is currently the most developed subwatershed, with 16% impervious cover and fair stream conditions. In contrast, LSTM 110 and LSTM 111 are small, high quality headwater tributaries dominated by forest cover and rural land uses.

Build-out of the 1994 Master Plan would also result in the loss of over 60 acres of interior forest. About 18 of these acres may be directly impacted by development, namely on the County and Pulte properties. The remaining loss would be attributed to fragmentation and overall reduction in forest cover, reducing the size and buffer of contiguous forest. Approximately 57 acres on lands with a slope greater than 15% would be developed under the 1994 Master Plan, with 6 of these acres on lands with a slope greater than 25%. These include the Pulte, County, and Miles Coppola properties, as well as the MD 355 Bypass.

An appreciable difference in potential stream and watershed impacts associated with Scenarios 3, 4 and 5 is not uniformly noted by these analyses. The similarity in limits of disturbance results in similar impacts to natural resources. The exception is Scenario 5, where a revised MD 355 Bypass realignment reduced stream impacts from approximately 1,100 feet in Scenarios 3 and 4 to 700 feet in Scenario 5, and eliminates wetland impacts.

The results of the hydrologic model indicate that ESD will not fully mitigate the impacts of development on hydrology in the watershed. Scenario 2 results in the largest increases in volume of runoff and stream flow. In most subwatersheds, the differences between the development proposed under Scenario 3 versus Scenario 4 were too small to result in any significant model response. Of the four development scenarios, Scenario 5 showed the lowest increase over existing conditions as a result of the reduced imperviousness, with the greatest benefits predicted in LSTM110, LSTM111 and LSTM206. Improvements were also seen in LSTM201 and at the downstream modeling points at LSTM202, LSTM203, LSTM302, LSTM303B and the study outlet point at LSTM304.

Impacts from potential channel erosion resulting from altered hydrology were not explicitly analyzed as part of this study, due to uncertainty of future stream response. However, research does indicate that channel erosion can be a significant sediment source.

Given the level of development proposed, increases in stormwater runoff volume and peak flow can be expected in all development scenarios despite the application of ESD practices (Center for Watershed Protection, 2013). Literature review of case studies and monitoring to document the effectiveness of ESD and similar low impact development (LID) strategies are limited and don't appear to exist at a watershed scale of analysis. Where case studies do exist at a subdivision scale, there is no conclusive evidence that ESD fully protects stream health.

ESD represents the state of the practice for site planning and post-construction stormwater runoff management. However, rigorous and comprehensive implementation across or within watersheds has not occurred nor been monitored to establish a base of literature where we can conclude that watershed impacts won't be observed.

While gaining watershed-based knowledge on the efficacy of ESD will be valuable, it may not be prudent to have initial experience and studies conducted in high quality watersheds.

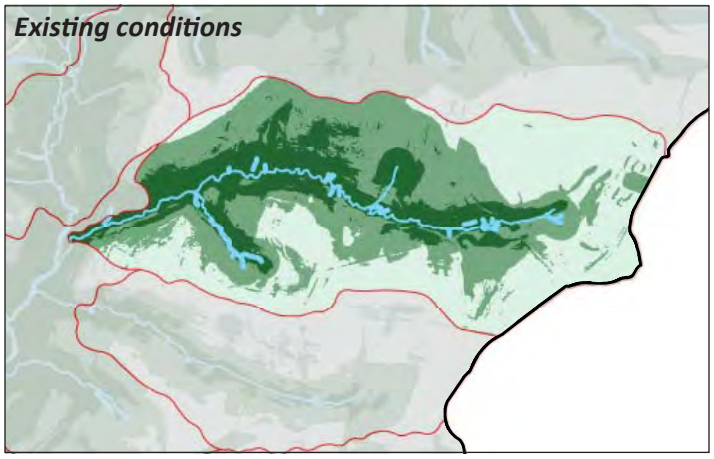
Additional development within the Ten Mile Creek watershed will have a negative impact on watershed health and stream quality. Minimizing impact to Ten Mile Creek will require the following measures:

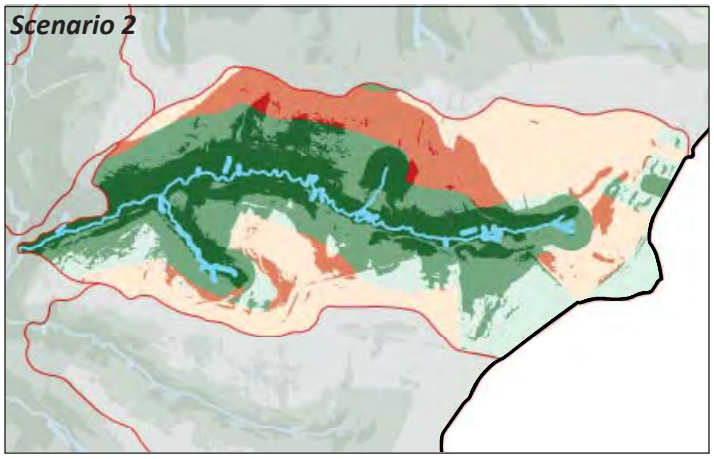
- Minimize disturbance of natural resources throughout the Ten Mile Creek study area, especially forest cover in the headwater areas.
- Reduce development west of I-270, with an emphasis on reducing impacts to upland forested areas and steep slopes. In particular, preserve existing conditions in the high quality headwater subwatersheds LSTM 110 (King Spring) and LSTM 111. In LSTM 202, reduce the extent of development on County-owned property (per Scenarios 3, 4 and 5) so that existing forest is not disturbed.
- Focus and prioritize development east of I-270 in LSTM 206.
- If development occurs in subwatersheds LSTM 110 and LSTM 111, the limits of disturbance set forth in Scenarios 3, 4 and 5 should be applied.
- Minimize direct impacts to natural resources associated with new infrastructure, namely the MD 355 Bypass and the sanitary sewer extension.
- Strictly enforce erosion and sediment control regulations, with special emphasis on proposed clearing and grading limits.
- Preserve riparian corridors and establish buffers around “zero order” or ephemeral streams not currently regulated.
- Reduce the 1994 Master Plan impervious levels in the headwater areas of LSTM206, LSTM201 and LSTM202 to protect those headwater tributaries and the mainstem of Ten Mile Creek.
- Within any proposed developed areas, employ site planning techniques as the first measure of Environmental Site Design. Prioritize preservation and protection of natural resources; conservation of natural drainage patterns; minimization of impervious areas; clustering of development; and limiting soil disturbance, mass grading and compaction. Achieve control of required volumes or enhanced volumes with the ESD treatment practices selected to achieve the most watershed benefits based on evaluation of site-specific and subwatershed-specific considerations.
- Design stream outfalls to reduce impacts associated with large flows (e.g., implement step pool conveyances at all outfalls).

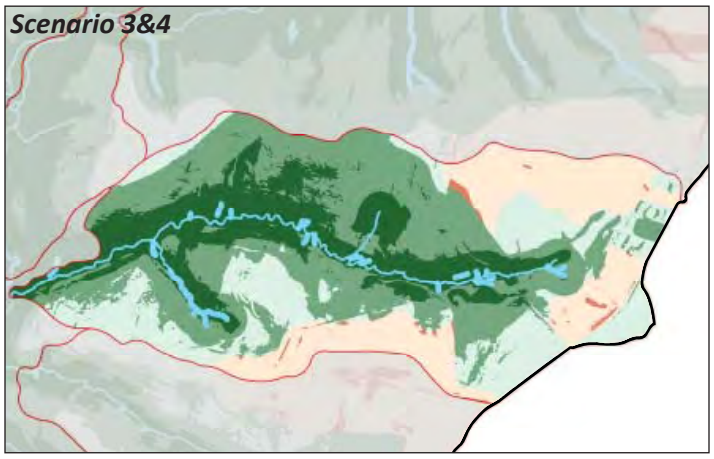
Attachment A. Ten Mile Creek Subwatershed Profiles



TEN MILE CREEK
Contributing Subwatersheds: LSTM110



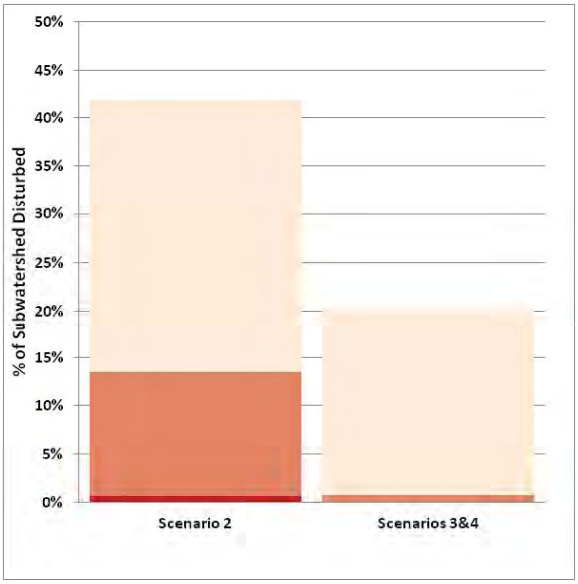




EXISTING CONDITIONS

Drainage Area (acres) – 211
% Impervious – 2%
% Forested – 45%
Stream Length (feet) – 8,535
IBI (average 1994-2012) – 35/good

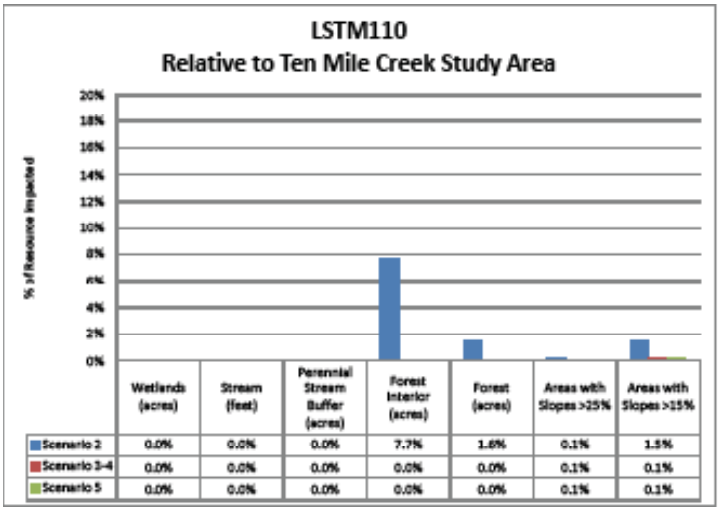
LSTM101
Subwatershed Disturbance



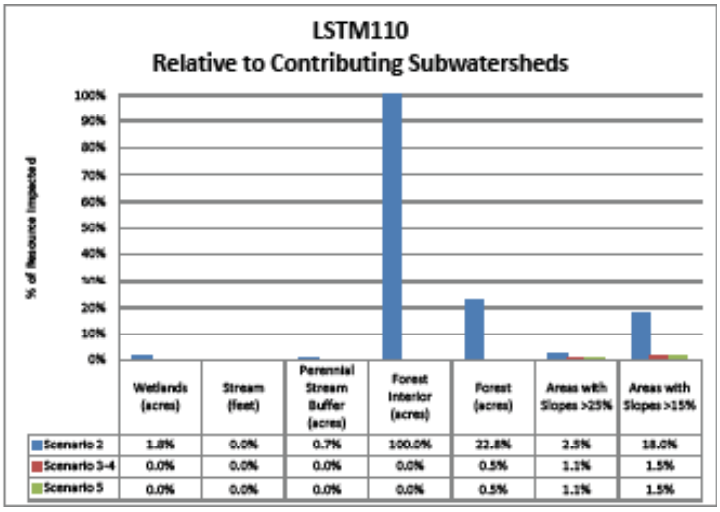
LEGEND

Natural Resource Attributes Undisturbed	Natural Resource Attributes Disturbed
0 Least	0
1 - 2	1 - 2
3 - 9 Most	3 - 9

IMPACTS ON RESOURCES

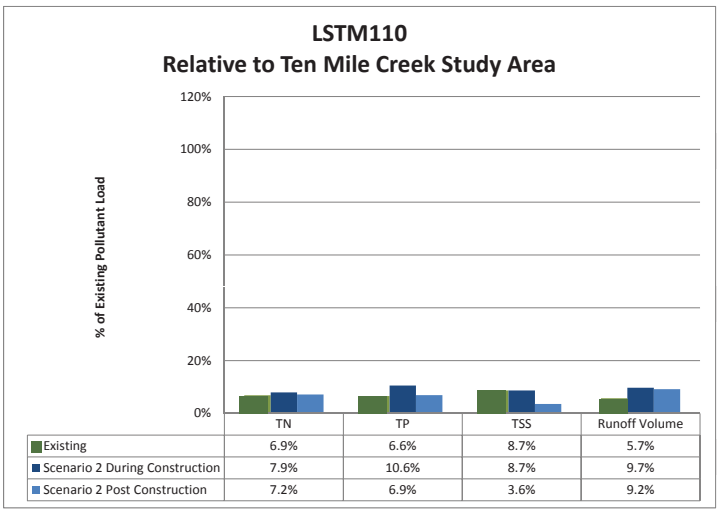


	Wetlands (acres)	Stream (feet)	Perennial Stream Buffer (acres)	Forest Interior (acres)	Forest (acres)	Areas with Slopes >25%	Areas with Slopes >15%
Scenario 2	0.0%	0.0%	0.0%	7.7%	1.6%	0.1%	1.5%
Scenario 3-4	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%
Scenario 5	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%

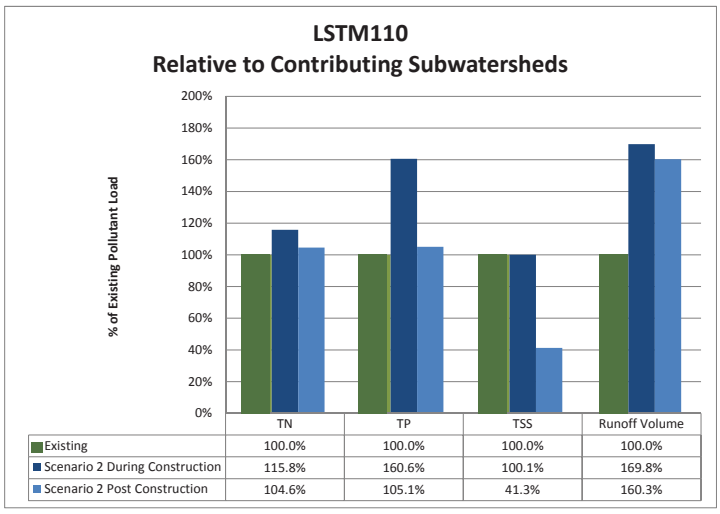


	Wetlands (acres)	Stream (feet)	Perennial Stream Buffer (acres)	Forest Interior (acres)	Forest (acres)	Areas with Slopes >25%	Areas with Slopes >15%
Scenario 2	1.8%	0.0%	0.7%	100.0%	22.8%	2.5%	18.0%
Scenario 3-4	0.0%	0.0%	0.0%	0.0%	0.5%	1.1%	1.5%
Scenario 5	0.0%	0.0%	0.0%	0.0%	0.5%	1.1%	1.5%

POLLUTANT LOAD ANALYSIS

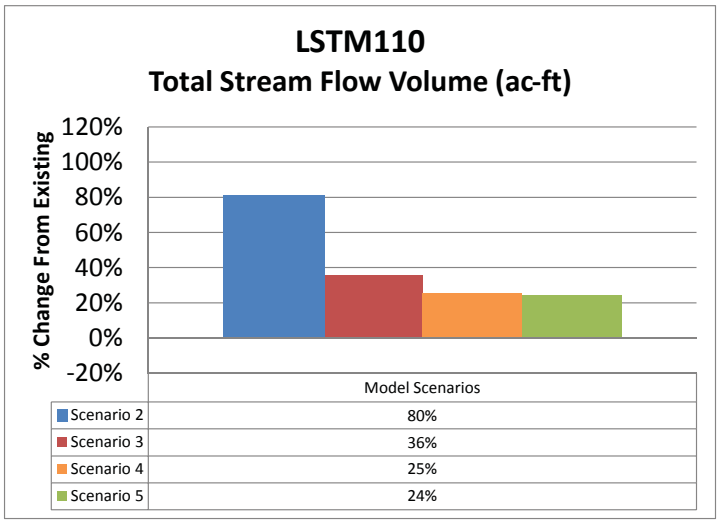


	TN	TP	TSS	Runoff Volume
Existing	6.9%	6.6%	8.7%	5.7%
Scenario 2 During Construction	7.9%	10.6%	8.7%	9.7%
Scenario 2 Post Construction	7.2%	6.9%	3.6%	9.2%

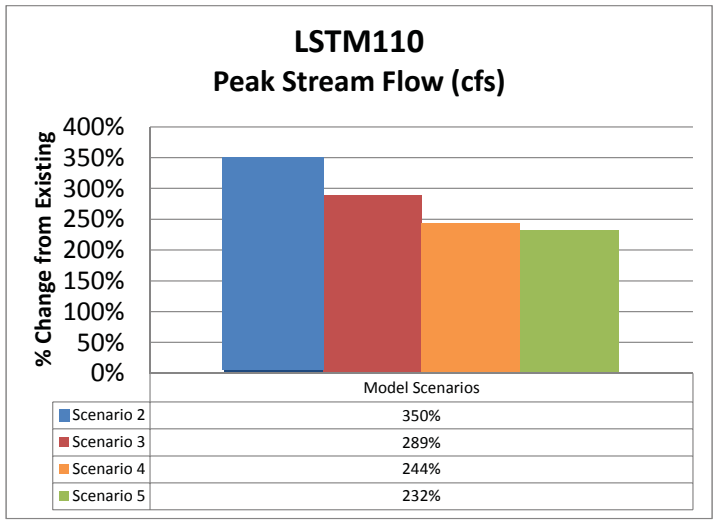


	TN	TP	TSS	Runoff Volume
Existing	100.0%	100.0%	100.0%	100.0%
Scenario 2 During Construction	115.8%	160.6%	100.1%	169.8%
Scenario 2 Post Construction	104.6%	105.1%	41.3%	160.3%

HYDROLOGY (1-YEAR, 24-HOUR STORM) Note: Scale of Peak Stream flow is 0%-400%



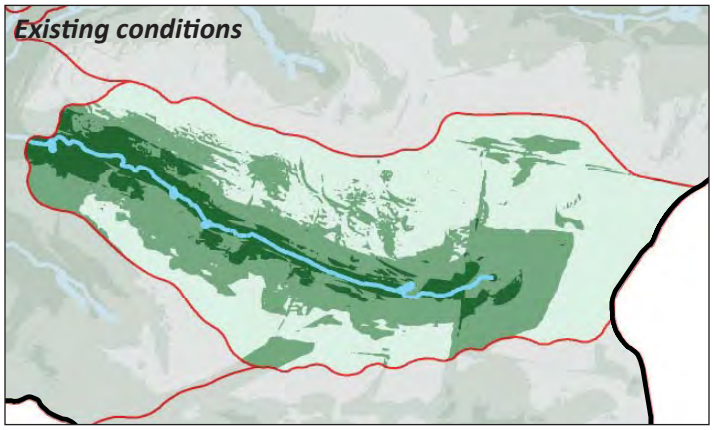
	Model Scenarios
Scenario 2	80%
Scenario 3	36%
Scenario 4	25%
Scenario 5	24%

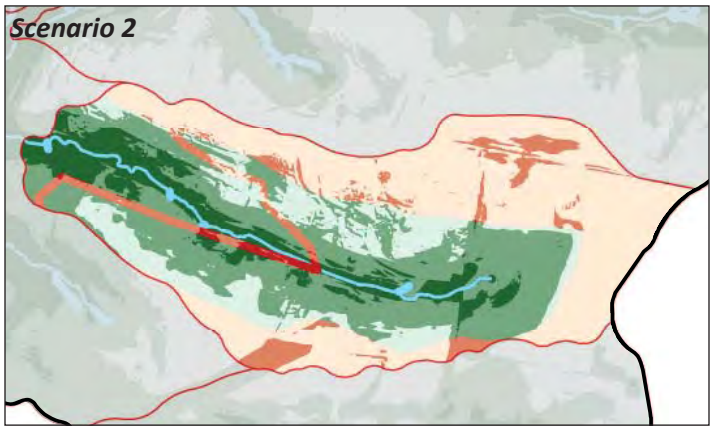


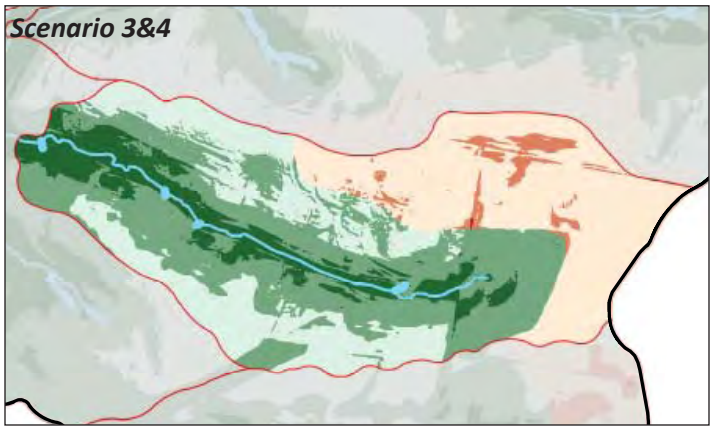
	Model Scenarios
Scenario 2	350%
Scenario 3	289%
Scenario 4	244%
Scenario 5	232%



TEN MILE CREEK
Contributing Subwatersheds: LSTM111



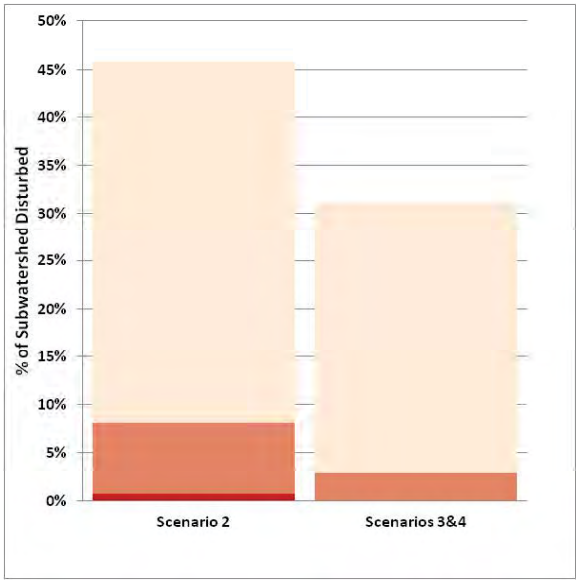




EXISTING CONDITIONS

Drainage Area (acres) – 104
% Impervious – 1%
% Forested – 19%
Stream Length (feet) – 3,273
IBI (average 1994-2012) – 30/good

LSTM111
Subwatershed Disturbance

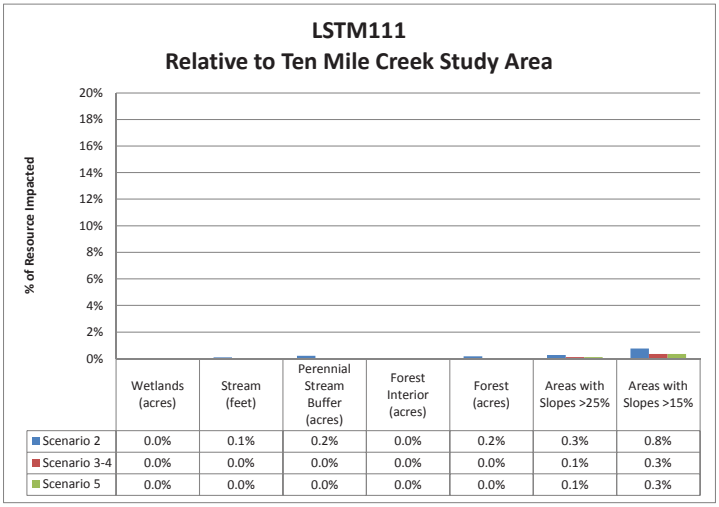


LEGEND

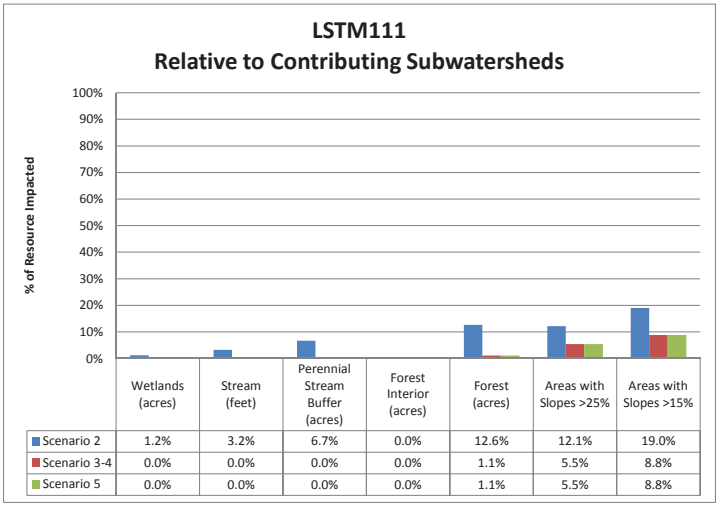
Natural Resource Attributes Undisturbed
- 0 Least
- 1 - 2
- 3 - 9 Most

Natural Resource Attributes Disturbed
- 0
- 1 - 2
- 3 - 9

IMPACTS ON RESOURCES

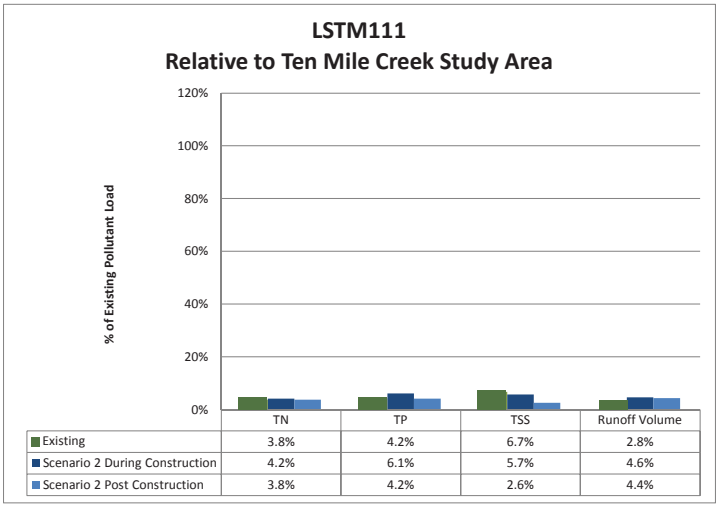


	Wetlands (acres)	Stream (feet)	Perennial Stream Buffer (acres)	Forest Interior (acres)	Forest (acres)	Areas with Slopes >25%	Areas with Slopes >15%
Scenario 2	0.0%	0.1%	0.2%	0.0%	0.2%	0.3%	0.8%
Scenario 3-4	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.3%
Scenario 5	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.3%

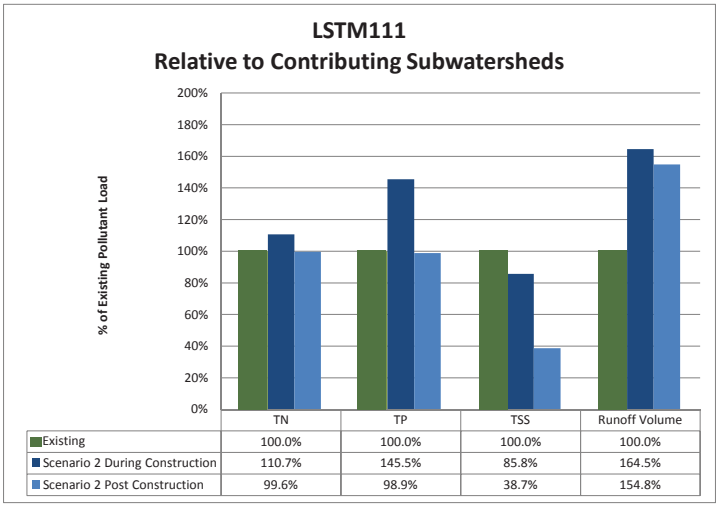


	Wetlands (acres)	Stream (feet)	Perennial Stream Buffer (acres)	Forest Interior (acres)	Forest (acres)	Areas with Slopes >25%	Areas with Slopes >15%
Scenario 2	1.2%	3.2%	6.7%	0.0%	12.6%	12.1%	19.0%
Scenario 3-4	0.0%	0.0%	0.0%	0.0%	1.1%	5.5%	8.8%
Scenario 5	0.0%	0.0%	0.0%	0.0%	1.1%	5.5%	8.8%

POLLUTANT LOAD ANALYSIS

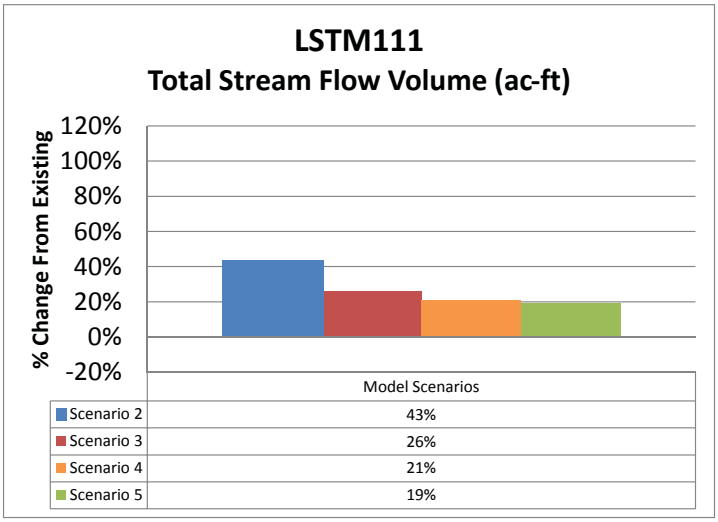


	TN	TP	TSS	Runoff Volume
Existing	3.8%	4.2%	6.7%	2.8%
Scenario 2 During Construction	4.2%	6.1%	5.7%	4.6%
Scenario 2 Post Construction	3.8%	4.2%	2.6%	4.4%

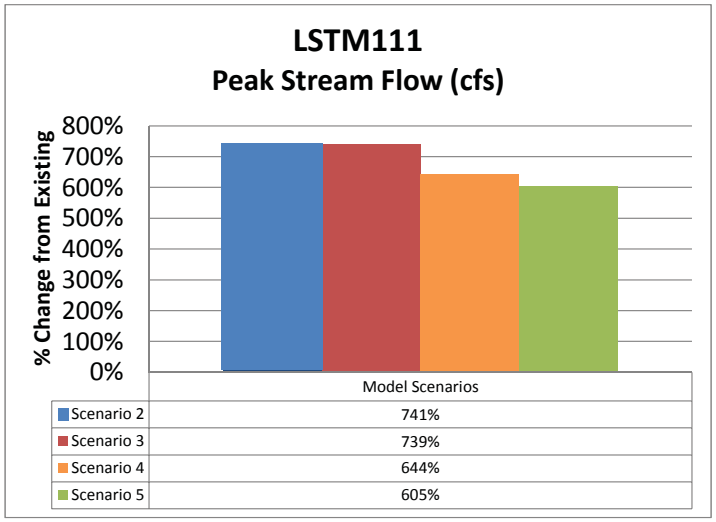


	TN	TP	TSS	Runoff Volume
Existing	100.0%	100.0%	100.0%	100.0%
Scenario 2 During Construction	110.7%	145.5%	85.8%	164.5%
Scenario 2 Post Construction	99.6%	98.9%	38.7%	154.8%

HYDROLOGY (1-YEAR, 24-HOUR STORM) Note: Scale of Peak Stream flow is 0%-800%



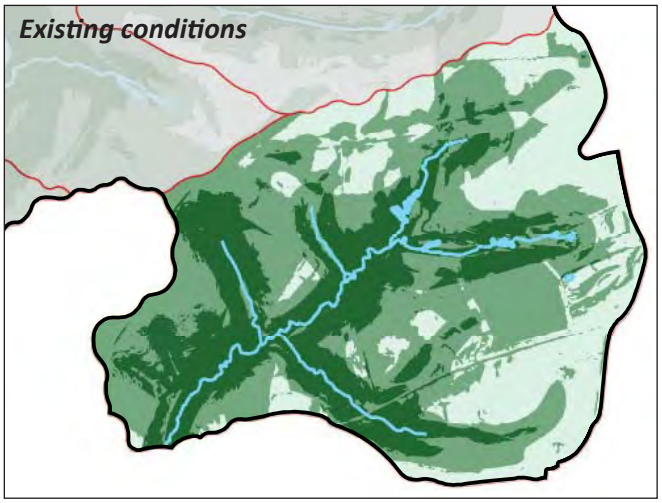
	Model Scenarios
Scenario 2	43%
Scenario 3	26%
Scenario 4	21%
Scenario 5	19%

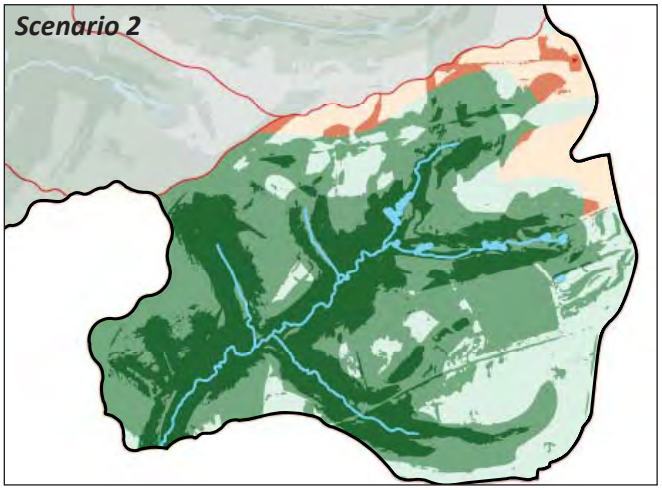


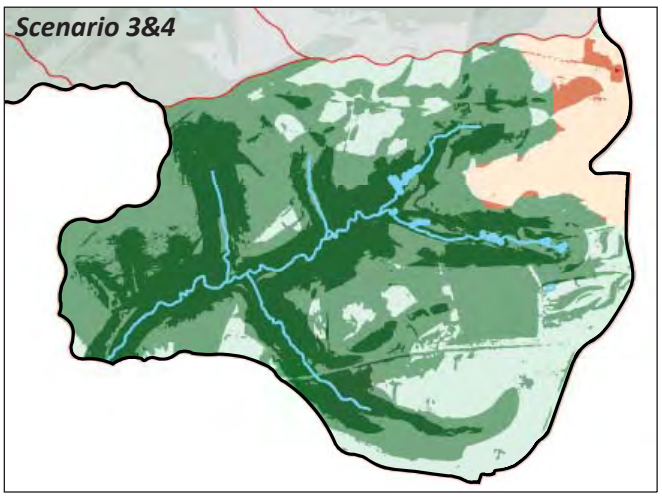
	Model Scenarios
Scenario 2	741%
Scenario 3	739%
Scenario 4	644%
Scenario 5	605%



TEN MILE CREEK
Contributing Subwatersheds: LSTM112



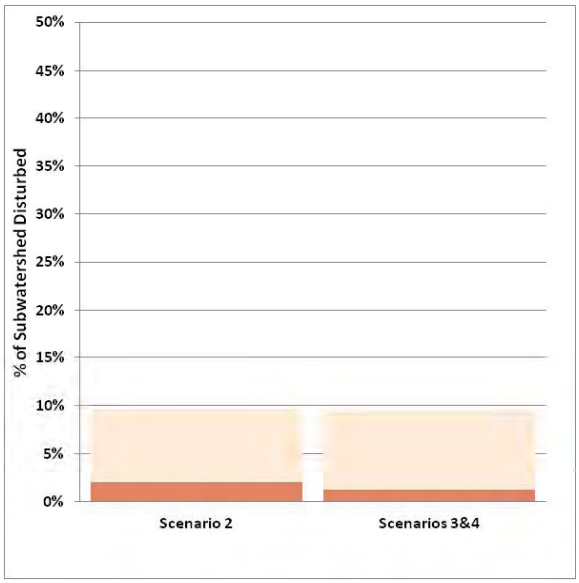




EXISTING CONDITIONS

Drainage Area (acres) – 228
% Impervious – 3%
% Forested – 49%
Stream Length (feet) – 8,841
IBI (average 1994-2012) – 30/good

LSTM112
Subwatershed Disturbance

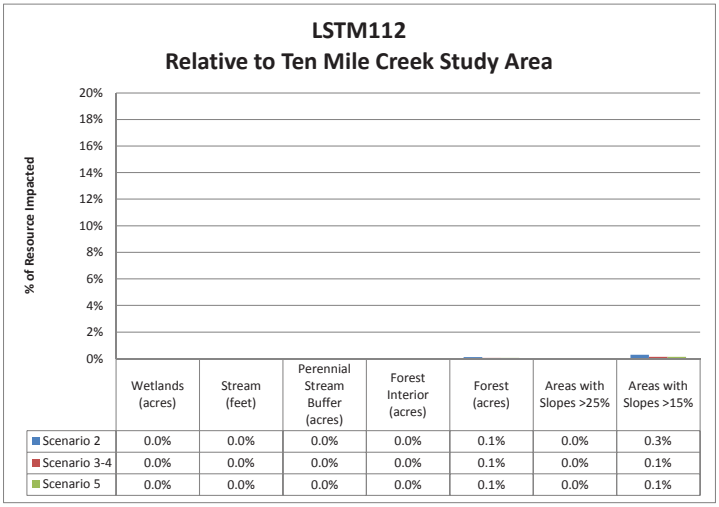


LEGEND

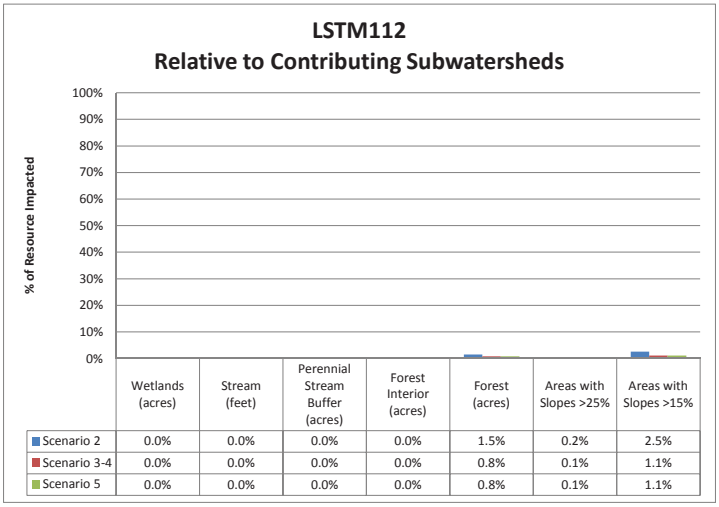
Natural Resource Attributes Undisturbed
- 0 Least
- 1 - 2
- 3 - 9 Most

Natural Resource Attributes Disturbed
- 0
- 1 - 2
- 3 - 9

IMPACTS ON RESOURCES

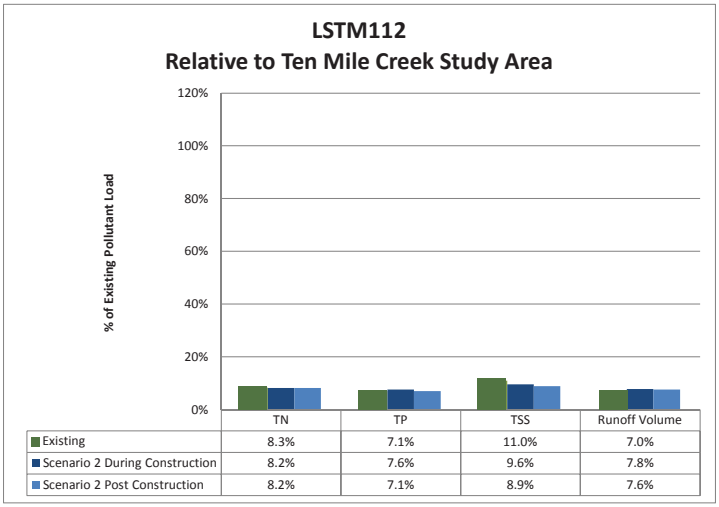


	Wetlands (acres)	Stream (feet)	Perennial Stream Buffer (acres)	Forest Interior (acres)	Forest (acres)	Areas with Slopes >25%	Areas with Slopes >15%
Scenario 2	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.3%
Scenario 3-4	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.1%
Scenario 5	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.1%

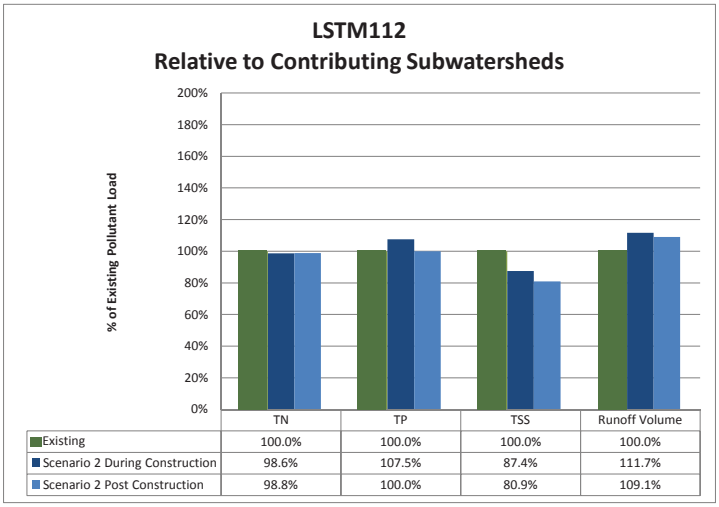


	Wetlands (acres)	Stream (feet)	Perennial Stream Buffer (acres)	Forest Interior (acres)	Forest (acres)	Areas with Slopes >25%	Areas with Slopes >15%
Scenario 2	0.0%	0.0%	0.0%	0.0%	1.5%	0.2%	2.5%
Scenario 3-4	0.0%	0.0%	0.0%	0.0%	0.8%	0.1%	1.1%
Scenario 5	0.0%	0.0%	0.0%	0.0%	0.8%	0.1%	1.1%

POLLUTANT LOAD ANALYSIS

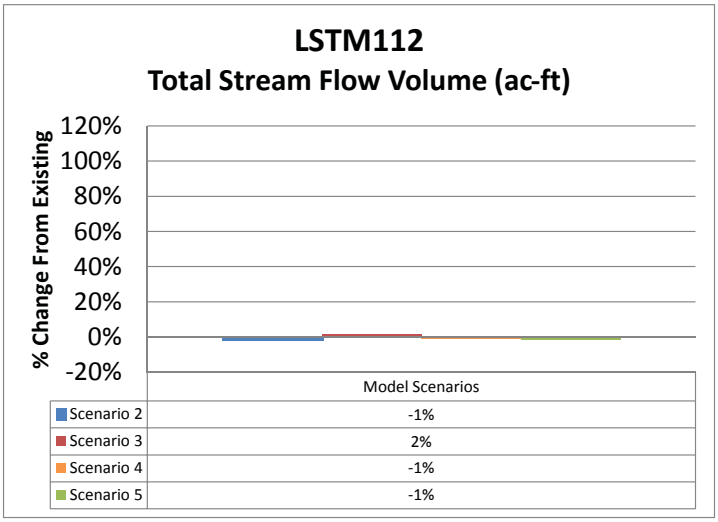


	TN	TP	TSS	Runoff Volume
Existing	8.3%	7.1%	11.0%	7.0%
Scenario 2 During Construction	8.2%	7.6%	9.6%	7.8%
Scenario 2 Post Construction	8.2%	7.1%	8.9%	7.6%

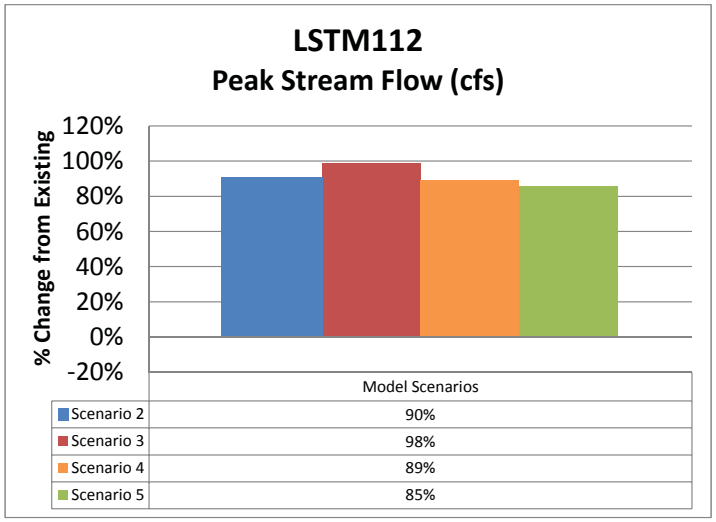


	TN	TP	TSS	Runoff Volume
Existing	100.0%	100.0%	100.0%	100.0%
Scenario 2 During Construction	98.6%	107.5%	87.4%	111.7%
Scenario 2 Post Construction	98.8%	100.0%	80.9%	109.1%

HYDROLOGY (1-YEAR, 24-HOUR STORM)



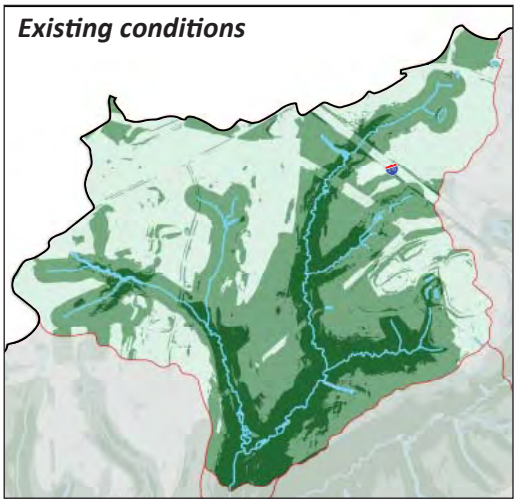
	Model Scenarios
Scenario 2	-1%
Scenario 3	2%
Scenario 4	-1%
Scenario 5	-1%

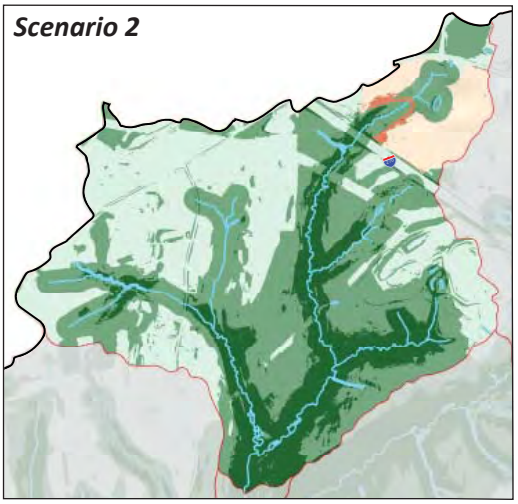


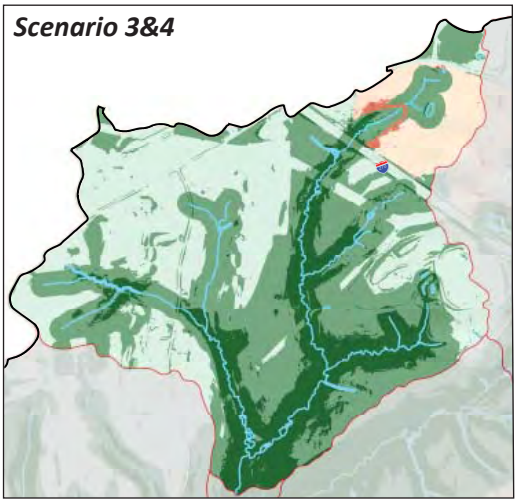
	Model Scenarios
Scenario 2	90%
Scenario 3	98%
Scenario 4	89%
Scenario 5	85%



TEN MILE CREEK
Contributing Subwatersheds: LSTM201



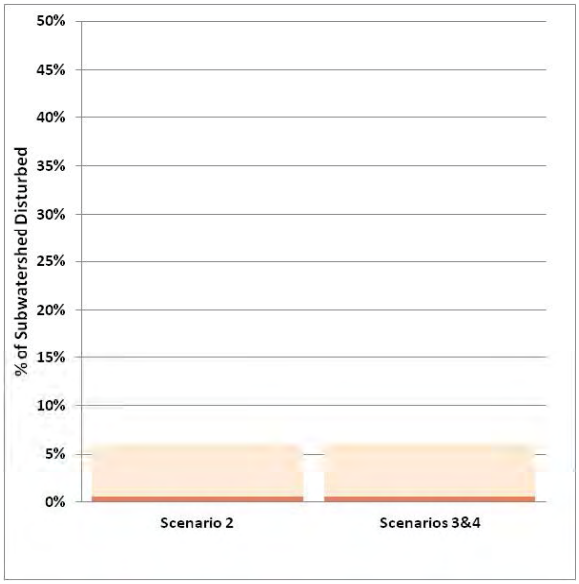




EXISTING CONDITIONS

Drainage Area (acres) – 611
% Impervious – 4%
% Forested – 44%
Stream Length (feet) – 25,396
IBI (average 1994-2012) – 31/good

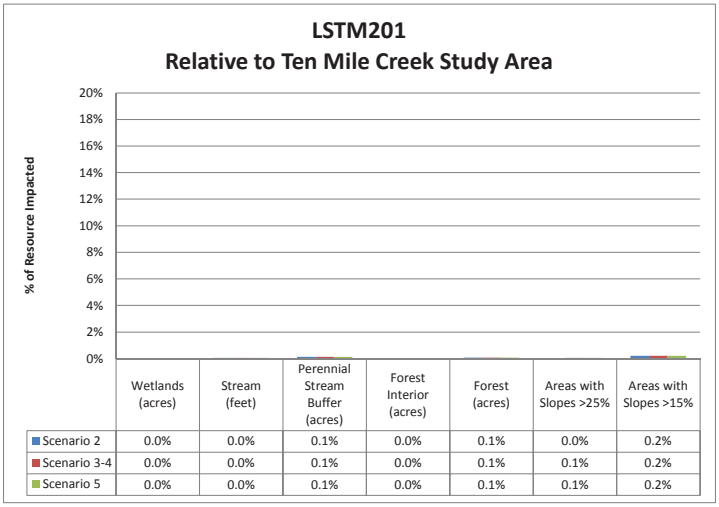
LSTM201
Subwatershed Disturbance



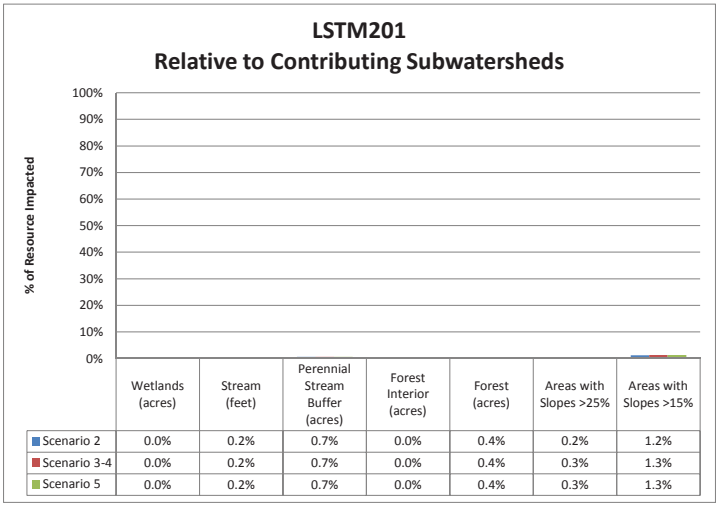
LEGEND

Natural Resource Attributes Undisturbed	Natural Resource Attributes Disturbed
0 Least	0
1 - 2	1 - 2
3 - 9 Most	3 - 9

IMPACTS ON RESOURCES

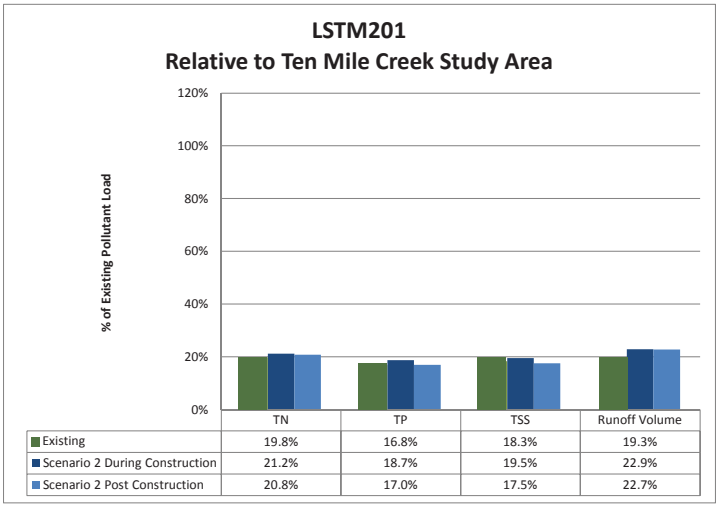


	Wetlands (acres)	Stream (feet)	Perennial Stream Buffer (acres)	Forest Interior (acres)	Forest (acres)	Areas with Slopes >25%	Areas with Slopes >15%
Scenario 2	0.0%	0.0%	0.1%	0.0%	0.1%	0.0%	0.2%
Scenario 3-4	0.0%	0.0%	0.1%	0.0%	0.1%	0.1%	0.2%
Scenario 5	0.0%	0.0%	0.1%	0.0%	0.1%	0.1%	0.2%

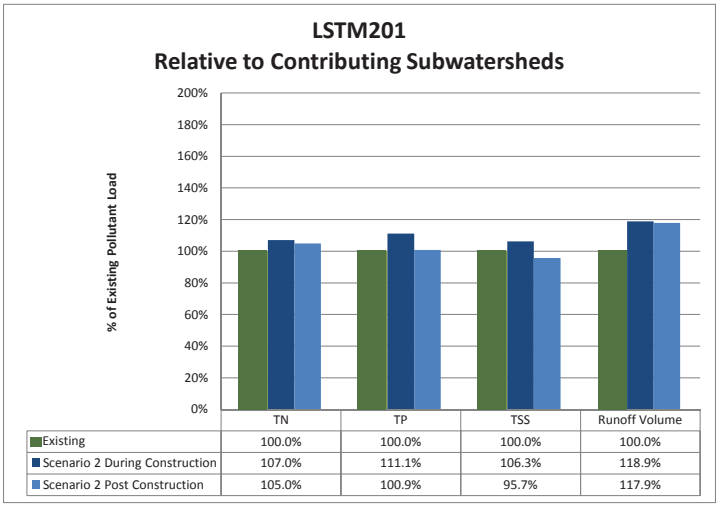


	Wetlands (acres)	Stream (feet)	Perennial Stream Buffer (acres)	Forest Interior (acres)	Forest (acres)	Areas with Slopes >25%	Areas with Slopes >15%
Scenario 2	0.0%	0.2%	0.7%	0.0%	0.4%	0.2%	1.2%
Scenario 3-4	0.0%	0.2%	0.7%	0.0%	0.4%	0.3%	1.3%
Scenario 5	0.0%	0.2%	0.7%	0.0%	0.4%	0.3%	1.3%

POLLUTANT LOAD ANALYSIS

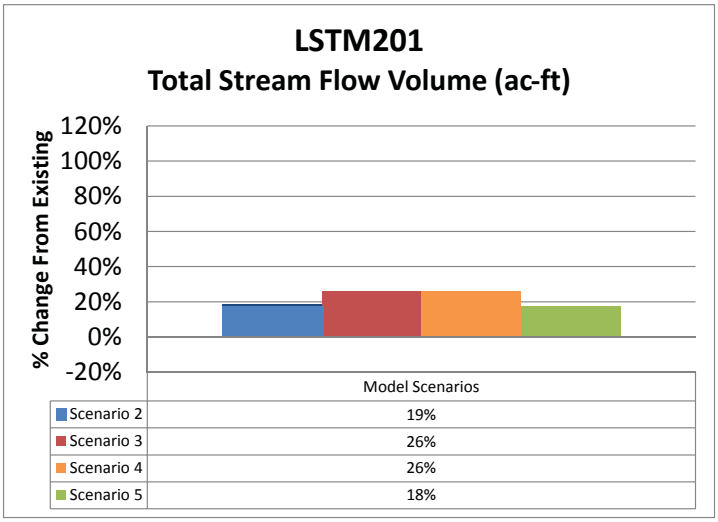


	TN	TP	TSS	Runoff Volume
Existing	19.8%	16.8%	18.3%	19.3%
Scenario 2 During Construction	21.2%	18.7%	19.5%	22.9%
Scenario 2 Post Construction	20.8%	17.0%	17.5%	22.7%

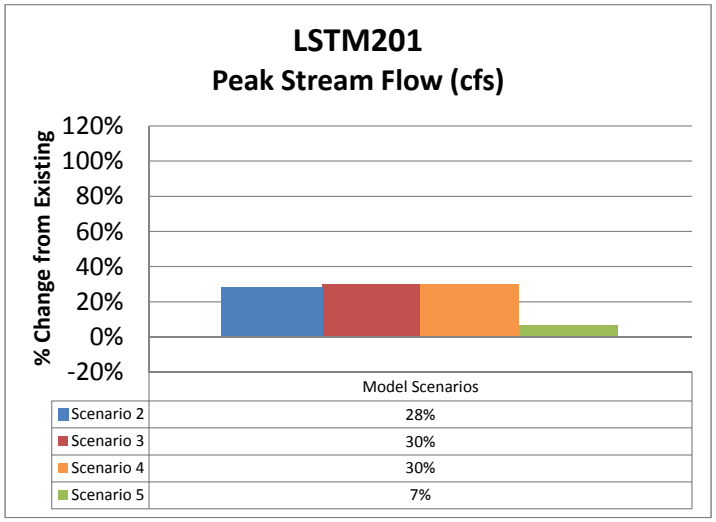


	TN	TP	TSS	Runoff Volume
Existing	100.0%	100.0%	100.0%	100.0%
Scenario 2 During Construction	107.0%	111.1%	106.3%	118.9%
Scenario 2 Post Construction	105.0%	100.9%	95.7%	117.9%

HYDROLOGY (1-YEAR, 24-HOUR STORM)



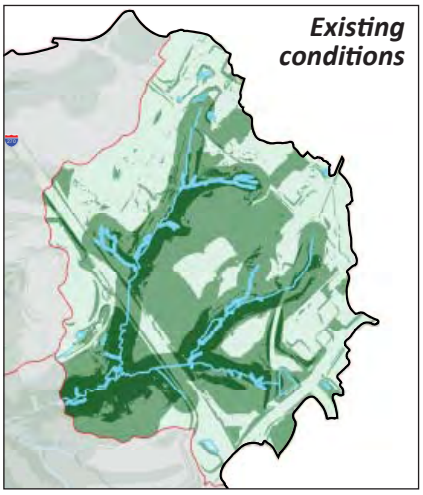
Model Scenarios	
Scenario 2	19%
Scenario 3	26%
Scenario 4	26%
Scenario 5	18%

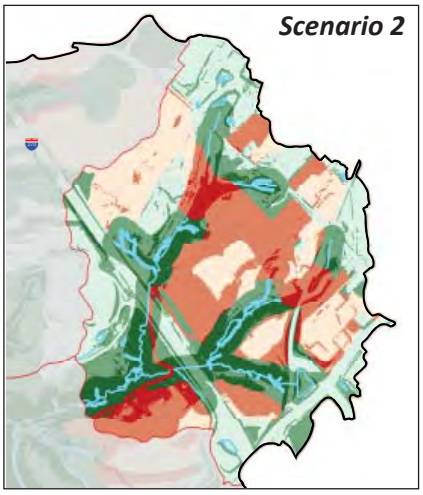


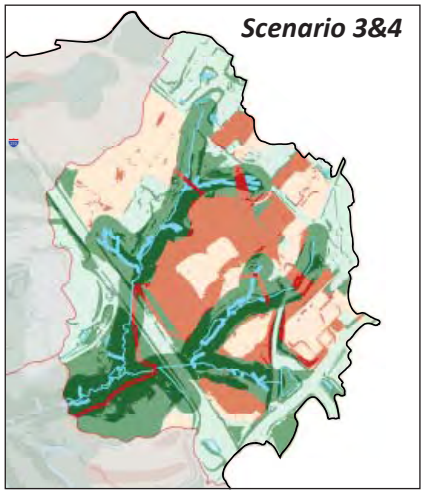
Model Scenarios	
Scenario 2	28%
Scenario 3	30%
Scenario 4	30%
Scenario 5	7%



TEN MILE CREEK
Contributing Subwatersheds: LSTM206



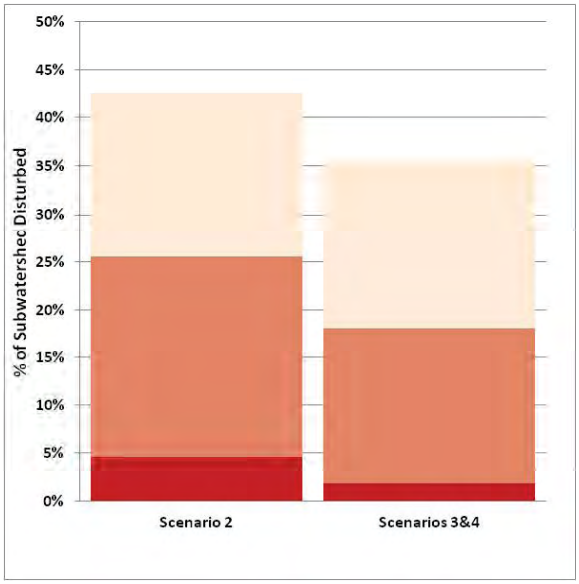




EXISTING CONDITIONS

Drainage Area (acres) – 370
% Impervious – 16%
% Forested – 41%
Stream Length (feet) – 13,202
IBI (average 1994-2012) – 21/fair

LSTM206
Subwatershed Disturbance

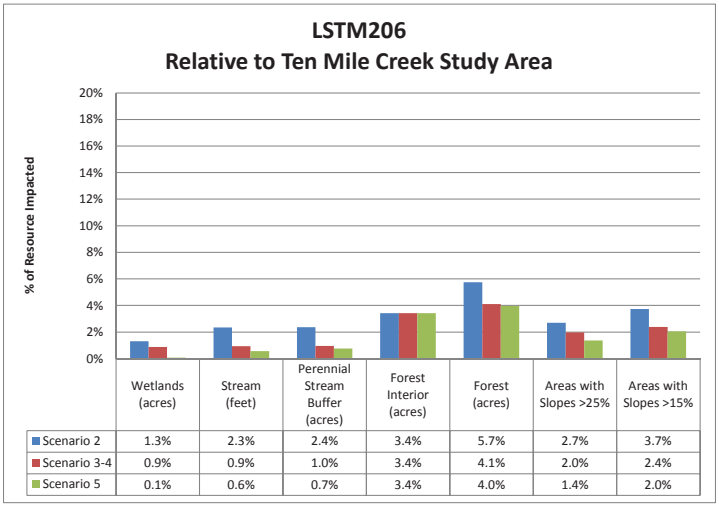


LEGEND

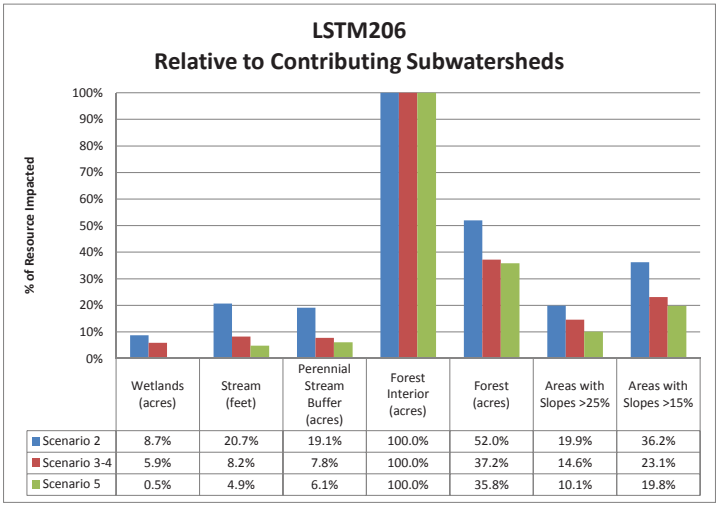
Natural Resource Attributes Undisturbed
- 0 Least
- 1 - 2
- 3 - 9 Most

Natural Resource Attributes Disturbed
- 0
- 1 - 2
- 3 - 9

IMPACTS ON RESOURCES

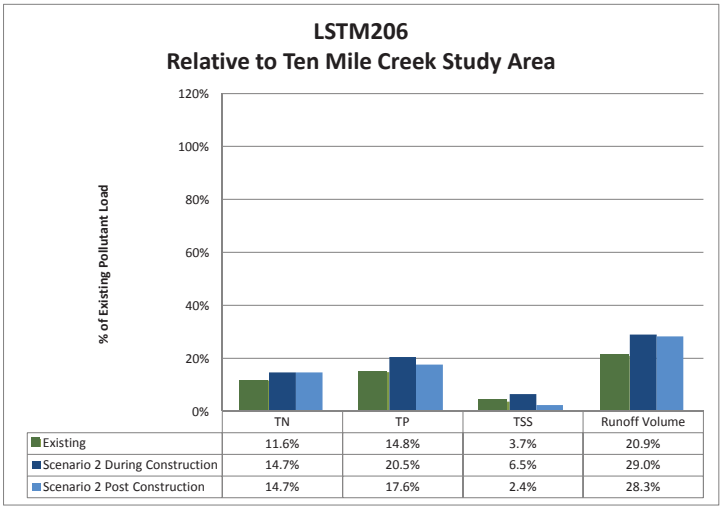


	Wetlands (acres)	Stream (feet)	Perennial Stream Buffer (acres)	Forest Interior (acres)	Forest (acres)	Areas with Slopes >25%	Areas with Slopes >15%
Scenario 2	1.3%	2.3%	2.4%	3.4%	5.7%	2.7%	3.7%
Scenario 3-4	0.9%	0.9%	1.0%	3.4%	4.1%	2.0%	2.4%
Scenario 5	0.1%	0.6%	0.7%	3.4%	4.0%	1.4%	2.0%

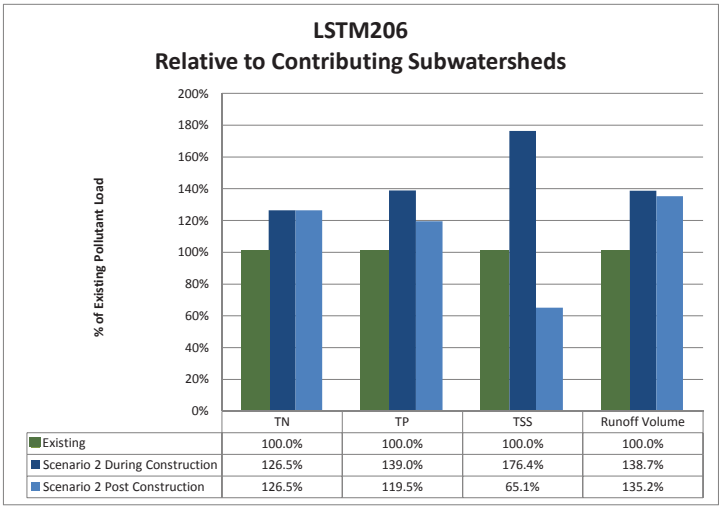


	Wetlands (acres)	Stream (feet)	Perennial Stream Buffer (acres)	Forest Interior (acres)	Forest (acres)	Areas with Slopes >25%	Areas with Slopes >15%
Scenario 2	8.7%	20.7%	19.1%	100.0%	52.0%	19.9%	36.2%
Scenario 3-4	5.9%	8.2%	7.8%	100.0%	37.2%	14.6%	23.1%
Scenario 5	0.5%	4.9%	6.1%	100.0%	35.8%	10.1%	19.8%

POLLUTANT LOAD ANALYSIS

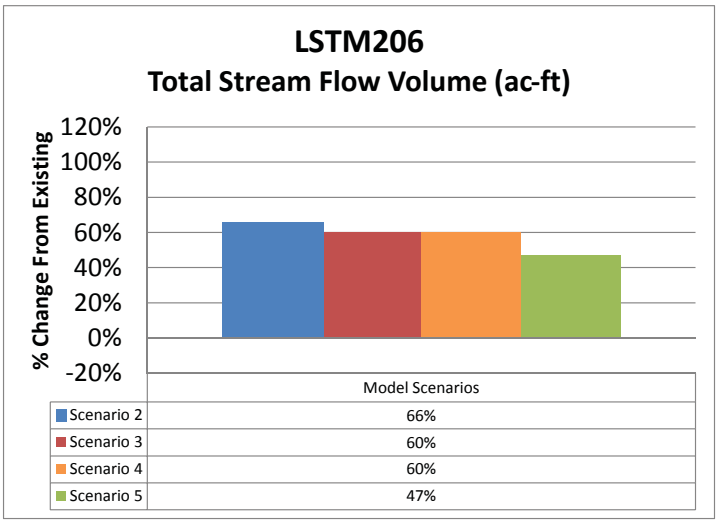


	TN	TP	TSS	Runoff Volume
Existing	11.6%	14.8%	3.7%	20.9%
Scenario 2 During Construction	14.7%	20.5%	6.5%	29.0%
Scenario 2 Post Construction	14.7%	17.6%	2.4%	28.3%

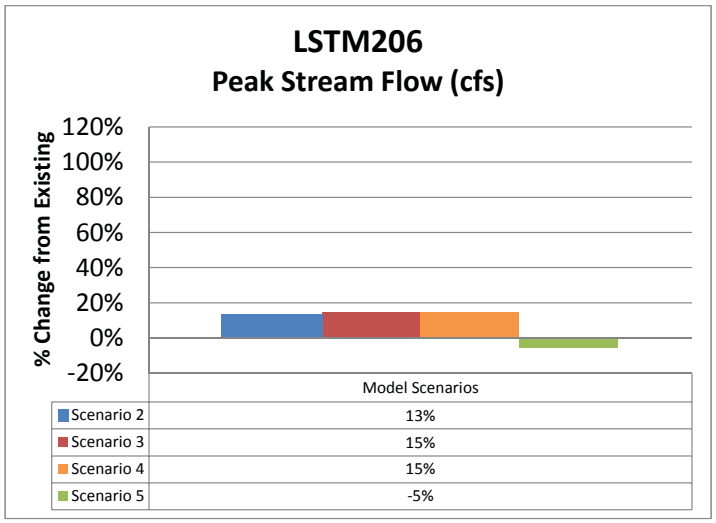


	TN	TP	TSS	Runoff Volume
Existing	100.0%	100.0%	100.0%	100.0%
Scenario 2 During Construction	126.5%	139.0%	176.4%	138.7%
Scenario 2 Post Construction	126.5%	119.5%	65.1%	135.2%

HYDROLOGY (1-YEAR, 24-HOUR STORM)



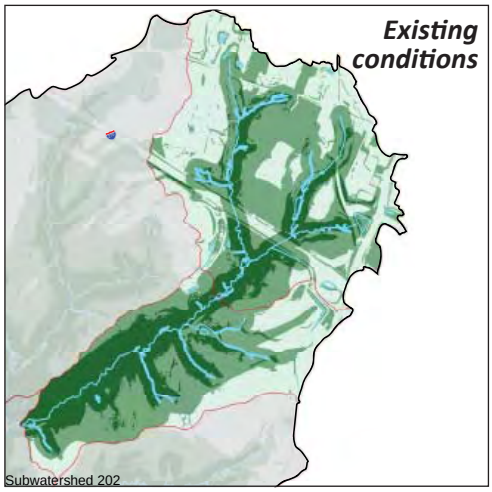
	Model Scenarios
Scenario 2	66%
Scenario 3	60%
Scenario 4	60%
Scenario 5	47%

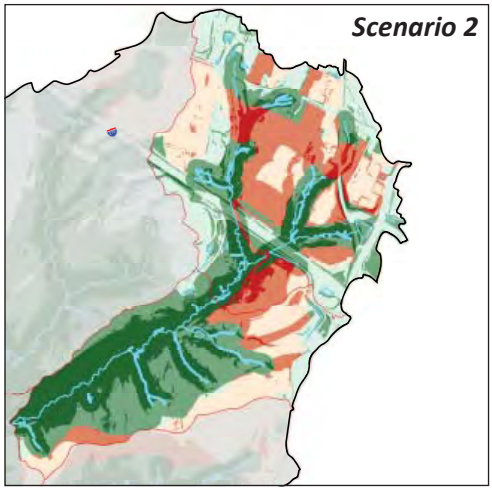


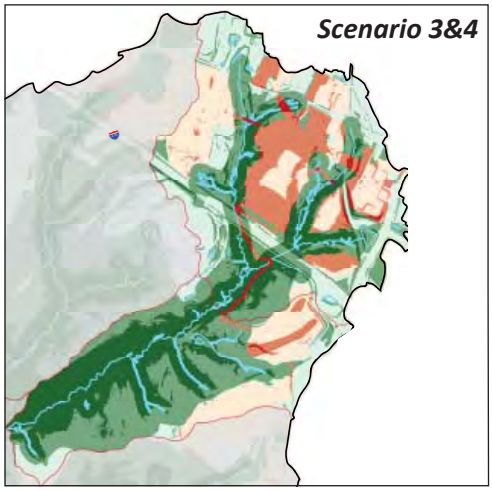
	Model Scenarios
Scenario 2	13%
Scenario 3	15%
Scenario 4	15%
Scenario 5	-5%



TEN MILE CREEK
Contributing Subwatersheds: LSTM206 & LSTM202



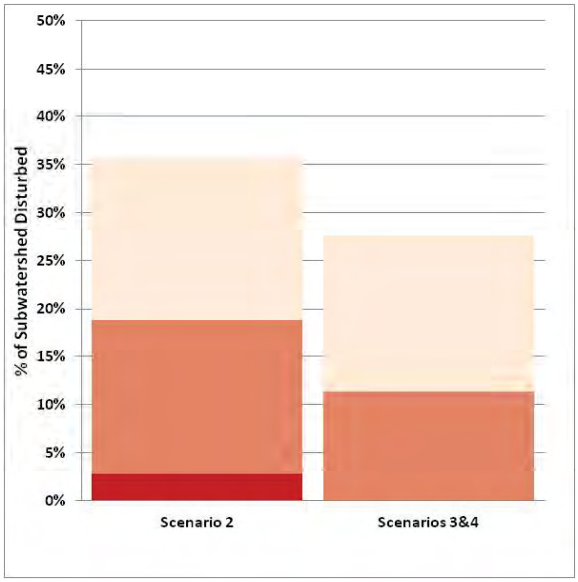




EXISTING CONDITIONS

Drainage Area (acres) – 613
% Impervious – 11%
% Forested – 52%
Stream Length (feet) – 20,707
IBI (average 1994-2012) – 30/good

LSTM206 & LSTM202
Subwatershed Disturbance

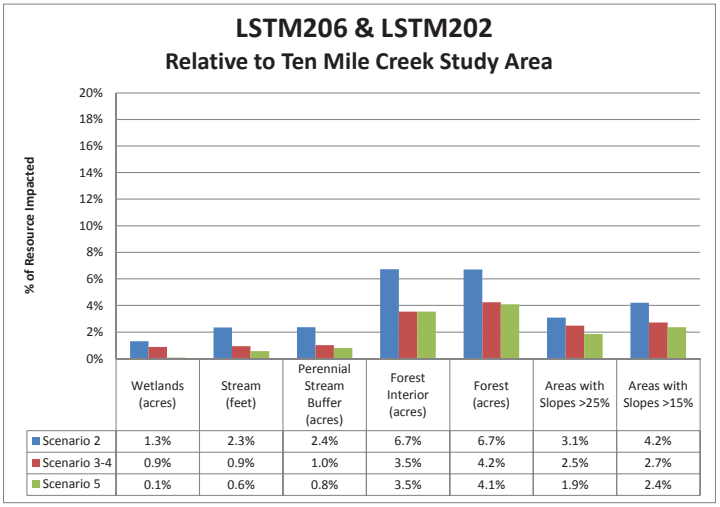


LEGEND

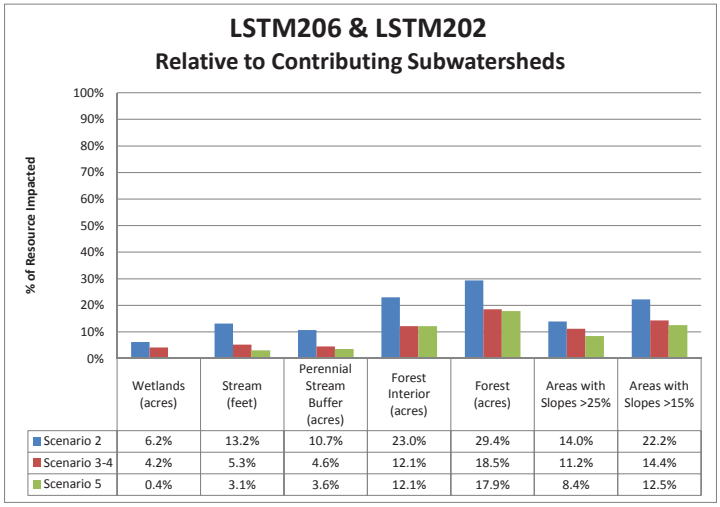
Natural Resource Attributes Undisturbed
- 0 Least
- 1 - 2
- 3 - 9 Most

Natural Resource Attributes Disturbed
- 0
- 1 - 2
- 3 - 9

IMPACTS ON RESOURCES

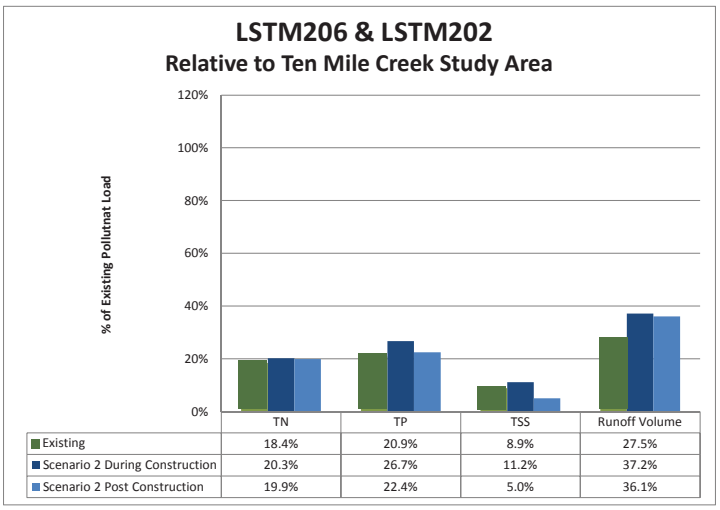


	Wetlands (acres)	Stream (feet)	Perennial Stream Buffer (acres)	Forest Interior (acres)	Forest (acres)	Areas with Slopes >25%	Areas with Slopes >15%
Scenario 2	1.3%	2.3%	2.4%	6.7%	6.7%	3.1%	4.2%
Scenario 3-4	0.9%	0.9%	1.0%	3.5%	4.2%	2.5%	2.7%
Scenario 5	0.1%	0.6%	0.8%	3.5%	4.1%	1.9%	2.4%

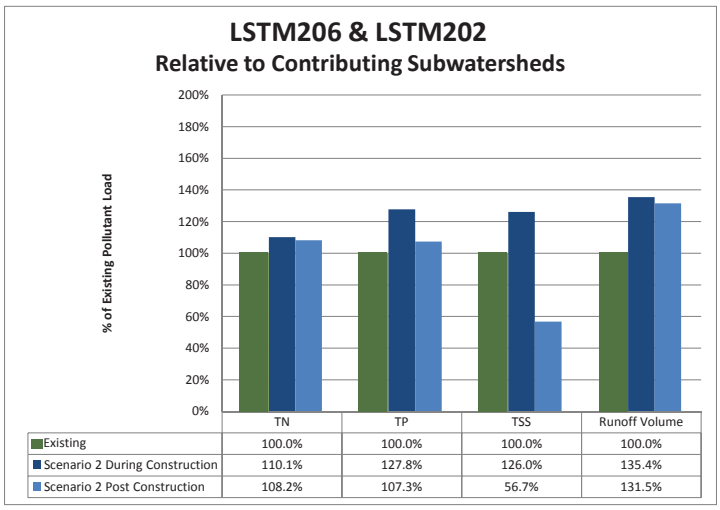


	Wetlands (acres)	Stream (feet)	Perennial Stream Buffer (acres)	Forest Interior (acres)	Forest (acres)	Areas with Slopes >25%	Areas with Slopes >15%
Scenario 2	6.2%	13.2%	10.7%	23.0%	29.4%	14.0%	22.2%
Scenario 3-4	4.2%	5.3%	4.6%	12.1%	18.5%	11.2%	14.4%
Scenario 5	0.4%	3.1%	3.6%	12.1%	17.9%	8.4%	12.5%

POLLUTANT LOAD ANALYSIS

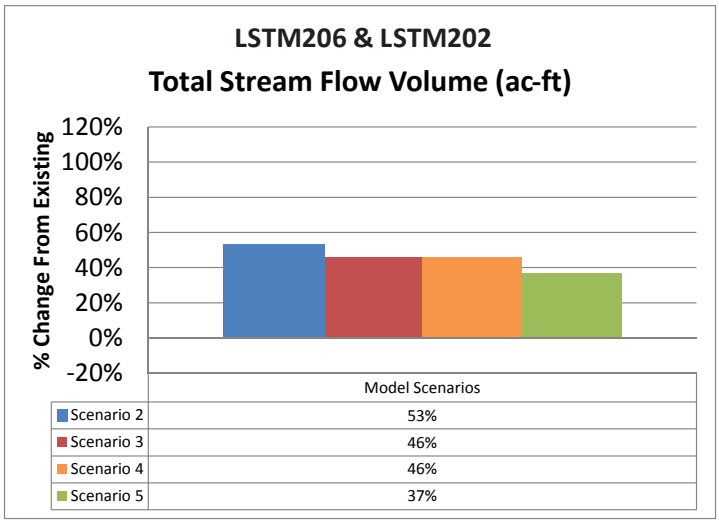


	TN	TP	TSS	Runoff Volume
Existing	18.4%	20.9%	8.9%	27.5%
Scenario 2 During Construction	20.3%	26.7%	11.2%	37.2%
Scenario 2 Post Construction	19.9%	22.4%	5.0%	36.1%

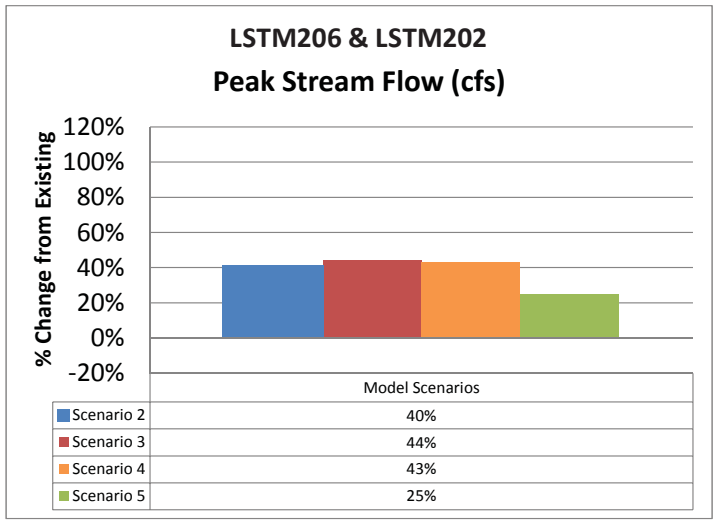


	TN	TP	TSS	Runoff Volume
Existing	100.0%	100.0%	100.0%	100.0%
Scenario 2 During Construction	110.1%	127.8%	126.0%	135.4%
Scenario 2 Post Construction	108.2%	107.3%	56.7%	131.5%

HYDROLOGY (1-YEAR, 24-HOUR STORM)



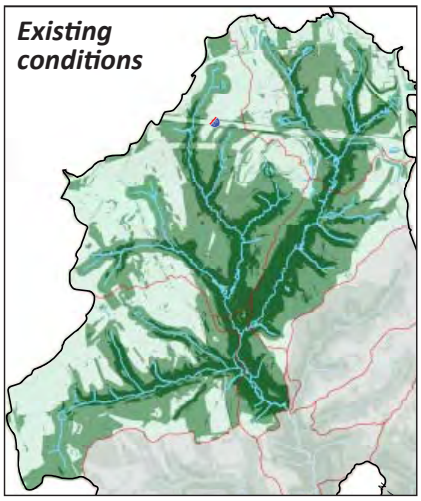
	Model Scenarios
Scenario 2	53%
Scenario 3	46%
Scenario 4	46%
Scenario 5	37%

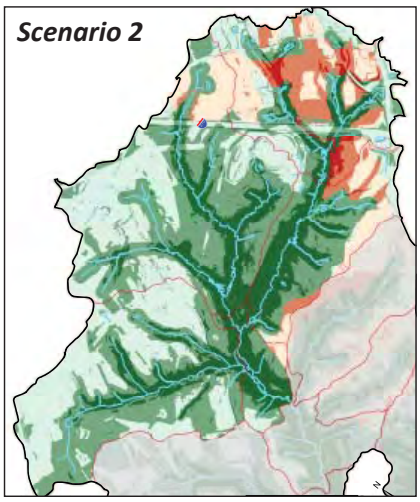


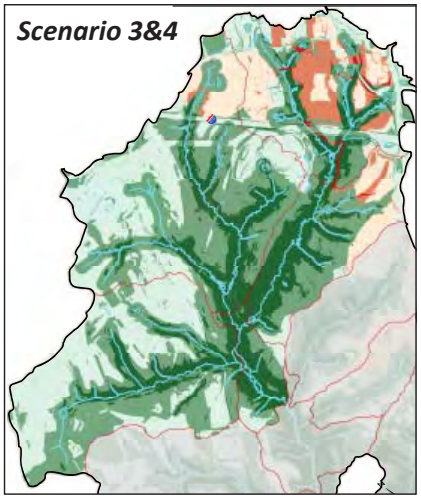
	Model Scenarios
Scenario 2	40%
Scenario 3	44%
Scenario 4	43%
Scenario 5	25%



TEN MILE CREEK
Contributing Subwatersheds: LSTM206, LSTM202, LSTM201, LSTM203, & LSTM302



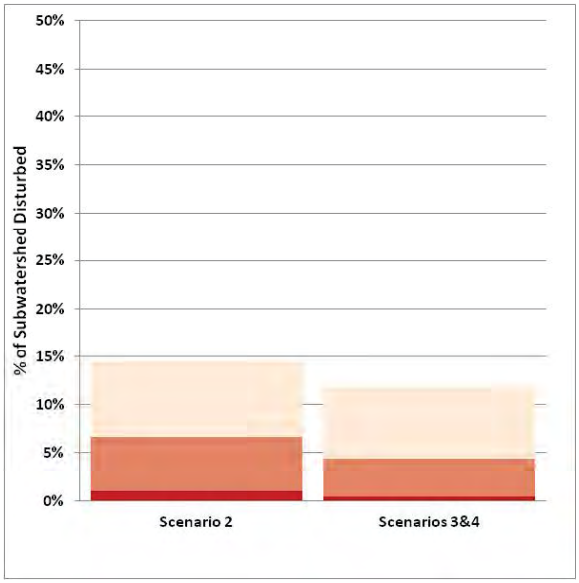




EXISTING CONDITIONS

Drainage Area (acres) – 1,794
% Impervious – 5%
% Forested – 47%
Stream Length (feet) – 68,412
IBI (average 1994-2012) – 35/good

LSTM206, LSTM202, LSTM201, LSTM203, & LSTM302 Subwatershed Disturbance

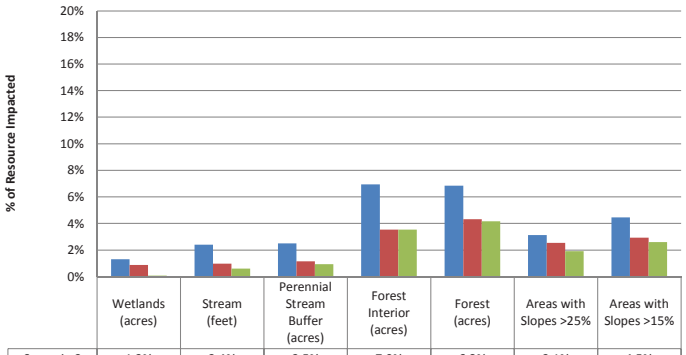


LEGEND

Natural Resource Attributes Undisturbed	Natural Resource Attributes Disturbed
0 Least	0
1 - 2	1 - 2
3 - 9 Most	3 - 9

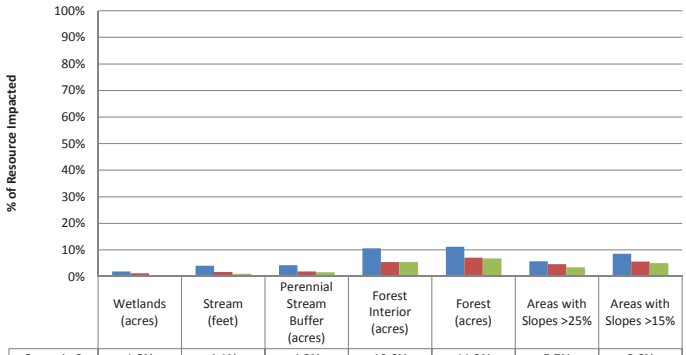
IMPACTS ON RESOURCES

LSTM206, LSTM202, LSTM201, LSTM203, & LSTM302
Relative to Ten Mile Creek Study Area



	Wetlands (acres)	Stream (feet)	Perennial Stream Buffer (acres)	Forest Interior (acres)	Forest (acres)	Areas with Slopes >25%	Areas with Slopes >15%
Scenario 2	1.3%	2.4%	2.5%	7.0%	6.8%	3.1%	4.5%
Scenario 3-4	0.9%	1.0%	1.1%	3.5%	4.3%	2.5%	2.9%
Scenario 5	0.1%	0.6%	0.9%	3.5%	4.2%	1.9%	2.6%

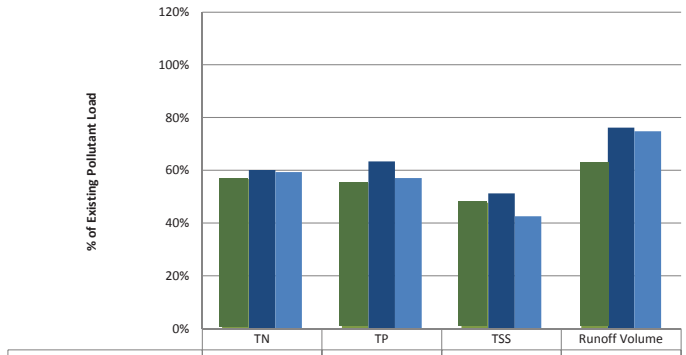
LSTM206, LSTM202, LSTM201, LSTM203, & LSTM302
Relative to Contributing Subwatersheds



	Wetlands (acres)	Stream (feet)	Perennial Stream Buffer (acres)	Forest Interior (acres)	Forest (acres)	Areas with Slopes >25%	Areas with Slopes >15%
Scenario 2	1.8%	4.1%	4.2%	10.6%	11.2%	5.7%	8.6%
Scenario 3-4	1.2%	1.7%	1.9%	5.4%	7.1%	4.6%	5.7%
Scenario 5	0.1%	1.0%	1.6%	5.4%	6.8%	3.5%	5.0%

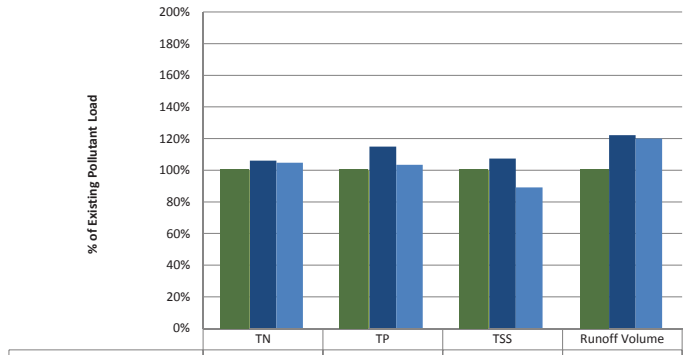
POLLUTANT LOAD ANALYSIS

LSTM206, LSTM202, LSTM201, LSTM203, & LSTM302
Relative to Ten Mile Creek Study Area



	TN	TP	TSS	Runoff Volume
Existing	56.6%	55.1%	47.7%	62.4%
Scenario 2 During Construction	60.1%	63.4%	51.3%	76.2%
Scenario 2 Post Construction	59.3%	57.0%	42.6%	74.8%

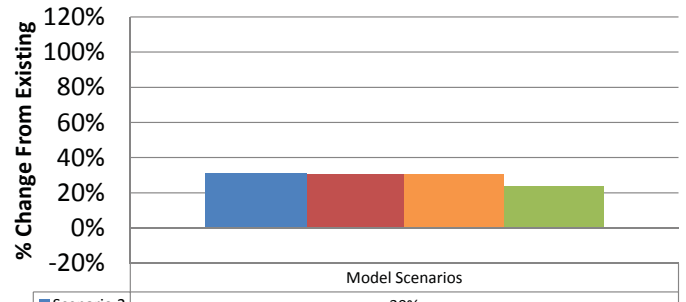
LSTM206, LSTM202, LSTM201, LSTM203, & LSTM302
Relative to Contributing Subwatersheds



	TN	TP	TSS	Runoff Volume
Existing	100.0%	100.0%	100.0%	100.0%
Scenario 2 During Construction	106.1%	115.0%	107.4%	122.2%
Scenario 2 Post Construction	104.7%	103.5%	89.2%	120.0%

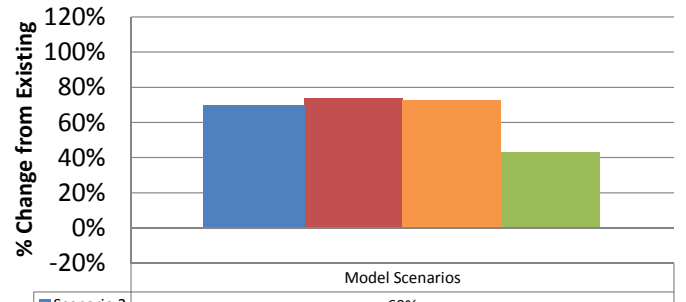
HYDROLOGY (1-YEAR, 24-HOUR STORM)

LSTM206, LSTM202, LSTM201, LSTM203, & LSTM302
Total Stream Flow Volume (ac-ft)



	Model Scenarios
Scenario 2	30%
Scenario 3	30%
Scenario 4	30%
Scenario 5	24%

LSTM206, LSTM202, LSTM201, LSTM203, & LSTM302
Peak Stream Flow (cfs)

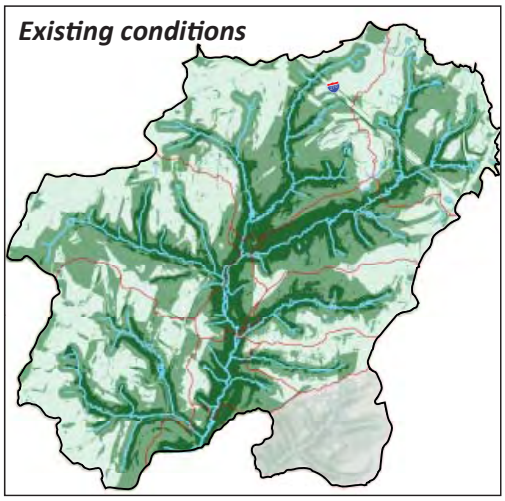


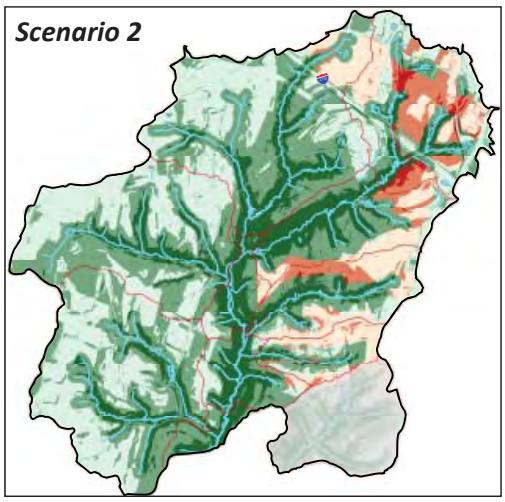
	Model Scenarios
Scenario 2	69%
Scenario 3	74%
Scenario 4	73%
Scenario 5	43%

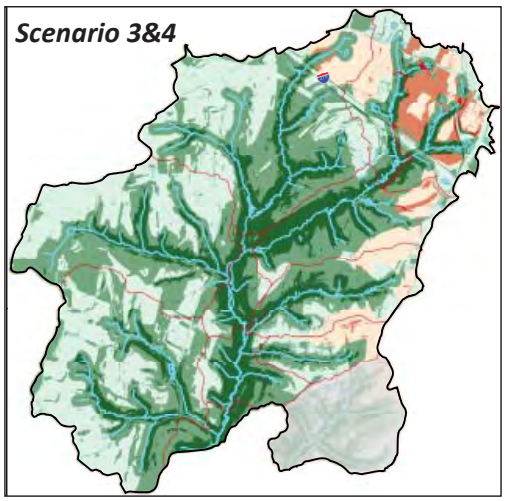


TEN MILE CREEK

Contributing Subwatersheds: LSTM206, LSTM202, LSTM201, LSTM203, LSTM204, LSTM110, LSTM111, LSTM302, LSTM303B, & LSTM304



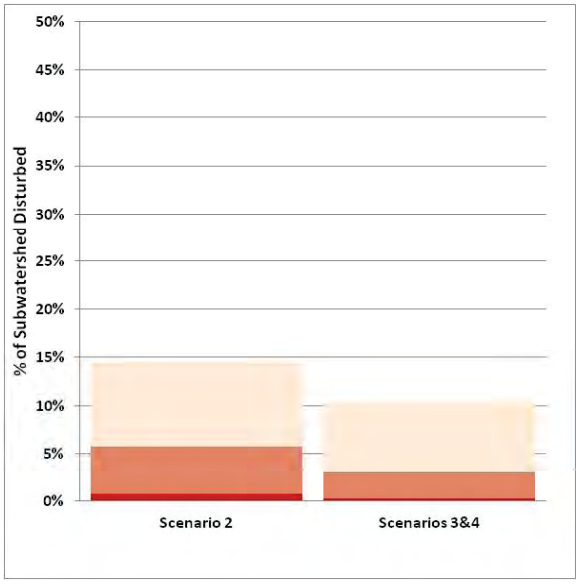




EXISTING CONDITIONS

Drainage Area (acres) – 2,818
% Impervious – 4%
% Forested – 45%
Stream Length (feet) – 107,252
IBI (average 1994-2012) – 35/good

LSTM206, LSTM202, LSTM201, LSTM203, LSTM204, LSTM110, LSTM111, LSTM302, LSTM303B, & LSTM304
Subwatershed Disturbance

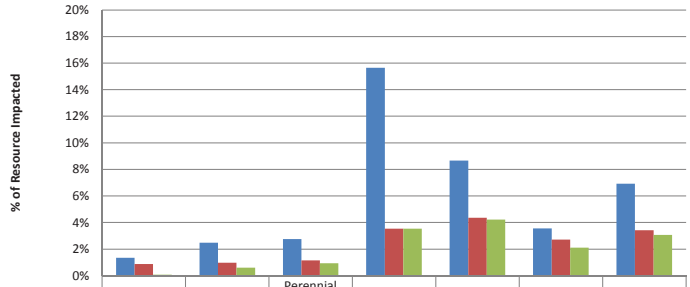


LEGEND

Natural Resource Attributes Undisturbed	Natural Resource Attributes Disturbed
0 Least	0
1 - 2	1 - 2
3 - 9 Most	3 - 9

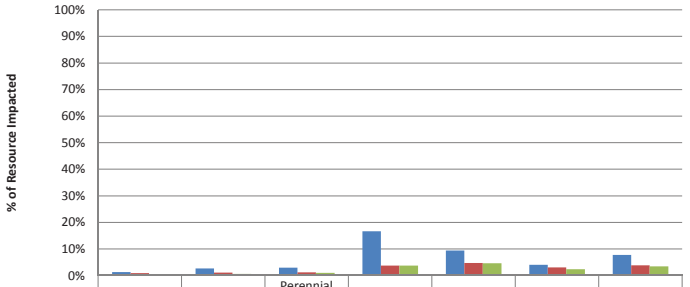
IMPACTS ON RESOURCES

LSTM206, LSTM202, LSTM201, LSTM203, LSTM204, LSTM110, LSTM111, LSTM302, LSTM303B, & LSTM304
Relative to Ten Mile Creek Study Area



	Wetlands (acres)	Stream (feet)	Perennial Stream Buffer (acres)	Forest Interior (acres)	Forest (acres)	Areas with Slopes >25%	Areas with Slopes >15%
Scenario 2	1.3%	2.5%	2.8%	15.6%	8.7%	3.6%	6.9%
Scenario 3-4	0.9%	1.0%	1.1%	3.5%	4.4%	2.7%	3.4%
Scenario 5	0.1%	0.6%	0.9%	3.5%	4.2%	2.1%	3.1%

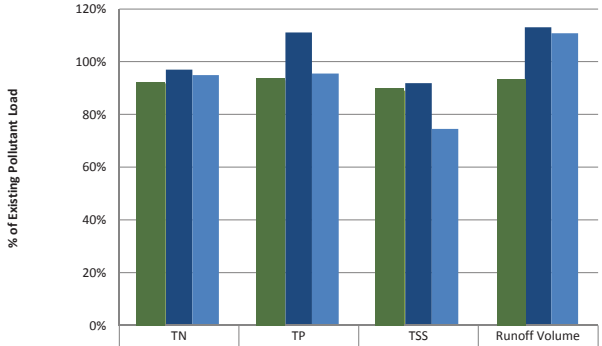
LSTM206, LSTM202, LSTM201, LSTM203, LSTM204, LSTM110, LSTM111, LSTM302, LSTM303B, & LSTM304
Relative to Contributing Subwatersheds



	Wetlands (acres)	Stream (feet)	Perennial Stream Buffer (acres)	Forest Interior (acres)	Forest (acres)	Areas with Slopes >25%	Areas with Slopes >15%
Scenario 2	1.3%	2.7%	3.0%	16.7%	9.4%	4.0%	7.8%
Scenario 3-4	0.9%	1.1%	1.2%	3.8%	4.8%	3.1%	3.8%
Scenario 5	0.1%	0.7%	1.0%	3.8%	4.6%	2.4%	3.5%

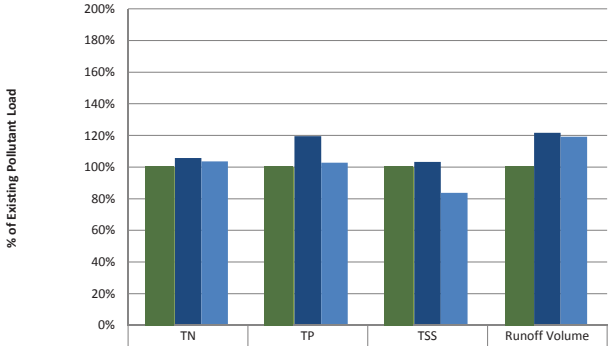
POLLUTANT LOAD ANALYSIS

LSTM206, LSTM202, LSTM201, LSTM203, LSTM204, LSTM110, LSTM111, LSTM302, LSTM303B, & LSTM304
Relative to Ten Mile Creek Study Area



	TN	TP	TSS	Runoff Volume
Existing	91.7%	92.9%	89.0%	93.0%
Scenario 2 During Construction	96.9%	111.1%	91.9%	113.1%
Scenario 2 Post Construction	94.9%	95.5%	74.5%	110.8%

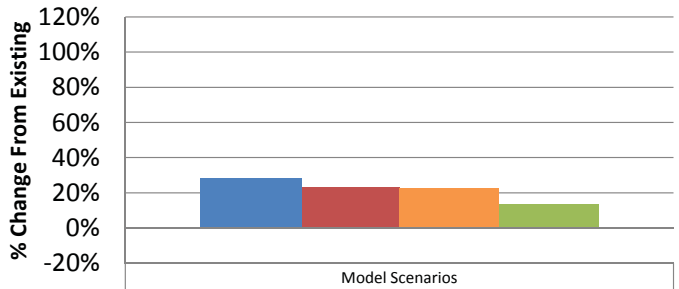
LSTM206, LSTM202, LSTM201, LSTM203, LSTM204, LSTM110, LSTM111, LSTM302, LSTM303B, & LSTM304
Relative to Contributing Subwatersheds



	TN	TP	TSS	Runoff Volume
Existing	100.0%	100.0%	100.0%	100.0%
Scenario 2 During Construction	105.7%	119.5%	103.3%	121.6%
Scenario 2 Post Construction	103.5%	102.7%	83.7%	119.2%

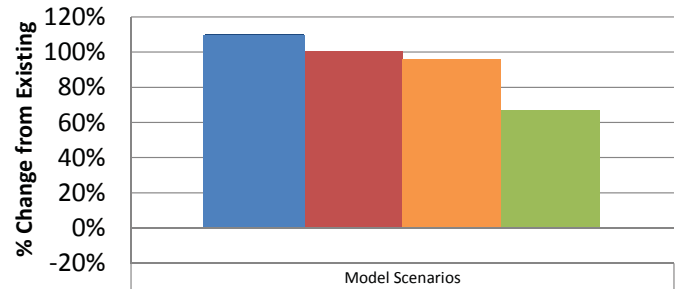
HYDROLOGY (1-YEAR, 24-HOUR STORM)

LSTM206, LSTM202, LSTM201, LSTM203, LSTM204, LSTM110, LSTM111, LSTM302, LSTM303B, & LSTM304
Total Stream Flow Volume (ac-ft)



	Model Scenarios
Scenario 2	28%
Scenario 3	23%
Scenario 4	22%
Scenario 5	13%

LSTM206, LSTM202, LSTM201, LSTM203, LSTM204, LSTM110, LSTM111, LSTM302, LSTM303B, & LSTM304
Peak Stream Flow (cfs)



	Model Scenarios
Scenario 2	110%
Scenario 3	100%
Scenario 4	96%
Scenario 5	67%

Attachment B. Existing Conditions in the Ten Mile Creek Study Area

Existing Conditions
in the Ten Mile Creek Study Area
In Support of the Limited Amendment to the Clarksburg Master Plan

Prepared for:
Maryland-National Capital Park & Planning Commission
Montgomery County Planning Department

Prepared by:

Biohabitats
Brown AND Caldwell
A Joint Venture

April 3, 2013

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LIST OF ACRONYMS

Best management practice (BMP)
IBI (index of biotic integrity)
Maryland Biological Stream Survey (MBSS)
Maryland Department of Natural Resources (MDNR)
Maryland Historical Trust (MHT)
Maryland-National Capital Park and Planning Commission (M-NCPPC)
Montgomery County Department of Environmental Protection (DEP)
Montgomery County Department of Permitting Services (DPS)
Research and development (R&D)
Sediment and erosion control (S&EC)
Special Protection Area (SPA)
Stormwater management (SWM)
Total maximum daily load (TMDL)
Transfer of development rights (TDRs)
United States Environmental Protection Agency (U.S. EPA)
USDA Natural Resources Conservation Service (NRCS)
Water quality limited segment (WQLS)

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EXECUTIVE SUMMARY

The Ten Mile Creek watershed in northwestern Montgomery County is the focus of an environmental analysis study in support of the Limited Amendment to the Clarksburg Master Plan, being undertaken by the Maryland-National Capital Park and Planning Commission (M-NCPPC) Montgomery County Planning Department. This environmental analysis is being conducted for the Planning Department by Biohabitats and Brown and Caldwell, a Joint Venture, with support from the Center for Watershed Protection. It is being done in collaboration with Montgomery County Department of Environmental Protection (DEP) and Montgomery County Department of Permitting Services (DPS).

As the purpose of this study is to determine the baseline environmental conditions in order to evaluate potential watershed response to development within the Ten Mile Creek watershed, this report and future analyses will focus only on subwatersheds upstream of the existing USGS gage station and those that have the potential to be directly affected by development (Figure E.1). These subwatersheds are referred to as the Ten Mile Creek "study area." The Ten Mile Creek study area drains approximately 4.8 square miles of primarily rural and forested lands in Montgomery County, flowing from its headwaters just north of Frederick Road to Little Seneca Lake.

Existing conditions in the Ten Mile Creek were evaluated through review of GIS data and numerous reports and studies of the watershed. Key watershed characteristics are described below:

- Ten Mile Creek feeds into Little Seneca Lake, which serves as a reservoir providing additional flow to the Potomac River, a public raw water supply, during drought periods (Montgomery County Department of Park and Planning, 1994). The aquifer in the study area is designated as a Sole Source Aquifer per the United States Environmental Protection Agency's (U.S. EPA) Sole Source Aquifer Program (Greenhorne & O'Mara, Inc., 1992).

- Base flows are low in the summer months and the creek is susceptible to low flows from lack of rain. However, even in the driest years tributaries have continued to flow and to provide cool, clean water as refuge for the stream biotic community. Montgomery County DEP located seeps and springs throughout the Ten Mile Creek study area, the majority are in headwaters of tributaries to Ten Mile Creek. Both are necessary to maintain base flows in headwater streams (Montgomery County Department of Environmental Protection, 2013).

- Wetlands are concentrated along Ten Mile Creek mainstem. These are predominantly palustrine forested wetlands and are groundwater-dominated.

- Beaver have developed a series of dams in the upper reaches of Ten Mile Creek which provide pools that act as refuge for fish, amphibians and reptiles during the drier summer months and habitat for wintering waterfowl and wildlife in the winter months (Montgomery County Planning Department, 2009). In addition, "bird surveys in 2009 observed or heard 12 migratory nesting forest interior bird species in Stage 4 forest interior areas of Ten Mile Creek" (Montgomery County Planning Department, 2009).

- Development in the overall watershed is low, and roughly half of the study area is forested. Imperviousness is approximately 4%, and the remaining land cover in the study area is predominantly a mix of non-forested pervious area, including pasture, cropland, and turf. Ten Mile

Creek subwatersheds labeled LSTM206 and LSTM201 have the highest impervious cover and urban land uses.

- Subwatersheds LSTM202 and LSTM201, as well as, subwatersheds along the mainstem have the highest forested land cover. The forested cover along the mainstem and through LSTM202 and LSTM201 is a major contiguous hub linking hubs in Black Hill and Little Bennett Regional Parks by corridors. MDNR (2003) defines hubs as areas that consist of large contiguous tracts of forest land that are integral to the ecological health of the state and corridors as linear remnants of these vital habitats that form linkages among the hubs. The largest gap in forest cover occurs in northeast LSTM201, north of I-270 which bisects the corridor to Little Bennett Regional Park. Forested areas within the study area are characterized as upland or bottomland hardwood forest. Upland hardwood forest is particularly prevalent in the western portion of study area. Bottomland hardwood forests are located along stream, floodplains and wetland areas within the watershed.

- Soils within the study area were formed from weathered phyllite, a metamorphic rock, and are generally rocky with a shallow to moderate depth to bedrock and steep slopes. Based on soil survey mapping, 45 percent slopes are the steepest slopes found along the upland stream valley. The upland summits range from 3 to 8 percent slopes (Soil Survey Staff, 2013). Erodible soils were prevalent in subwatersheds LSTM203, LSTM204, LSTM202, and LSTM112. The shallow bedrock, slopes, and erodible soils could pose general siting restrictions for foundations, septic systems, roads, basements, etc., as well as a challenge for erosion and sediment control during construction activities, and post-construction stormwater management. In addition, disturbance to the shallow soils, as a result of grading associated with development, could also create negative impacts to local stream habitat and biology.

- Long-term and spatially comprehensive geomorphic monitoring data are not available for Ten Mile Creek. The limited available datasets and field observations suggest that the streams are very dynamic (i.e. streams frequently move and deposit material and adjust their shape). Evidence of widespread and significant channel degradation (i.e. chronic lowering of the channel bed with time), which is often observed in highly disturbed watersheds, is not evident in the Ten Mile Creek watershed. Flood flows along many reaches of Ten Mile Creek still access the floodplain, sustaining important geomorphic and ecological processes. Streams in the region have been subjected to an extended history of changes in sediment supply and hydrology due to land use changes. Like many streams in the region, Ten Mile Creek has adjusted in response to these historic changes, and continues to adjust to existing inputs of water and sediment.

- Long-term monitoring of the stream habitat within the Ten Mile Creek watershed by DEP, including measurement of the physical habitat and sampling of biological communities (fish, benthic macroinvertebrates, and herptofauna), indicates that the overall biological condition is in the good range (63-87) with an average score for all stations of 77. Two subwatersheds (LSTM110 and LSTM110) scored in the excellent range (>87) and two subwatersheds (LSTM112 and LSTM206) scored fair (41-63).

- In-stream physical habitat conditions (such as stream bed and bank conditions) show signs of decline since 2007. While the change is subtle over time, these conditions are indicative of a watershed that is sensitive and is responding to various stressors. Evidence of declining habitat conditions include increased embeddedness (the degree to which coarse bed material is choked by fine sediments), sedimentation, and decreased streambank vegetation. However a proportional

response in the overall biological condition has not been observed. Long-term monitoring data collected by DEP does generally indicate that the proportion of sensitive taxa, both fish and benthic macroinvertebrate, present within the watershed are declining while the tolerant individuals are increasing in both number and richness.

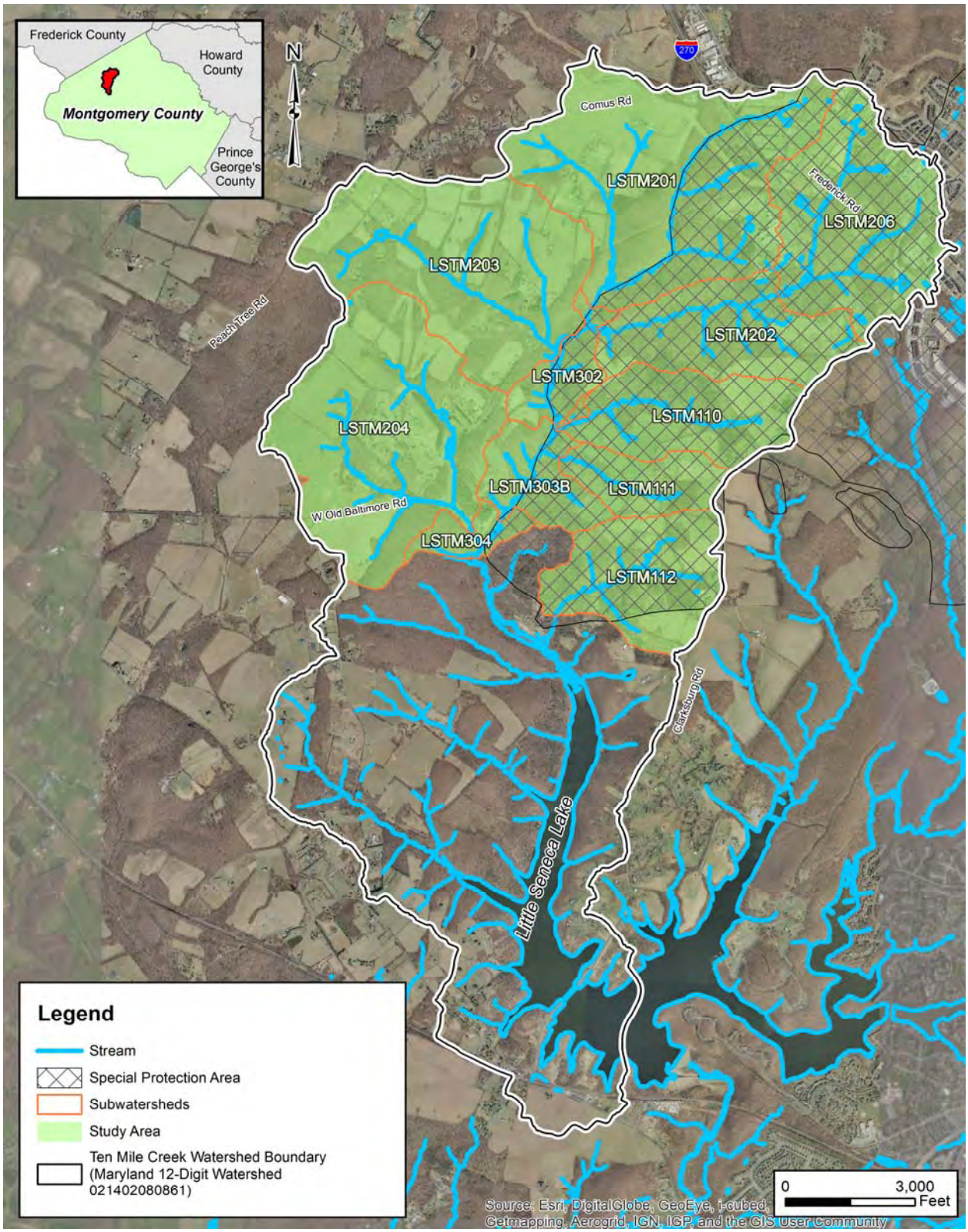


Figure E.1. Ten Mile Creek Watershed and Subwatersheds

1.0 INTRODUCTION

1.1 Introduction to the Existing Conditions Report

In response to a request by the Montgomery County Council, the Montgomery County Planning Department has asked the Planning Board to prepare a Limited Amendment to the Clarksburg Master Plan to determine how to achieve the Plan's community-building goals for the Town Center District, while protecting Ten Mile Creek. The amendment will include a comprehensive analysis of environmentally sensitive areas in the Ten Mile Creek watershed to determine ways to balance development potential and the community objectives specified in the 1994 plan with the need to protect water quality. This environmental analysis is being conducted for the Planning Department by Biohabitats and Brown and Caldwell, a Joint Venture, with support from the Center for Watershed Protection.

This report on existing conditions within the Ten Mile Creek watershed is the first product developed for this analysis. As the purpose of this study is to determine the baseline environmental conditions in order to evaluate potential watershed response to development within the Ten Mile Creek watershed, this report and future analyses will focus only on subwatersheds upstream of the existing USGS gage station and those that have the potential to be directly affected by development. These subwatersheds, displayed in Figure E.1, will be referred to as the Ten Mile Creek "study area." Sections 2, 3 and 4 provide more detailed information on the study area's land use and land cover, natural features, and community features.

A number of documents were reviewed while developing this baseline assessment; a complete listing of all Ten Mile Creek related documents obtained and reviewed is provided in Appendix A, along with a list of all GIS data sources used to create maps.

1.2 Introduction to the Ten Mile Creek Watershed

The Ten Mile Creek watershed (12-digit watershed code 021402080861) is located in the Clarksburg area of northwestern Montgomery County (Figure E.1). The drainage area of the ***study area*** within Ten Mile Creek – the focus of this report and future analyses – is approximately 3,046 acres (4.8 square miles) and drains into Little Seneca Lake reservoir (Figure 1.1), which flows into the Potomac River.

Ten Mile Creek originates just north of MD 335 (Frederick Road) and flows into Little Seneca Lake. Little Seneca Lake serves as a reservoir providing additional flow to the Potomac River, a public raw water supply, during drought periods (Montgomery County Department of Park and Planning, 1994). Little Seneca Lake, constructed from 1982 to 1985, has a surface area of 505 acres, a shoreline of 15.7 miles, and an average depth of 24.7 feet. The dam was constructed of earth and rock and rises 91 feet above the stream (Greenhorne & O'Mara, 1992). Ten Mile Creek and its tributaries are designated as a Use I-P stream – protection of water contact recreation, aquatic life and drinking water supply (Montgomery County Department of Park and Planning, 1994).

A portion of Ten Mile Creek study area, all land east of Ten Mile Creek mainstem and north of West Old Baltimore Road, is located within the Clarksburg Master Plan Special Protection Area (SPA). The SPA was developed as a result of the Clarksburg Area Master Plan, adopted in 1994, and also includes portions of Little Seneca Creek, Cabin Branch, and Wildcat Branch subwatersheds (Montgomery County Department of Environmental Protection, 2012). In addition, a portion of the watershed west of Ten Mile Creek is within the county-wide Agricultural Reserve. This is a result of the western portion of the watershed

being dominated by larger parcels and agriculture land uses (Montgomery County Department of Park and Planning, 1994). A basic profile of the study area is provided in Table 1.1. The study area within Ten Mile Creek includes 11 subwatersheds (Table 1.2 and Figure E.1).

Table 1.1. Profile of the Current Ten Mile Creek Study Area

Area in Montgomery County	• 3,046 acres (4.8 square miles)
Stream Length	• Approximately 22 miles (including Ten Mile Creek and its tributaries)
Land Use	• 46% Forest • 38% Rural • 7% Low Density Residential
Land Cover	• 4% Impervious Cover • 46% Forest Cover • Remaining land cover predominantly a mix of non-forested pervious area, including pasture, cropland, and turf
Water Quality	• Use I-P Stream
Major Transportation Routes	• Dwight D. Eisenhower Memorial Highway (I-270) • Frederick Road (MD 355)
Significant Natural and Historical Features	• Rustic roads • Old Baltimore Road stream ford • Cemeteries • 1994 Clarksburg Master Plan Individual Sites (Clarksburg School, Moneysworth Farm, and Cephas Summers House) • 1994 Clarksburg Master Plan Historical District (Clarksburg Historical District)

Table 1.2. Ten Mile Creek Study Area Subwatersheds

Subwatershed	Within Special Protection Area (SPA)	Area (acres)	Area (square miles)	Percent of Study Area
LSTM110	Yes	211	0.3	7%
LSTM111	Yes	104	0.2	3%
LSTM112	Partial	228	0.4	7%
LSTM201	Partial	611	1.0	20%
LSTM202	Yes	243	0.4	8%
LSTM203	No	493	0.8	16%
LSTM204	No	544	0.8	18%
LSTM206	Yes	370	0.6	12%
LSTM302	Partial	77	0.1	3%
LSTM303B	Partial	117	0.2	4%
LSTM304	Partial	49	0.1	2%
TOTAL		**3,046**	**4.8**	**100%**

Source: (Montgomery County Planning Department & Montgomery County Department of Environmental Protection, 2013)

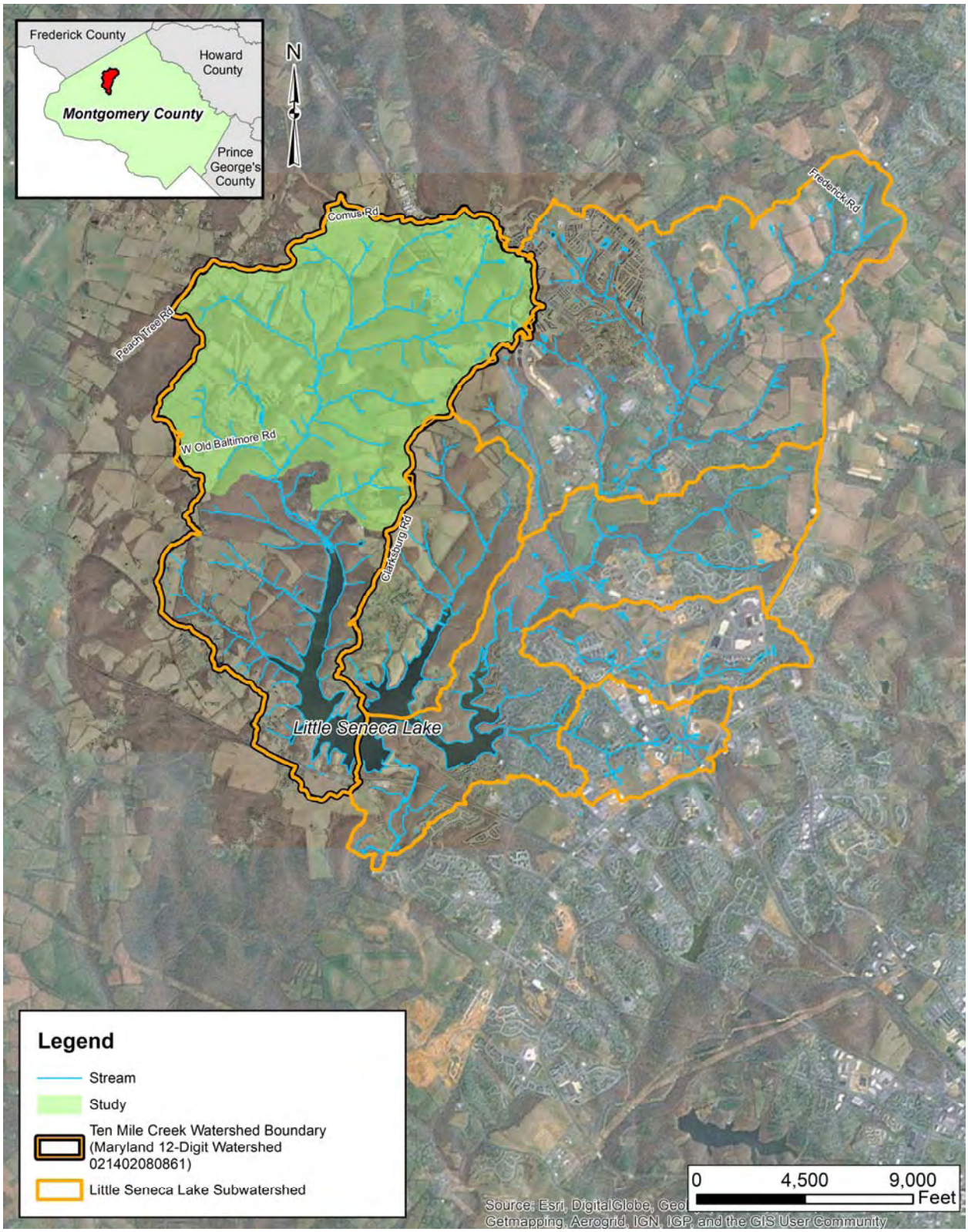


Figure 1.1. Little Seneca Lake Watershed

2.0 LAND USE AND LAND COVER

2.1 Existing Land Use

The principal land uses within the Ten Mile Creek study area include forest, rural, and low-density residential, as shown in Figure 2.1 and Table 2.1. The east side of the study area is within the Clarksburg SPA. The remainder is zoned Rural Density Transfer (RDT) and is not part of the SPA because the rural zoning precludes significant development of the area.

Table 2.1. Land Use in the Ten Mile Creek Study Area

Land Use	Area (acres)	Percent of Total
Forest	1,420	46%
Rural	1,145	38%
Low-density Residential	203	7%
Transportation	86	3%
Institutional	75	2%
Bare Ground	38	1%
Water & Wetlands	27	1%
Medium-density Residential	20	1%
Industrial	16	1%
Commercial	9	<1%
High-density Residential	7	<1%
TOTAL	**3,046**	**100%**

Data source: Maryland Department of Planning, 2007 (Montgomery County Planning Department & Montgomery County Department of Environmental Protection, 2013)

Table 2.2 lists completed or active development projects according to the County's SPA Reports. As shown in the table, construction is currently underway or has been completed on several projects in the study area.

Table 2.2. Recent Development Activity in the Clarksburg Special Protection Area

Development	Subwatershed	Land Use	Status
Clarksburg Detention Facility	LSTM206, LSTM202, LSTM201 & LSTM106	34 acres, Jail	• Under Construction in 1998 • Construction Completed in 2002 • Stormwater Conversion in April 2003
Stringtown Road Extension	LSTM206	17 acres, Roadway	• Under Construction 2004 • Construction Completed in November 2006
Gateway Commons	LSTM206		• March 2008, <30% under construction • November 2008, 30 to 60% constructed • 2010, >60% completed, and 30 to 60% permanently stabilized
Gateway 270 Corporations	LSTM206		• Construction Completed in 2010

Data source: DEP SPA Reports, 1994-2010

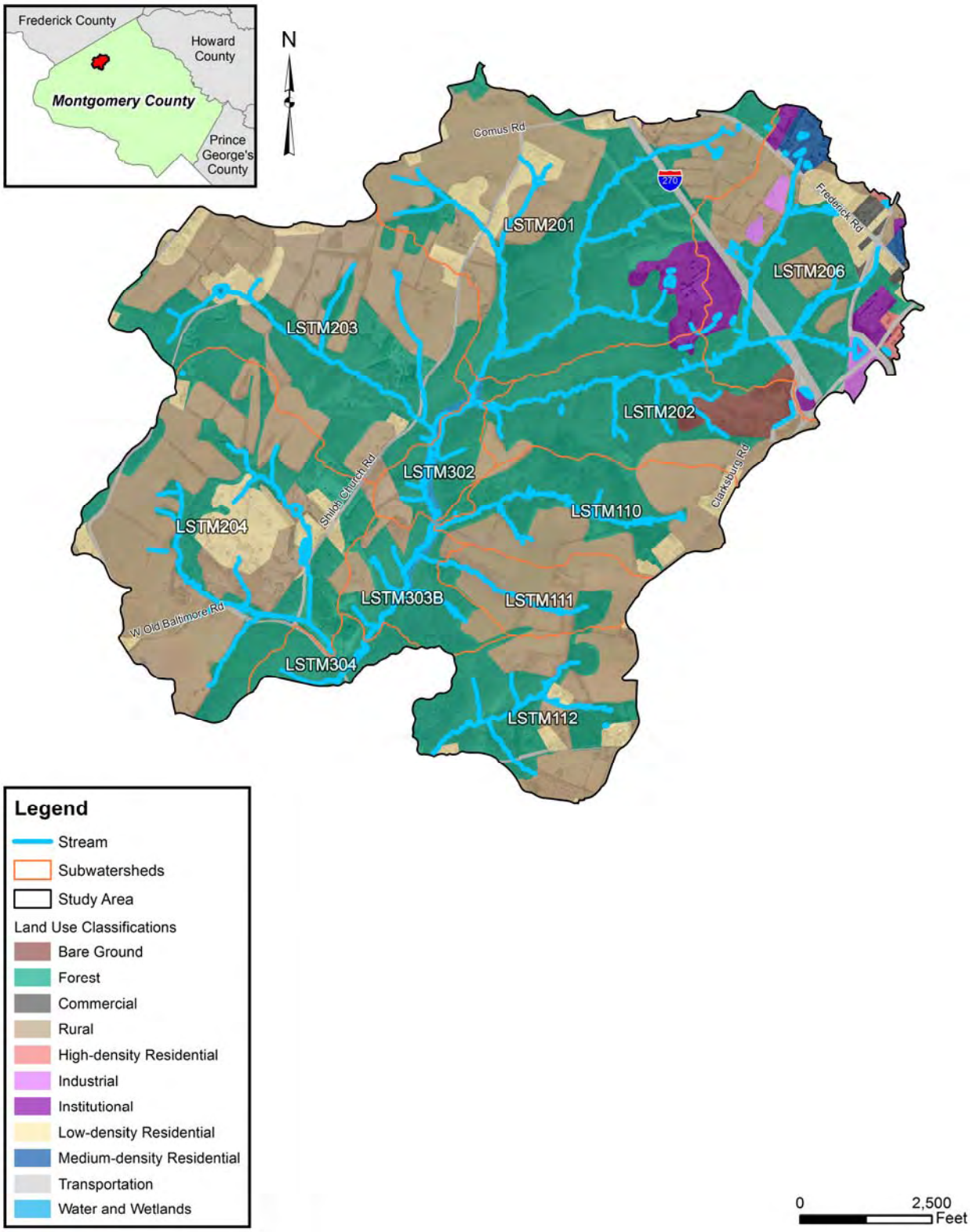


Figure 2.1. Land Use in the Ten Mile Creek Study Area

2.2 Land Cover

Forty-six percent of the Ten Mile Creek study area (Figure 2.2) is in forest cover, while only 4% is in impervious cover. Forest cover and imperviousness by subwatershed is displayed in Table 2.3. Remaining land cover in the study area is predominantly a mix of non-forested pervious area, including pasture, cropland, and turf.

Smaller subwatersheds along the mainstem of Ten Mile Creek have the highest percentage of forest cover, including LSTM304, LSTM303B, and LSTM302. The largest contributors to forest cover in the study area includes subwatersheds LSTM201, LSTM203, LSTM204, LSTM202 and LSTM206. More discussion on the study area's forest cover, including forest interior and habitat value, is provided in Section 3.9 of this report.

Subwatershed LSTM206 has the highest percentage of imperviousness at 16%. It is also the largest contributor of impervious cover to the study area at nearly 49% of the total impervious cover acreage, followed by subwatershed LSTM201 at 19%. Both subwatersheds include I-270 and developed areas east of the highway.

Table 2.3. Imperviousness and Forest Cover in the Ten Mile Creek Study Area

Subwatershed	Subwatershed Imperviousness (%)	Contribution to Study Area Imperviousness (%)	Subwatershed Forest Cover (%)	Contribution to Study Area Forest Cover (%)
LSTM206	16.2%	48.9%	42%	11%
LSTM201	3.8%	19.0%	44%	19%
LSTM204	2.5%	11.0%	33%	13%
LSTM203	1.9%	7.6%	41%	14%
LSTM112	2.5%	4.7%	49%	8%
LSTM202	2.2%	4.5%	67%	12%
LSTM110	1.6%	2.7%	45%	7%
LSTM111	1.2%	1.0%	19%	1%
LSTM304	0.9%	0.4%	89%	3%
LSTM303B	0.1%	0.1%	77%	7%
LSTM302	0.1%	0.1%	83%	5%

Data source: DEP Impervious Cover, 2012; MCP Forest Cover, 2008 (Montgomery County Planning Department & Montgomery County Department of Environmental Protection, 2013)

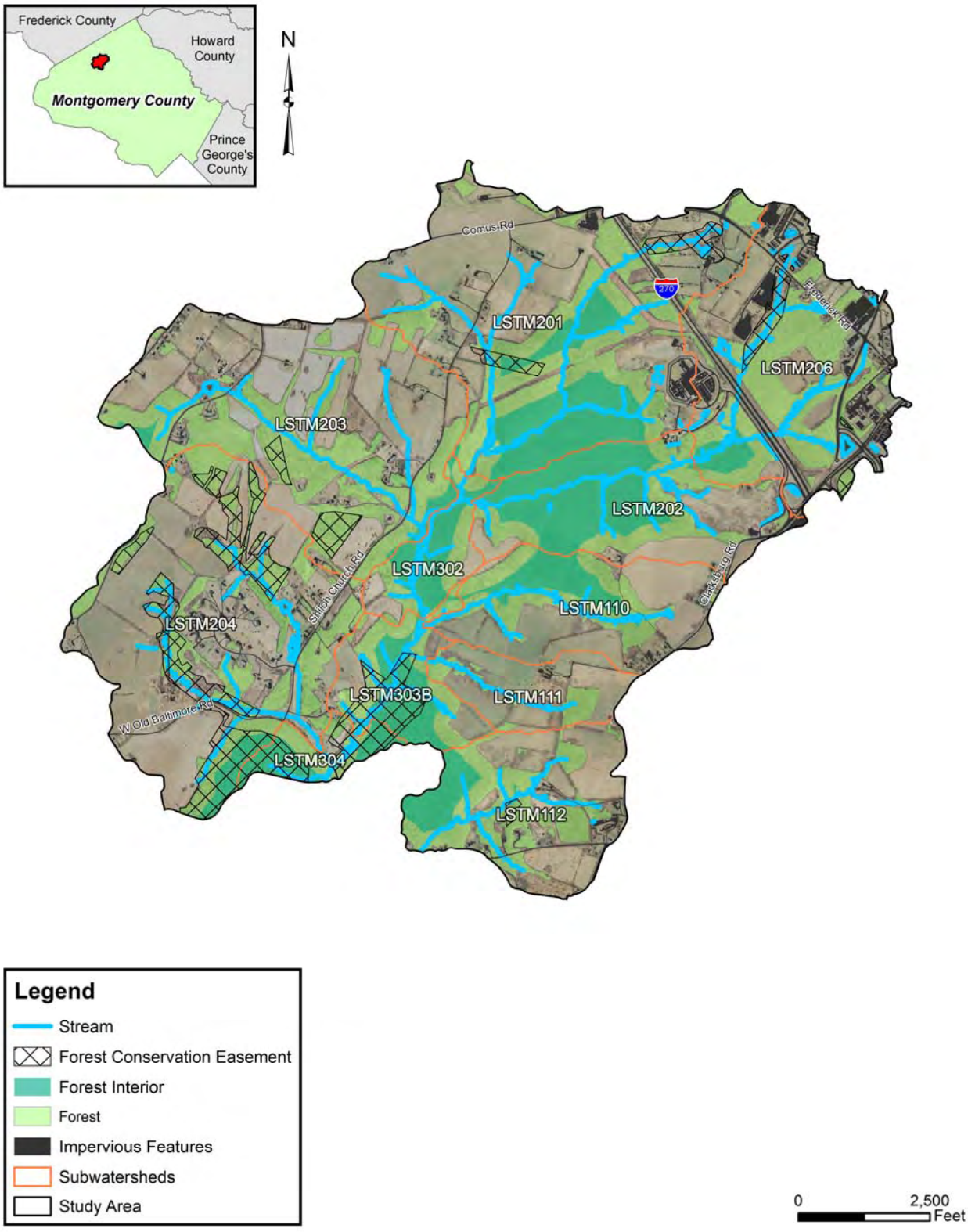


Figure 2.2. Land Cover in the Ten Mile Creek Study Area

2.3 Clarksburg Master Plan

The Ten Mile Creek watershed includes part of the Town Center District and all of the Ten Mile Creek Area in the 1994 Clarksburg Master Plan. The plan envisioned the Town Center District as a strong central focus for the entire master plan area, while also emphasizing the protection of Ten Mile Creek as a sensitive and fragile natural resource. The plan envisions land uses and densities that would result in relatively high levels of imperviousness. Most of the Ten Mile Creek area was placed in the last implementation stage to allow evaluation of protection measures and consideration of additional water quality measures and land use actions.

West of I-270, the master plan provisions for the Ten Mile Creek Area recommended a balance of environmental concerns, housing needs and employment uses in the high-technology employment corridor. The provisions included:

- employment sites with development criteria to help address environmental concerns,
- low density residential use for land west of MD 121,
- low density residential (2-4 units per acre) between the mainstem of the creek and Shiloh Church Road with a substantial area of private conservation area and parkland, and
- the remaining area in the watershed in rural residential (1 unit per 5 acres) and agricultural reserve.

The research and development (R&D) land in the Ten Mile Creek Area is limited to 15% imperviousness and with uses tightly clustered close to I-270. The residential area west of MD 121 is approximately 600 acres and is limited to a maximum of 900 units, with any units beyond the base density requiring the purchase of transfer of development rights (TDRs). The plan specifies that at least 70% must be single family dwellings, with the open space and conservation areas being undeveloped and forested.

3.0 NATURAL FEATURES

3.1 Climate

Table 3.1 shows the normal monthly temperature, precipitation and snowfall records from the nearest National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Center (NCDC) weather station. This station is located in southwest Damascus, Maryland, but the data is representative of the general climate conditions in the Ten Mile Creek watershed. Overall, the average mean daily temperature is 54.5 degrees Fahrenheit (NCDC, 2010). The average monthly precipitation reaches a maximum of 5.15 inches in May and a minimum of 3.01 inches in February. The mean precipitation total is 43.9 inches and the mean snow total is 26.0 inches (National Climate Data Center, 2010). Montgomery County's growing season, the period between the last killing frost in the spring and the first in the fall, extends from approximately the beginning of April to the end of October. The growing season is approximated by median dates (e.g., 50 percent probability) of 28°F air temperatures based on WETS tables available from NRCS National Water and Climate Center (National Weather and Climate Center, 2002).

Table 3.1. Summary of Monthly Normals 1981-2010

Month	Daily Maximum (°F)	Daily Minimum (°F)	Mean (°F)	Mean Precipitation Totals (in.)	Mean Snow Totals (in.)
January	39.8	25.0	32.4	3.09	10.0
February	44.3	26.9	35.6	3.01	6.8
March	53.0	34.0	43.5	4.04	3.0
April	64.4	43.6	54.0	3.47	1.0
May	72.9	51.8	62.3	5.15	0.0
June	81.4	60.7	71.1	3.57	0.0
July	85.6	65.1	75.3	3.46	0.0
August	83.8	64.2	74.0	3.08	0.0
September	77.2	56.7	67.0	4.22	0.0
October	65.2	46.3	55.8	3.82	0.0
November	54.8	38.0	46.4	3.61	1.2
December	43.5	29.0	36.3	3.38	4.0
Total				**43.9**	**26.0**

Data source: Weather station Damascus 3 SW, MD US (National Climate Data Center, 2010).

3.2 Topography

The Ten Mile Creek watershed is within the Mt. Airy Upland District of the Piedmont Upland Section of the Piedmont Plateau Province (Reger & Cleaves, 2008). This section of the Piedmont physiographic province is characterized by gently rolling upland of low relief to very rolling and hilly topography, with some major streams incised into narrow, steep-sided valleys. Stream network patterns have been affected by joints in the bedrock and interactions of thin siltstones and quartzites that are oblique to the bedrock strike (Reger & Cleaves, 2008).

Within the Ten Mile Creek study area, ground elevations range from 390 to 680 feet above sea level (Figure 3.1). Based on soil survey mapping, 45 percent slopes are the steepest slopes found along the upland stream valley. The upland summits ranged from 3 to 8 percent (Soil Survey Staff, 2013).

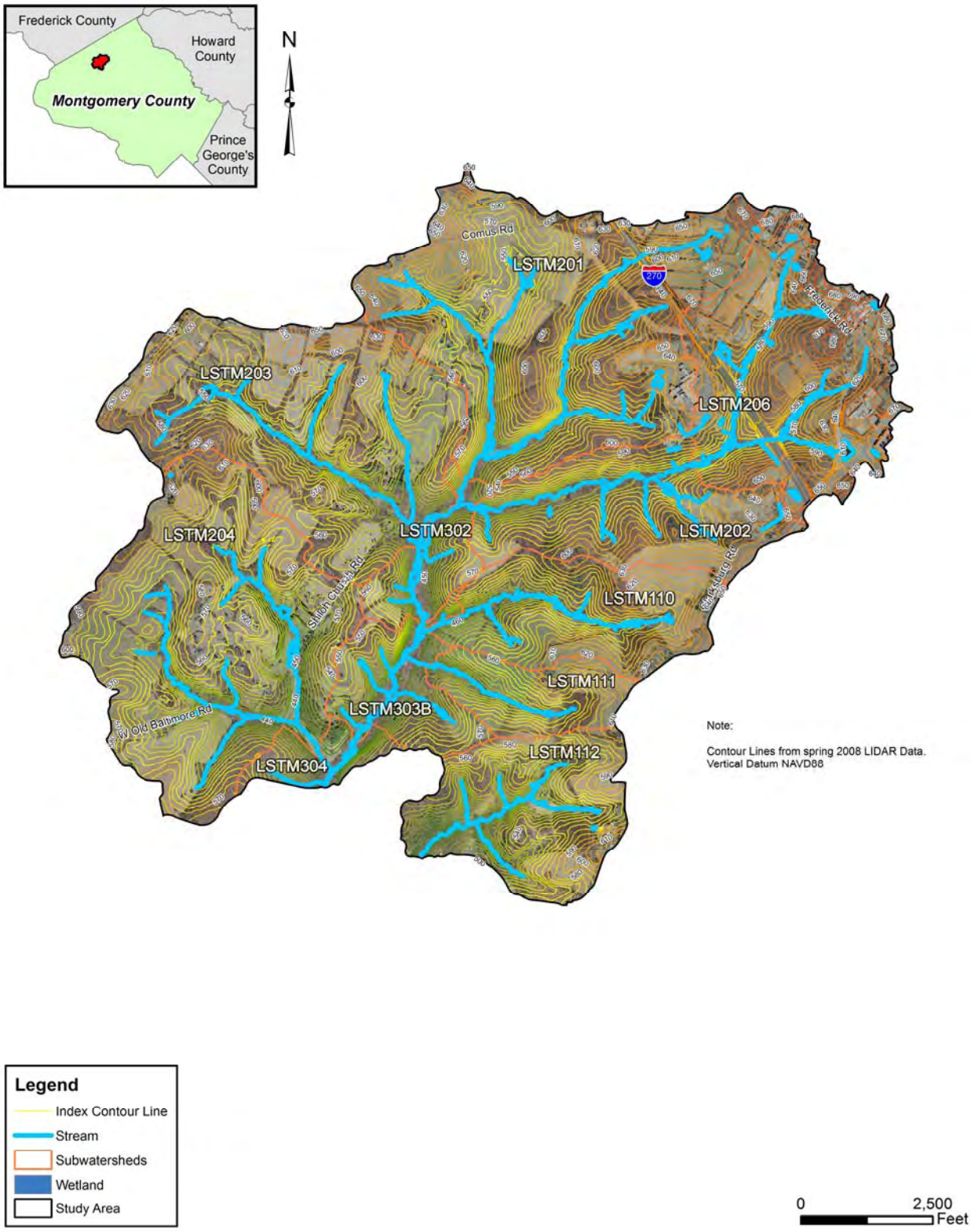


Figure 3.1. Ten Mile Creek Study Area Topography

3.3 Geology

Available GIS mapping shows one predominant bedrock lithology, phyllite, in the Ten Mile Creek study area. Phyllite is a metamorphosed rock (altered at depth by pressure and heat), intermediate in grade between a slate and mica schist. Additional mapping available online through the Maryland Geological Survey (1968) identifies the unit as the Ijamville Formation. The Ijamville Formation includes a suite of rocks that were originally sedimentary (a layered rock resulting from consolidation of sediment) and underwent alteration over time. Specific rock types identified by the Maryland Geological Survey (1968) include blue, green, or purple phyllite and phyllitic slate, with interbedded metasiltstone and metagraywacke and local pumiceous blebs. Lenses of quartz-rich rocks have also been observed in bedrock outcrops along streams in the Ten Mile Creek study area. The bedrock geology of Ten Mile Creek is typical of other nearby watersheds in Montgomery County, which are underlain by Western Piedmont metasedimentary rocks (sedimentary rocks altered by pressure and heat, Maryland Geological Survey [1968]). The phyllitic bedrock is associated with shallow soil formation in the Ten Mile Creek watershed.

3.4 Soils

According to USDA Natural Resources Conservation Service (NRCS) Soil Survey mapping, the study area within Ten Mile Creek is mapped with fifteen soil map units excluding water (Figure 3.2 and Table 3.2) (Soil Survey Staff, 2013). The soils map units mapped along nearly level ridge crests and side slopes of ridges formed in residuum (soil formed in place) weathered from phyllite and schist. The soil series composing these map units are either shallow to moderately deep with a restrictive layer of lithic (hard bedrock that is not able to be dug with hand tools) or paralithic (bedrock that can be dug with difficulty with hand tools) bedrock. Shallow soils have a restrictive layer ranging from 10 to 20 inches from the soil surface, while moderately deep soils have a restrictive layer ranging from 20 to 40 inches. The shallow and moderately deep soils are evidence that geology – phyllite – is more resistant to weathering and slower to form deep soils. In addition, these soil series are typically well drained, have steep slopes ranging from 15 to 45 percent slopes, and have rock fragments on the surface and throughout the soil profile. The soil map units mapped along Ten Mile Creek mainstem and its tributaries were formed in alluvium (soil deposited by flowing water) or colluvium (soil accumulated by the action of gravity). The soil series composing these map units are either poorly drained or moderately well drained and a few may experience flooding (Soil Survey Staff, 2013). A more detailed description of the soil map units and their soil series is provided in Appendix B.

The soils are able to support several vegetative habitats throughout the Ten Mile Creek study area including upland hardwood forests, bottomland hardwood forests, and palustrine forest wetlands, in addition to agricultural practices (i.e. pasture and crops) (Greenhorne & O'Mara, 1992; Montgomery County Department of Parks and Planning, 1994). The shallow depth to bedrock and steep slopes of the soils dominating the study area will be the most limiting factors to development (e.g., roads, excavation, etc.) and its associated erosion and sediment control.

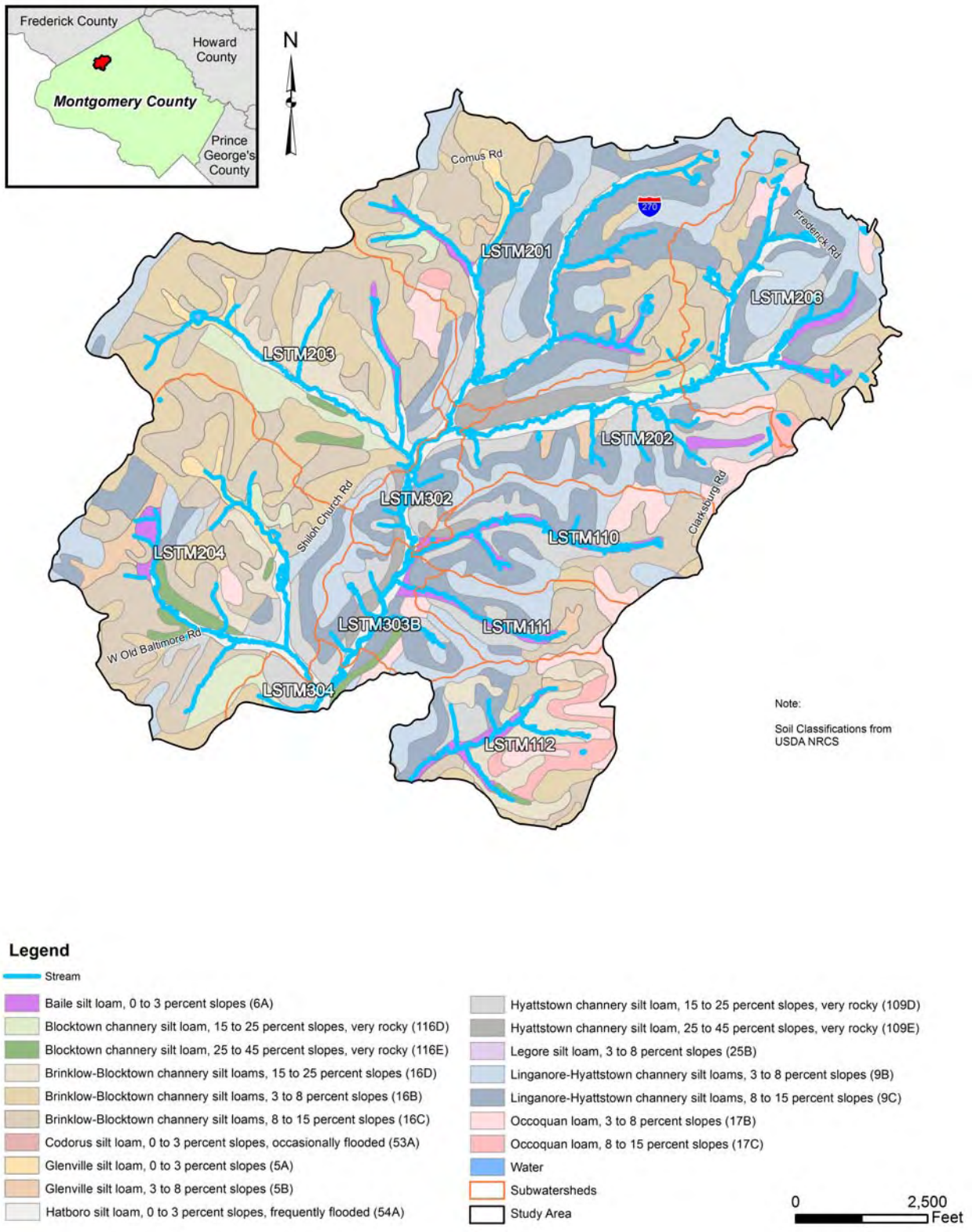


Figure 3.2. Ten Mile Creek Study Area Soils

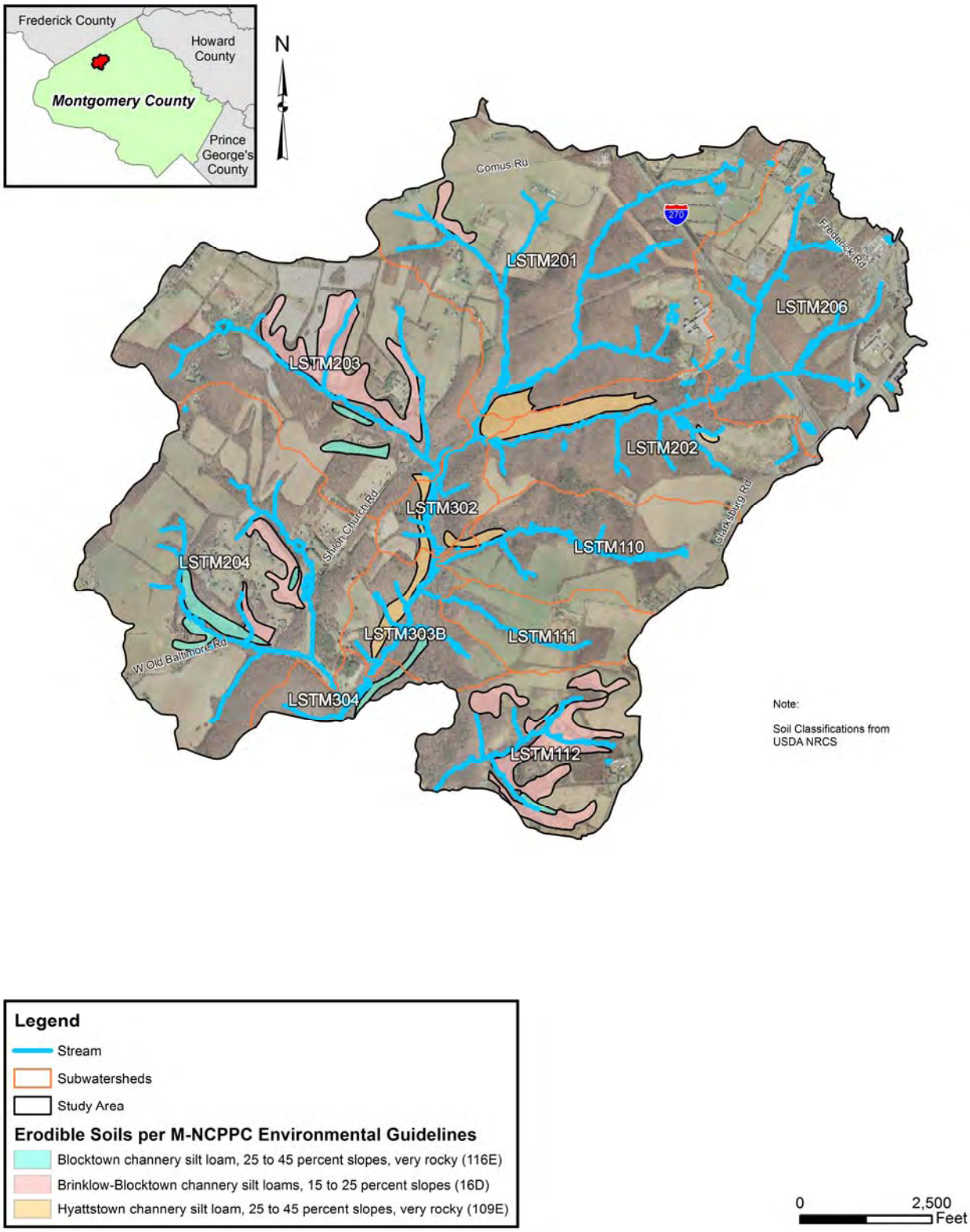


Figure 3.3. Ten Mile Creek Study Area Erodible Soils

Using the Planning Board's Environmental Guidelines list of erodible soils, the following soil map units were identified as erodible: Blocktown channery silt loam, 25 to 45 percent slopes, very rocky (116E); Brinklow-Blocktown channery silt loams, 15 to 25 percent slopes (16D); and Hyattstown channery silt loam, 25 to 45 percent slopes, very rocky (109E) (Figure 3.3) (Montgomery County Department of Park and Planning, 2000; Montgomery County Planning Department, 2013). The shallow depth to bedrock, presence of rock fragments on the surface and within the soil profile, and steep slopes of these selected map units can contribute to the soils' susceptibility to erosion. These same three characteristics are observed in other soil map units within the study area such as Blocktown channery loam, 15 to 25 percent slopes (116D) and Hyattstown channery silt loam, 15 to 25 percent slopes (109D). .

Subwatersheds with the highest percentage of erodible soils within the study area are LSTM112, LSTM203, LSTM303B, and LSTM302 (Table 3.3) in decreasing order. These subwatersheds tend to have the highest concentration of erodible soils because each subwatershed's landscape is highly dissected by the Ten Mile Creek mainstem or its tributaries, contributing to the presence of steeper slopes – a contributing factor to erodibility. It is typical of a highly dissected landscape to have steeper slopes.

Hydrologic soil groups (HSGs) help define the amount of runoff and infiltration capacity of a drainage area and are categorized into four groups – A, B, C, and D. "Most of the groupings are based on the premise that soils found within a climatic region that are similar in depth to a restrictive layer or water table, transmission rate of water, texture, structure, and degree of swelling when saturated, will have similar runoff responses (Natural Resources Conservation Service, 2009)." The four HSGs are briefly defined as follows (Natural Resources Conservation Service, 2009):

- Group A: Soil with low runoff potential and high infiltration capacity.
- Group B: Soil with moderately low runoff potential and moderately high infiltration capacity.
- Group C: Soil with moderately runoff potential and moderate infiltration capacity.
- Group D: Soil with high runoff potential and low infiltration capacity.

The HSGs dictate the type of stormwater management strategy applicable for development in a particular area based on parameters such as infiltration. For example, infiltration practices are best suited for HSG A or B soils, whereas practices with underdrains or detention practices are more appropriate for HSG C or D soils (Maryland Department of the Environment and Center for Watershed Protection, 2009). Three– B, C, and D – are within the study area (Table 3.2). Since infiltration can vary from location to location, infiltration should be field tested prior to the start of any design.

Table 3.2. Soils in the Study Area within Ten Mile Creek Study Area

Soil Map Unit Name (Symbol)	Acres of Study Area	Percent of Study Area	Hydrologic Soil Group
Glenville silt loam, 0 to 3 percent slopes (5A)	38.2	1.3%	C
Glenville silt loam, 3 to 8 percent slopes (5B)	52.1	1.7%	C
Baile silt loam, 0 to 3 percent slopes (6A)	93.3	3.1%	D
Linganore-Hyattstown channery silt loams, 3 to 8 percent slopes (9B)	424.2	13.9%	B
Linganore-Hyattstown channery silt loams, 8 to 15 percent slopes (9C)	493.7	16.2%	B
Brinklow-Blocktown channery silt loams, 3 to 8 percent slopes (16B)	473.8	15.6%	B
Brinklow-Blocktown channery silt loams, 8 to 15 percent slopes (16C)	544.3	17.9%	B
Brinklow-Blocktown channery silt loams, 15 to 25 percent slopes (16D)*	140.7	4.6%	B

Table 3.2. Soils in the Study Area within Ten Mile Creek Study Area

Soil Map Unit Name (Symbol)	Acres of Study Area	Percent of Study Area	Hydrologic Soil Group
Occoquan loam, 3 to 8 percent slopes (17B)	129.5	4.3%	B
Occoquan loam, 8 to 15 percent slopes (17C)	45.5	1.5%	B
Hatboro silt loam, 0 to 3 percent slopes, frequently flooded (54A)	169.5	5.6%	D
Hyattstown channery silt loam, 15 to 25 percent slopes, very rocky (109D)**	264.5	8.7%	C
Hyattstown channery silt loam, 25 to 45 percent slopes, very rocky (109E)*	55.4	1.8%	C
Blocktown channery silt loam, 15 to 25 percent slopes, very rocky (116D)**	84.7	2.8%	C
Blocktown channery silt loam, 25 to 45 percent slopes, very rocky (116E)*	34.4	1.1%	C
Water (W)	2.3	0.1%	-

*Identified as M-NCPPC's highly erodible soils.
**Identified as additional erodible soils of concern.

Data source: (Montgomery County Planning Department & Montgomery County Department of Environmental Protection, 2013)

Table 3.3. Erodible Soils by Subwatershed

Subwatershed	Erodible Soils[1]	
	Acreage	% of Subwatershed
LSTM110	2.2	1.1%
LSTM111	-	-
LSTM112	61.5	27.0%
LSTM201	14.7	2.4%
LSTM202	22.5	9.3%
LSTM203	65.1	13.2%
LSTM204	36.2	6.7%
LSTM206	-	-
LSTM302	9.7	12.6%
LSTM303B	15.0	12.8%
LSTM304	3.6	7.4%

Source:
[1] Montgomery County Planning Department, 2013)

3.5 Hydrology

Streams

The Ten Mile Creek study area is comprised of nearly 22 miles of streams (Figure 3.4). There are several sources of information descriptive of the stream hydrology in the Ten Mile Creek study area. Available information and resources are briefly summarized below, and include a relatively new stream gage and results from a synoptic flow survey conducted by DEP. However, as is typical for a watershed of this size, there is no long-term, more comprehensive gage network or hydrologic dataset available.

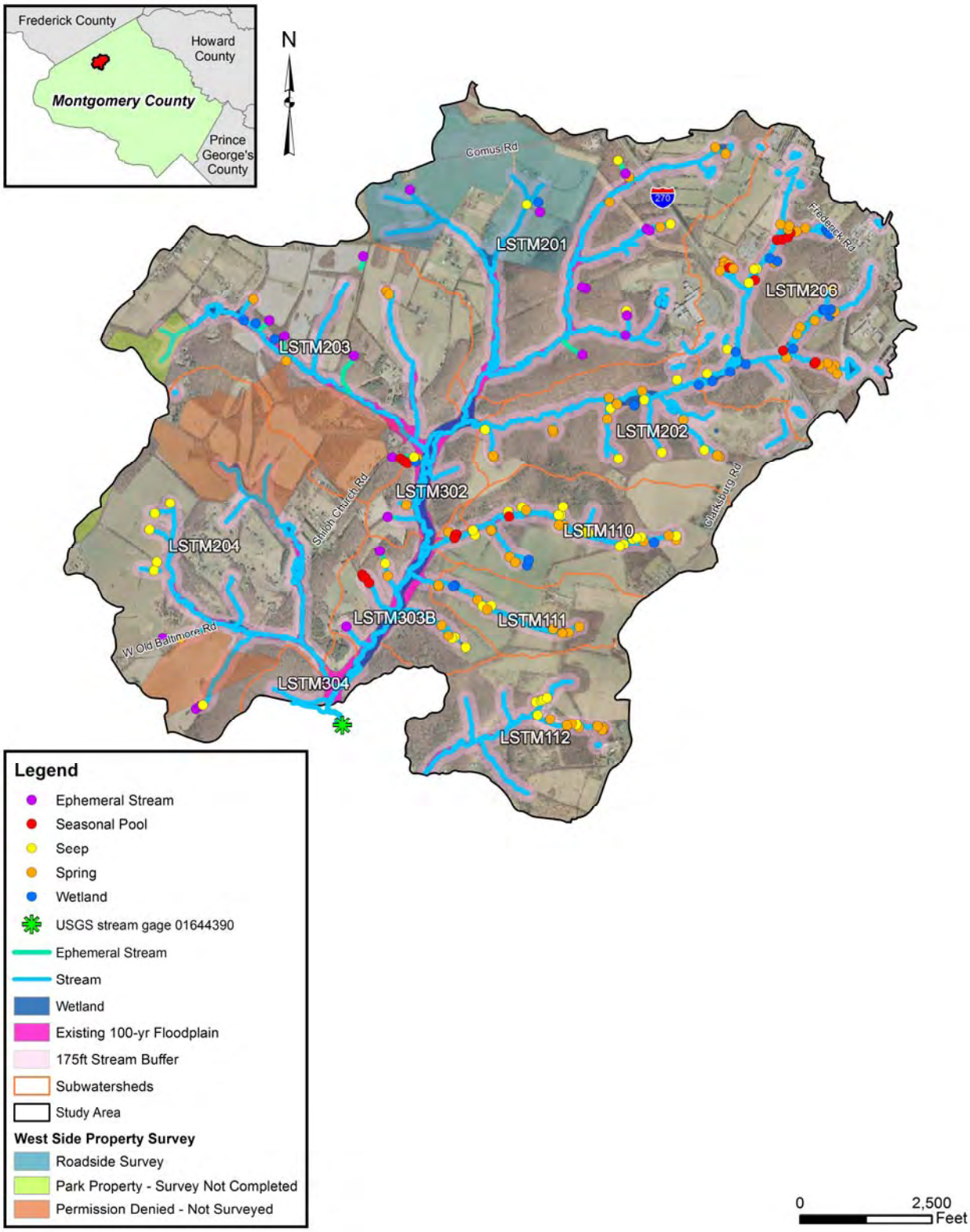


Figure 3.4. Key Hydrologic Features in the Ten Mile Creek Study Area

There is one gage (USGS gage 01644390) located on the left bank of Ten Mile Creek downstream from West Old Baltimore Road and approximately 0.3 mile upstream from Little Seneca Lake, just downstream of DEP monitoring station LSTM304 and the study area. The period of record is short and extends back only to October 2010. During the period of record, which includes two water years of data (the period between October 1st of one year and September 30th of the next), peak flows reached 2,180 cfs (February 2012, local storm) and 5,520 cfs (September 2011, Tropical Storm Lee) (United States Geologic Survey, 2013). Daily mean flows tend to fall between 0.5 and 2 cfs in the months of June through August and 2 to 10 cfs in the months of November through April (Appendix C). Better information about the magnitude and frequency of flows will be obtained as the period of record extends.

Montgomery County DEP has conducted "synoptic" flow measurements across the watershed during baseflow conditions. For each sample event, flow measurements are taken at 15 locations from headwaters to just above the reservoir on the same calendar day. The purpose is to broadly show the magnitude and relative contributions of subwatersheds to overall watershed baseflow hydrology at (approximately) the same time. The flow study was conducted three times in the summer (June and July) of 2009, and once in December 2012. Results are similar between sample events and years, with measured flows along headwaters streams less than 1 cfs, and mainstem flows reaching 1 cfs at approximately half of the full watershed area and exceeding 1 to 3 cfs at the downstream-most sample points (Appendix C).

As described in Section 1.2, the Ten Mile Creek watershed drains into Little Seneca Lake. Little Seneca Lake was created by the construction of a dam, which was completed in 1984, on Little Seneca Creek. Little Seneca Lake serves as a reservoir providing additional flow to the Potomac River, a public raw water supply, during drought periods, and also supports recreational activities (Montgomery County Department of Park and Planning, 1994). Based on available information reviewed, the reservoir does not affect the hydrology of Ten Mile Creek within the study area (i.e. via flow attenuation or backwater).

Wetlands

According to GIS data provided by Planning and DEP, the study area in Ten Mile Creek watershed has approximately 86 acres of wetlands (Figure 3.4; Table 3.4). This wetland acreage includes wetlands identified by County agencies, as well as wetlands identified during the 1997 Wetlands Study performed by C. Athanas, Ph.D. & Associates, Inc. and Dewberry & Davis (1997). The wetlands within the Ten Mile Creek study area are predominantly palustrine forested wetlands and are groundwater-dominated (Montgomery County Department of Park and Planning, 1994; Athanas & Dewberry & Davis, 1997). A palustrine forest wetland is defined as a nontidal wetland dominated by woody vegetation six meters or taller (Cowardin, Carter, Golet, & LaRoe, 1979).

The subwatersheds within the study area with the highest percentage of wetlands are LSTM302, LSTM303B, and LSTM304 (Table 3.4). All three subwatersheds are located along the Ten Mile Creek mainstem and contain a portion of the largest contiguous wetland area denoted by Planning and DEP GIS data (Figure 3.4) (Montgomery County Planning Department & Montgomery County Department of Environmental Protection, 2013).

Table 3.4. Wetland Coverage in Ten Mile Creek Study Area by Subwatershed

Subwatershed	Wetland Area (acres)	Percent of Subwatershed (%)
LSTM110	1.7	1%
LSTM111	0.5	1%
LSTM112	0.2	<1%
LSTM201	7.7	1%
LSTM202	5.3	2%
LSTM203	9.2	2%
LSTM204	2.6	<1%
LSTM206	12.9	3%
LSTM302	25.9	33%
LSTM303B	16.3	14%
LSTM304	4.0	8%
TOTAL	**86.3**	

Data source: (Montgomery County Planning Department & Montgomery County Department of Environmental Protection, 2013)

Springs and Seeps

Montgomery County DEP located 51 seeps and 78 springs throughout the Ten Mile Creek study area (Figure 3.4), mostly concentrated at the heads of tributaries and at the confluence of two streams. A seep is defined as a water feature exclusively fed by groundwater and does not typically flow, whereas a spring is a water feature fed by groundwater that flows intermittently or constantly (Montgomery County Department of Environmental Protection, 2012). Seeps and springs in the headwaters of tributaries to Ten Mile Creek are necessary to maintain base flows in headwater streams (Montgomery County Planning Department & Montgomery County Department of Environmental Protection, 2013). "These tributaries begin at springs such as the King Spring, Hancock Spring, and an unnamed spring along Frederick Road" near the intersection with Clarksburg Road. These springs have provided cool clean water for a long time as evidenced by the use of native rock by early settlers to protect the spring head. Trout and other sensitive aquatic species rely on this source of cool, clean water (Montgomery County Planning Department, 2009)." In general, there does not appear to be a correlation between the soil mapping unit and the presence of springs and seeps.

Groundwater

According to the Clarksburg Environmental & Water Resources Study (Greenhorne & O'Mara, Inc., 1992), the groundwater resources in Little Seneca Lake watershed, which contains Ten Mile Creek watershed, "are generally limited with respect to available yields. The majority of the existing wells produce only enough water for a single household and no municipal wells exist within the study area." The aquifer in the study area is designated as a Sole Source Aquifer per the U.S. EPA's Sole Source Aquifer Program (Greenhorne & O'Mara, Inc., 1992).

3.6 Stream Geomorphology

Geomorphology is the study of landforms, including hillslopes and rivers, and the processes that shape them. Geomorphic information can be used to evaluate why current landscapes look the way they do, and to predict future changes. The geomorphic study of rivers draws from field observations, historical information, and measurements of channel pattern and shape. Geomorphic study helps identify the

dominant processes active in a landscape. Along streams, this includes erosion and deposition of sediment along the bed and banks.

The general geomorphic history and fluvial processes active today in the study area are typical of the Maryland Piedmont physiographic region. Streams in the region reflect a complex legacy of historical land use practices, with three periods of differing hydrology and sediment supply, as summarized by Jacobson & Coleman (1986). Prior to colonization, floodplains were characterized by thin, fine overbank deposits. Following colonization in the period from 1730 to 1930, the morphology, or form, of streams and floodplains changed in response to greatly increased sediment supply and moderately increased discharges or stream flow. This resulted in thick, fine overbank sediment deposits on the floodplain and thin lateral accretion sands. After 1930, farm abandonment and the introduction of soil conservation practices slightly decreased water yield and substantially decreased sediment yield. Streams adjusted by reworking floodplain sediments, including removal of finer sediment and redeposition of coarsest sediment as a new, lower inset floodplain surface along a deeper, wider channel.

These types of observations demonstrate the role of watershed processes in the evolution of stream channels, as well as the relevance of geomorphic history in the explanation of appearance and behavior of streams. While this sequence of channel adjustment is broadly applicable to the Piedmont streams of Montgomery County, Ten Mile Creek is likely to have been subject to a similar cycle of inputs and adjustments in the historical past. In addition, streams in the Ten Mile Creek study area have been impacted by localized disturbances, both natural and man-made. Natural influences include vegetation (e.g., debris dams) and wildlife (e.g., beaver dam construction). Man-made or anthropogenic influences include stream straightening and channelization, channel crossings (e.g., fords, culverts at road crossings) and dam construction (e.g., mill ponds). A detailed inventory of these historical impacts is not available for the Ten Mile Creek watershed. However, there are known examples of these influences. Examples include current evidence of beaver activity in upper reaches of Ten Mile Creek (Montgomery County Planning Department, 2009; Figure 3.5), landowner accounts of small dams along the channel, and a long-term channel ford along West Old Baltimore Road.

There is little geomorphic data available documenting channel form change over time in the watershed. Montgomery County maintains a number of biological monitoring stations within the Ten Mile Creek watershed. At a majority of these stations, a monumented channel cross section was established as early as 1996. Resurvey of some these cross sections has occurred during some subsequent years (1997 and 1998 mostly; with a few resurveys in 1999, 2000, and 2006; and additional resurvey in 2013 where monuments could be found). Over this 16-year period, the degree of channel change varies considerably between sites. Data sets from stations with the most numerous resurveys (e.g., four years of survey or more) were reviewed to characterize the magnitude and rate of geomorphic adjustment at these stations. The stations reviewed are as follows:

- Station LSTM106 (inactive, tributary of LSTM201): This small tributary (<0.5 square mile drainage area) has maintained the most consistent channel shape, with only minor channel bed elevation changes.
- Station LSTM202 and LSTM206: Cross sections on these intermediate streams (0.5 - 1 square mile drainage area) show minor fluctuations in bed elevation. Sections with side or midchannel sediment bars, in which sediment is stored and remobilized during larger flow events, show the most fluctuations in channel bed shape and bank position.

- Station LSTM303B and LSTM304: These larger streams (>3 square mile drainage area) show the channel invert lowering about a foot across the complete survey record and some channel enlargement (i.e. an increase in cross-sectional area below the floodplain elevation).



Figure 3.5. Recent beaver activity along Ten Mile Creek near monitoring station LSTM206.

One may expect the potential for geomorphic adjustment (both short and long-term) to be greatest in the larger streams, with relatively greater cumulative changes in hydrology and sediment supply with increasing drainage area. Even so, it is difficult to definitively identify long-term trends in geomorphic adjustment relative to short-term fluctuations given limitations of the data set. A more extended monitoring record in conjunction with geomorphic mapping could be used to better evaluate this.

Observations made during field reconnaissance within the Ten Mile Creek watershed are consistent with available cross-sectional survey information. The tributaries and mainstem channel in the Ten Mile Creek watershed are active and respond to spatially variable conditions (e.g., debris, vegetation, beaver activity, cutoff channels). Bank erosion is apparent throughout the stream system, sometimes expressed along the outer edge of meander bends as nearly vertical banks three to four feet in height. Conversely, bed material is regularly mobilized and deposited in side and midchannel sediment bars, whose shape and elevation fluctuates in response to flood events. In most locations, the stream network is in contact with the adjacent floodplain, with recent sandy deposits and debris lines apparent along streamside trees. That floodplain connection effectively reduces the shear stresses or the force exerted by flowing water on the bed and bank within the main channel, and promotes maintenance of a bankfull channel geometry and thus floodplain connection, rather than downward bed incision. Figures 3.6 and 3.7 show two examples of typical stream conditions with increasing drainage area. While it is not possible to assess whether the stream system is in a true long-term geomorphic equilibrium based

on available data, there also is no clear evidence to suggest long-term chronic channel adjustment over the recent decadal time scale.



Figure 3.6. Example of channel dynamics along Ten Mile Creek near monitoring station LSTM206.



Figure 3.7. Channel conditions near USGS gage 01644390 downstream of monitoring station LSTM304.

The phyllitic material supplied to the channel tends to weather easily, breaking into small fragments, probably because of numerous planes of weakness, and forms particles that are platy in shape and observable on bars within Ten Mile Creek (Figure 3.8). More resistant quartz particles derived from veins in the bedrock tend to form larger, more rounded particles on the bed. Measurements taken by DEP in conjunction with channel cross sections between 1996 and 2006 demonstrate the grain-size distribution on channel bed material along representative riffles ranges in size from sand to very large cobble, with the majority in the coarse to very coarse gravel range. The limited amount of fine material (i.e. <2 mm which includes sand, silt, and clay) observed during sampling of these riffles is consistent with general field observations of relatively "clean" bed material dominated by gravels. Estimates of riffle embeddedness (the degree to which coarse bed material is choked by fine sediments) were made by DEP in conjunction with these same cross-sectional measurements to determine the percentage of a particle's surface surrounded by sand, silt or clay sediment in the stream bed. Estimates of embeddedness ranged between 12 and 43%, but were typically between 15 to 25%. Some disparity in the degree of embeddedness was observed between these estimates and those recorded in conjunction with DEP's biological monitoring reported in the following section. This disparity may be the result of a difference in sampling methodology and may indicate that riffle embeddedness reported above is lower than that of a 75-meter sampling reach, inclusive of riffles and pools, reported with the biological monitoring.



Figure 3.8. Example of bar deposits along Ten Mile Creek near monitoring station LSTM202.

3.7 Water Quality

All tributaries of Ten Mile Creek are designated by the State of Maryland as Use I-P streams (water contact recreation, protection of aquatic life, and public water supply) and are part of Little Seneca Lake, which serves as a reservoir providing additional flow to the Potomac River, a public raw water supply, during drought periods (Montgomery County Department of Park and Planning, 1994). Table 3.5 below lists the State standards for Use I-P streams. Ten Mile Creek was one of the last streams in Montgomery County to support brook trout (*Salvelinus fontinalis*), a highly sensitive native species requiring clean and cold water to survive (Montgomery County Department of Environmental Protection, 2004). In 2007, State and County fisheries biologists discovered three adult a non-native, more tolerant species of trout, brown trout (*Salmo trutta*), some distance above the West Old Baltimore Road ford (Montgomery County Department of Environmental Protection, 2009). These trout represented different age classes and did not appear to be hatchery raised. The trout were weighed, measured and returned to the creek. Fisheries biologists returned and conducted a wider survey of the creek but did not find additional trout. It is not known for certain if the three adults found are naturally occurring to Ten Mile Creek or not, but no signs of fish stocking, such as fin erosion, were observed. Regardless of the origin of the trout, the fact that the trout species were surviving in Ten Mile Creek are indicative of its excellent water quality. Brown trout were again found in 2008 and 2009 (Montgomery County Department of Environmental Protection, 2012).

Table 3.5. State Water Quality Standards for Use I-P Streams

Parameter	Standard
Maximum Total Fecal Coliform	200 log mean per 100 mL
Minimum Dissolved Oxygen	5 mg/L
Maximum Temperature	32° Celsius or Ambient, whichever is greater
pH	6.5 to 8.5
Maximum Turbidity	150 NTU
Maximum Monthly Average Turbidity	50 NTU

Data Source: DEP SPA Report, 2012

Water quality monitoring has been performed in Ten Mile Creek associated with three separate efforts: (1) DEP's Countywide Biological Stream Monitoring Program; (2) the Clarksburg Special Protection Area monitoring program; and (3) MDE and WSSC water quality data associated with Little Seneca Lake.

Countywide Biological Stream Monitoring Data

Data from the biological stream monitoring is limited to single point measurements during non-storm flow conditions, according to the station locations shown in Figure 3.9. Biological field collection of benthic macroinvertebrates is conducted during the spring index period (March 15 to April 30). Fish are collected in the summer index period (June 1 through the middle of October). More information on biological monitoring is provided in Section 2.8. During both sampling events, a multi-parameter probe is placed in the stream's laminar flow to measure water temperature, pH, dissolved oxygen, percent saturation, and conductivity. Air temperature and time of day is also recorded at all stations. Thus, the biological stream monitoring data is only representative of spring and summer conditions during non-storm flow conditions. Data collection has occurred for selected subwatersheds between 1995-2012, with an average of 17 samples per subwatershed.

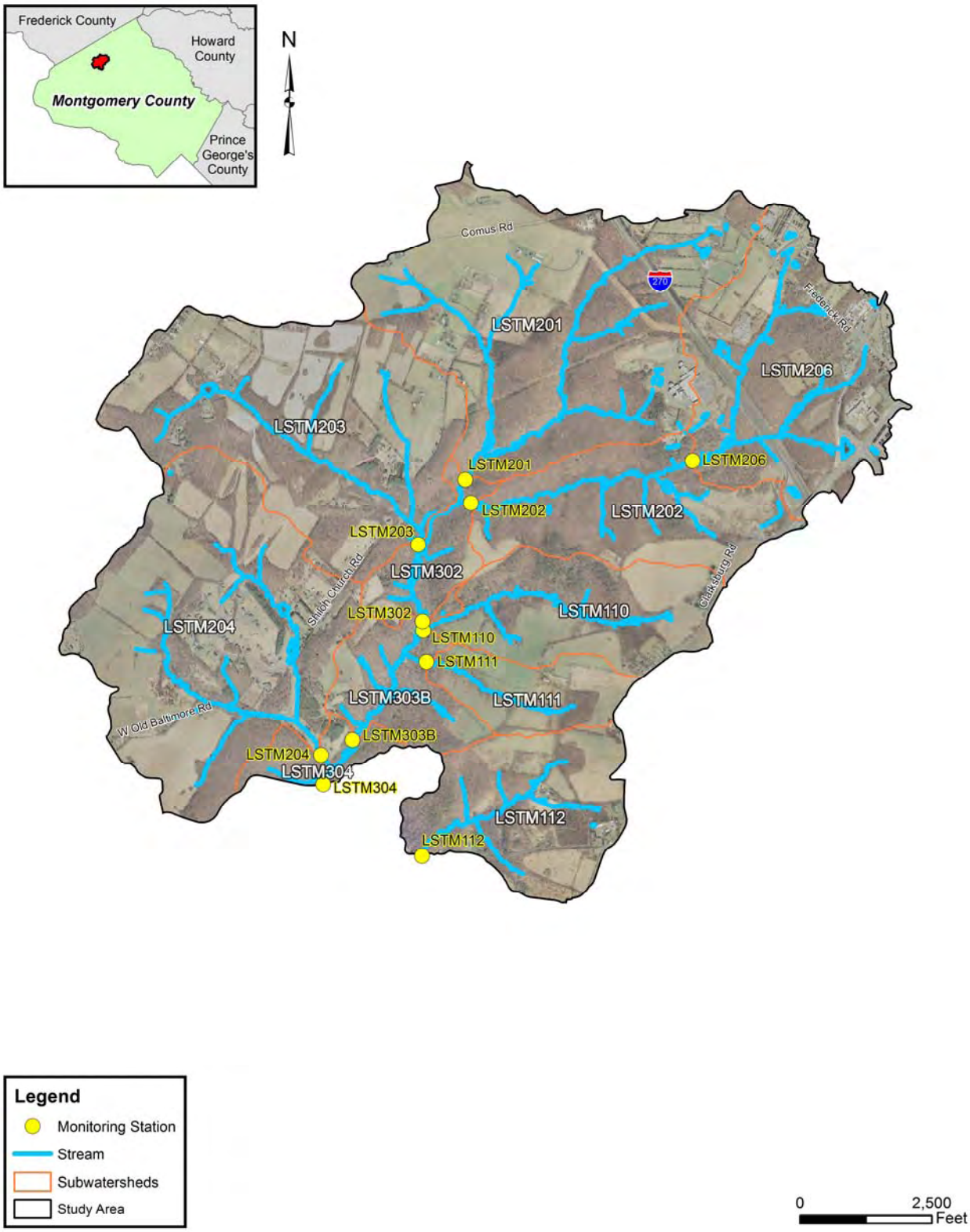


Figure 3.9. Habitat, Biological, and Geomorphic Stream Monitoring Sites in the Ten Mile Creek Study Area

Water temperature is an important measure of stream health, and has a standard maximum of 32 degrees Celsius for Use I-P streams. Higher temperatures can cause stress in aquatic biota. Figure 3.10 shows the water temperature readings across all of the Ten Mile Creek subwatersheds, which are all statistically similar with a median of 16 degrees Celsius. No readings were higher than 26 degrees Celsius during the biological stream surveys.

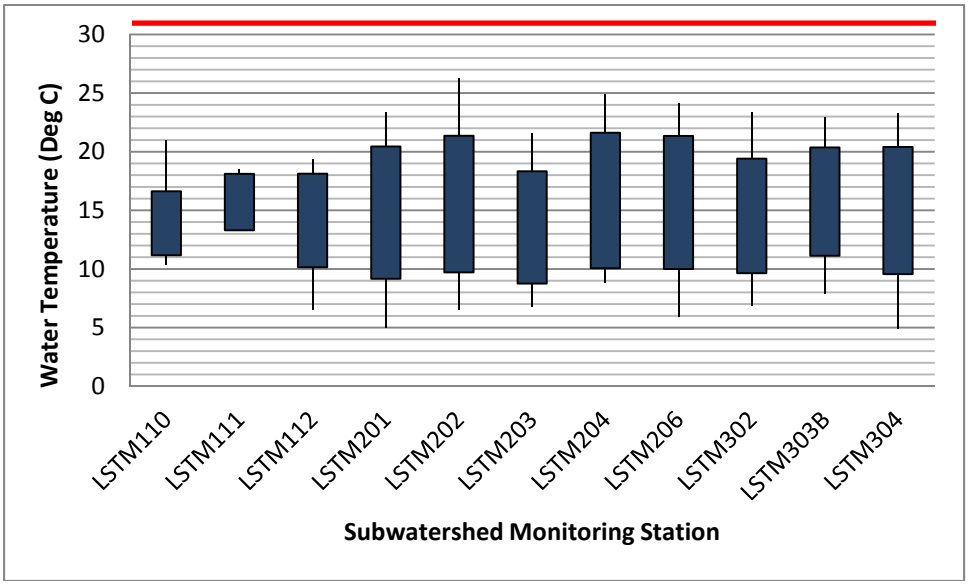


Figure 3.10. 90% Confidence Interval, Maximum, and Minimum Water Temperature Values for Ten Mile Creek Biological Stream Monitoring Stations. The red line indicates the State Standard for Maximum Temperature in Use I-P Streams (32 deg C).

In general, the optimal pH range for aquatic life is between 6.5 and 8.5 (EIFAC 1968 and U.S. EPA 1976). While many aquatic species can tolerate pH levels well outside this optimal range, water pH influences the solubility of metals and other pollutants that, if present, are toxic to aquatic life (EIFAC 1968 and U.S. EPA 1976). For the Ten Mile Creek subwatersheds, one subwatershed has consistently measured lower than the State Standard of 6.5: LSTM111. Several other subwatersheds, LSTM110, LSTM112, LSTM201, LSTM202, and LSTM303B, all have at least one reading below the State Standard (Figure 3.11). Similar conditions were observed in the 1992 Clarksburg Environmental & Water Resources Study, where it was noted that the, "low buffering capacity of Seneca Creek's [including Ten Mile Creek's] soft waters leads to large fluctuations in the pH in the stream. The pH levels vary by as much as 6 orders of magnitude..." (Greenhorne & O'Mara, Inc., 1992). The Biological Stream Monitoring data suggest differences in the headwater streams, LSTM110 and LSTM111, from the mainstem streams LSTM203, LSTM204, and LSTM206. The primary land uses within the subwatersheds LSTM110 and LSTM111 are cropland and pasture, with a lack of a continuous riparian buffer apparent (Figures 2.1 and 2.2). There are no stormwater management facilities in these subwatersheds (Figure 4.2).

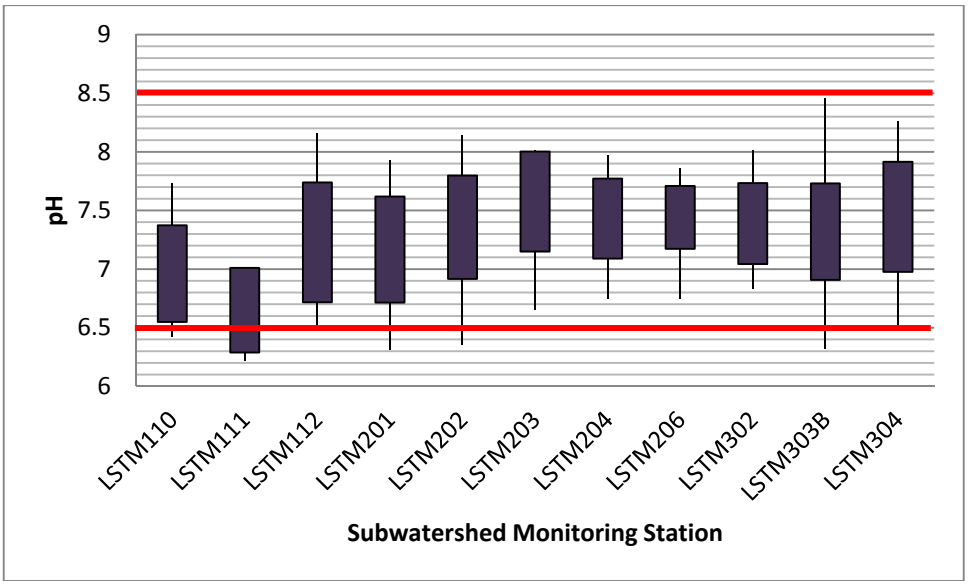


Figure 3.11. 90% Confidence Interval, Maximum, and Minimum for pH Values for Ten Mile Creek Biological Stream Monitoring Stations. The red lines indicate the State Standard for Maximum (8.5) and Minimum (6.5) pH in Use I-P Streams.

Dissolved oxygen is necessary for aerobic respiration of aquatic life. From the biological stream monitoring data, dissolved oxygen in the Ten Mile Creek subwatersheds have remained above the State standard of 5 mg/L. No single subwatershed appears significantly different, with an average of 9.3 mg/L (Figure 3.12).

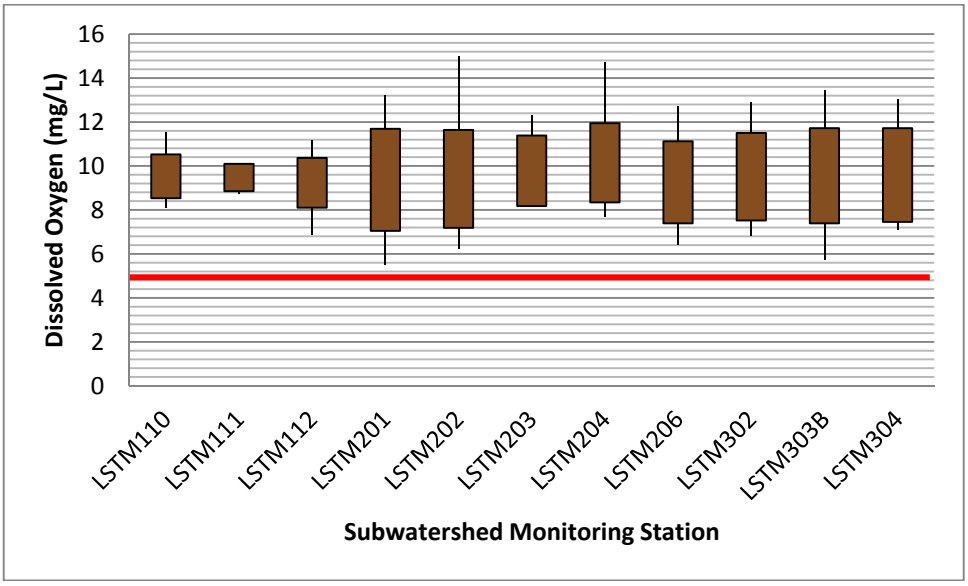


Figure 3.12. 90% Confidence Interval, Maximum, and Minimum Dissolved Oxygen Values for Ten Mile Creek Biological Stream Monitoring Stations. The red line indicates the State Standard for Minimum Dissolved Oxygen in Use I-P Streams (5 mg/L).

The percent saturation of dissolved oxygen in the water is an indirect measure of the biological oxygen demand. Saturation below 100% indicates a greater rate of aerobic respiration than can be equilibrated with the atmosphere. Saturation above 100% indicates generation of oxygen within the water column,

such as through photosynthesis of algae. There are no standards for percent saturation, but the Ten Mile Creek subwatersheds are all statistically similar with an average of 90% saturation (Figure 3.13).

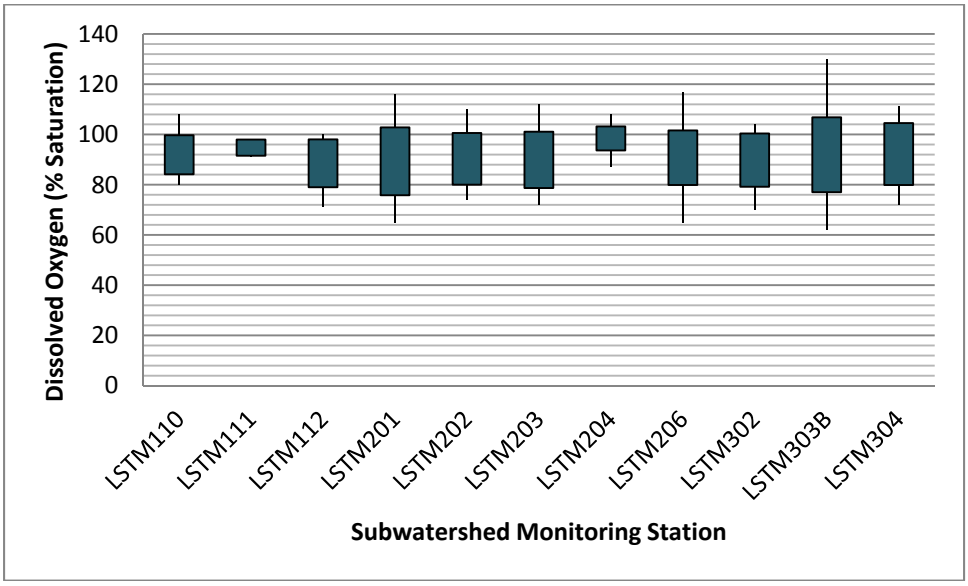


Figure 3.13. 90% Confidence Interval, Maximum, and Minimum for Percent Saturation of Dissolved Oxygen Values for Ten Mile Creek Biological Stream Monitoring Stations.

Conductivity values are related to the type and concentration of inorganic ions in the water column. Examples of these inorganic constituents include chloride, carbonate, nitrate, sulfate, and phosphate anions as well as sodium, calcium, magnesium, iron, and aluminum cations. Elevated conductivity is commonly associated with development and urbanization upstream in the watershed and often attributed to runoff from roadways (U.S. EPA, 2010). However, there are currently no water quality standards for conductivity, and a threshold for biological impairment has not been clearly defined for this parameter. Two subwatersheds have shown a significantly higher conductivity reading in the watershed: LSTM202 and LSTM206. LSTM203 has had some high readings, but overall is not significantly different from the rest of the watershed (Figure 3.14). LSTM206 has the most development and highest level of impervious cover (16%) in the watershed (Figures 2.1 and 2.2). The principal urban land uses include transportation (I-270), residential, institutional (Clarksburg Detention Center), and some commercial, all scattered throughout the subwatershed. LSTM206 also has the most stormwater management facilities of all the subwatersheds (Figure 4.2). LSTM202 is mostly forested and has a much lower level of development than LSTM206. However, LSTM206 directly feeds into LSTM202, which could account for the higher conductivity readings.

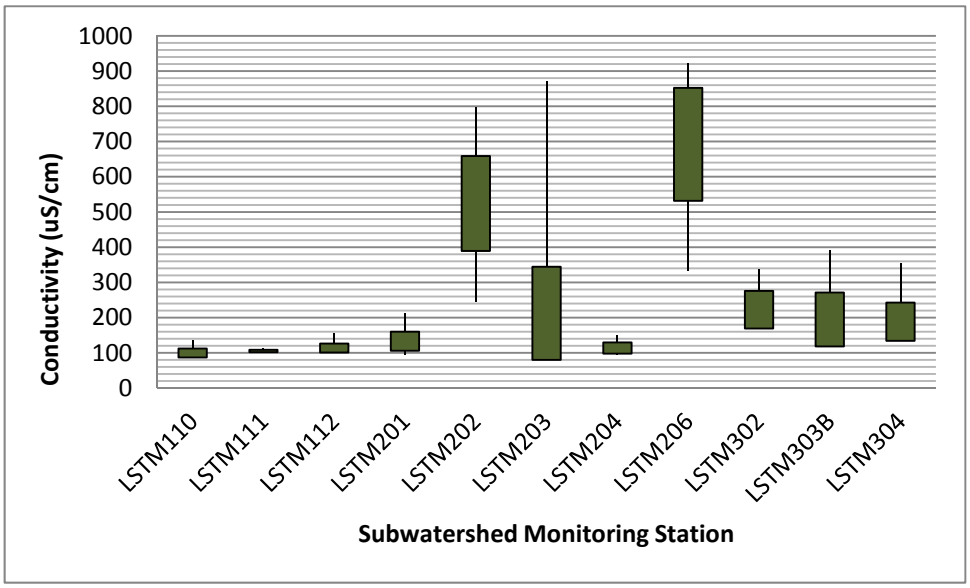


Figure 3.14. 90% Confidence Interval, Maximum, and Minimum for Conductivity Values for Ten Mile Creek Biological Stream Monitoring Stations

Special Protection Area Water Quality Monitoring

The Clarksburg SPA monitoring fulfills the requirements in Montgomery County Code, Section 19-67(d) for "the effectiveness of best management practices and the observed impact of development on the biological integrity of streams in special protection areas," (Montgomery County Department of Environmental Protection, 2012). The best management practices (BMPs) monitored for effectiveness were predominantly structural facilities such as sediment and erosion control (S&EC) basins that were monitored during construction, and stormwater management (SWM) facilities that were monitored after construction activity was completed.

The County SPA Reports provide information on year-to-year stream conditions for Ten Mile Creek on a station by station basis. Due to the decline in biological stream conditions in an eastern tributary of Ten Mile Creek (mostly east of I-270, subwatershed LSTM206) during development, an investigation was made into possible reasons for the decline (as reported in the 2006 SPA Annual Report). High conductivity readings were found throughout the drainage area to the station. No specific cause for the high conductivity readings could be identified, but the sensitivity of Ten Mile Creek to change is apparent (Montgomery County Department of Environmental Protection, 2008).

Monitoring was required during construction of the Clarksburg Detention Center, located on the west side of I-270 just north of the Rt. 121 interchange in subwatersheds LSTM206 and LSTM201. During construction, monitoring occurred from 1997-2003. Three groundwater wells were monitored to determine nutrients and water table elevation. During the late 1970's, a parcel of land near the Detention Center property was used for WSSC sewage sludge disposal (Montgomery County Department of Environmental Protection, 2010). Sludge contains high concentrations of nutrients. Much of the sludge was removed from the area that was to be disturbed during the beginning phase of construction.

Results of the groundwater monitoring showed the concentration of total phosphorus (TP) from all three wells remained low, except for samples obtained on 4/2/98 and 8/17/99, which could have been related to land disturbance and removal of the buried sewage sludge. Since 8/17/99 TP concentrations

have remained relatively low. Concentrations did increase slightly at all three wells on 9/17/02. Nitrate concentrations were consistently higher in one of the wells downstream of construction, with values as much as three times above the EPA drinking water standard of 10.0 mg/l. Presumably, the sewage sludge, which was not removed from the area immediately surrounding this well, is the cause of high nitrate concentration. Nitrate concentrations in the other two wells went down during the period of study, from 7.2 mg/l on 11/24/97 to 0.18 mg/l on 9/17/02 in one well, and from 5.25 mg/l on 11/24/97 to 0.83 mg/l on 9/17/02 in the other. The decrease in nitrate concentrations in these two wells is likely due to removal of sewage sludge from the site (Montgomery County Department of Environmental Protection, 2003).

The County SPA Reports also provide information on stream temperature monitoring. The station records vary according to development in the watershed, in order to evaluate conditions immediately downstream. Temperature monitoring conducted in Ten Mile Creek indicated that the water temperatures were found to stay below the Maryland Use Class I-P criteria limit. Anomalies, such as in late August 1998 when station LSTM202 began to show large daily temperature ranges, were attributed to the pool in which the temperature logger was deployed getting low enough to expose the logger to air temperatures. Results from LSTM303B in 2003 show mean water temperature was higher than any other area in the Clarksburg SPA. This is likely due to differences in stream channel characteristics between Ten Mile Creek and Little Seneca Creek. In Ten Mile Creek the stream channel tends to be wide and shallow. This allows the stream to warm up more as there is greater exposure to warm ambient air temperatures. In contrast, results from LSTM112 in 2003 show water temperature was cooler than most other areas in the Clarksburg SPA. This was the first year data was collected from this fairly large tributary to Ten Mile Creek (Montgomery County Department of Environmental Protection, 2004).

Seneca Lake Water Quality Monitoring

MDE and WSSC have performed water quality monitoring within the Seneca Creek watershed basin in order to assess impairments in Little Seneca Lake and monitor the lake as an important source of drinking water in Montgomery County. The Lake was identified on Maryland's 1998 list of water quality limited segments (WQLSs) as being impaired by nutrients. An analysis of recent monitoring data (2001) shows that the criteria associated with nutrients are being met, and the designated use in Little Seneca Lake is supported (Maryland Department of the Environment, 2006). This analysis supports the conclusion that a total maximum daily load (TMDL) for nutrients is not necessary to achieve water quality in this case. A TMDL is used to determine the maximum amount of a pollutant a waterbody can receive without violating water quality standards for the waterbody's designated use. The report was used to support the nutrient listing change for Little Seneca Lake from Category 5 ("waterbodies impaired by one or more pollutants and requiring a TMDL") to Category 2 ("surface waters that are meeting some standards and have insufficient information to determine attainment of other standards") when MDE proposed the revision of Maryland's 303(d) list for public review. Urban development is occurring in portions of the Little Seneca Lake watershed, and is expected to increase in the future. It is expected that over time, the character of the watershed may change as a consequence of land conversion and development. Although the waters of Little Seneca Lake do not presently display signs of eutrophication, the State reserves the right to require future controls in the Little Seneca Lake watershed if evidence suggests nutrients from the basin are contributing to water quality problems.

3.8 Aquatic Habitat and Biology

Since 1994, the Montgomery County DEP has established and regularly monitored physical habitat and biological communities at 11 permanent sampling stations within the Ten Mile Creek Watershed as part of the Clarksburg Special Protection Area monitoring program (Figure 3.9). At each station DEP field crews assess the physical structure and condition of habitat and sample the benthic macroinvertebrate, fish and salamander communities.

Various metrics describing the composition and ecology of these biological communities can be combined into a multi-metric Index of Biotic Integrity (IBI) to represent the quality of a particular stream ecosystem (Karr, 1981). These various IBI metrics can then be compared to those of known regional reference sites to predict the probable stream condition (Hughes, Larsen, & Omernik, 1986). The DEP has developed IBIs for both fish and macroinvertebrates that reference the least impacted streams in the County to determine the stream condition (Montgomery County Department of Environmental Protection, 2009). Additionally, these biological data can be compared with the statewide IBI developed by the Maryland Biological Stream Survey (MBSS), which stratified by ecological region and statistically validated to ensure discrimination efficiency, reduce redundancy, and improve accuracy (Southerland et al., 2005).

The following sections outline the sampling methodologies and summarize the biological conditions and observed trends over the 19 years of data provided by DEP. Observed trends were not rigorously tested, but derived from observations in the data and determining simple linear regressions and associated correlation coefficients (R^2). A more detailed discussion of the individual metrics for each of the indices and a summary table of available data and IBI scores for the respective sampling efforts are presented in Appendix D.

Benthic Macroinvertebrates

The benthic macroinvertebrate communities were assessed by DEP staff during spring index periods of the respective sampling years in accordance with the Maryland Biological Stream Survey (MBSS) methods (Kayzak, 2001). The DEP Benthic IBI evaluates 8 metrics, which are summed to describe the overall health of the benthic macroinvertebrate community.

The 2012 Benthic IBI scores for each subwatershed are shown in Figure 3.15. The average of the 1994 – 2012 composite Benthic IBI scores for each subwatershed are shown in Figure 3.16.The overall ranges of Benthic IBI scores, as shown in Figure 3.17, indicate that the benthic macroinvertebrate community within the Ten Mile Creek drainage is in generally good condition. Applying the MBSS Benthic IBI to this data set corroborates this conclusion. Both Benthic IBIs do rank LSTM206 one condition class lower (e.g. fair versus good) than the other stations. Over the 15 years Station LSTM206 was monitored, eight years scored Fair, five years scored Good and two years scored Poor. The lowest scores occurred between 2005 and 2008 with some recovery after 2008, but no long-term trends of further degradation or recovery were interpreted from the data. This is conclusion is supported by the time series data for all stations shown in Figure 3.18.

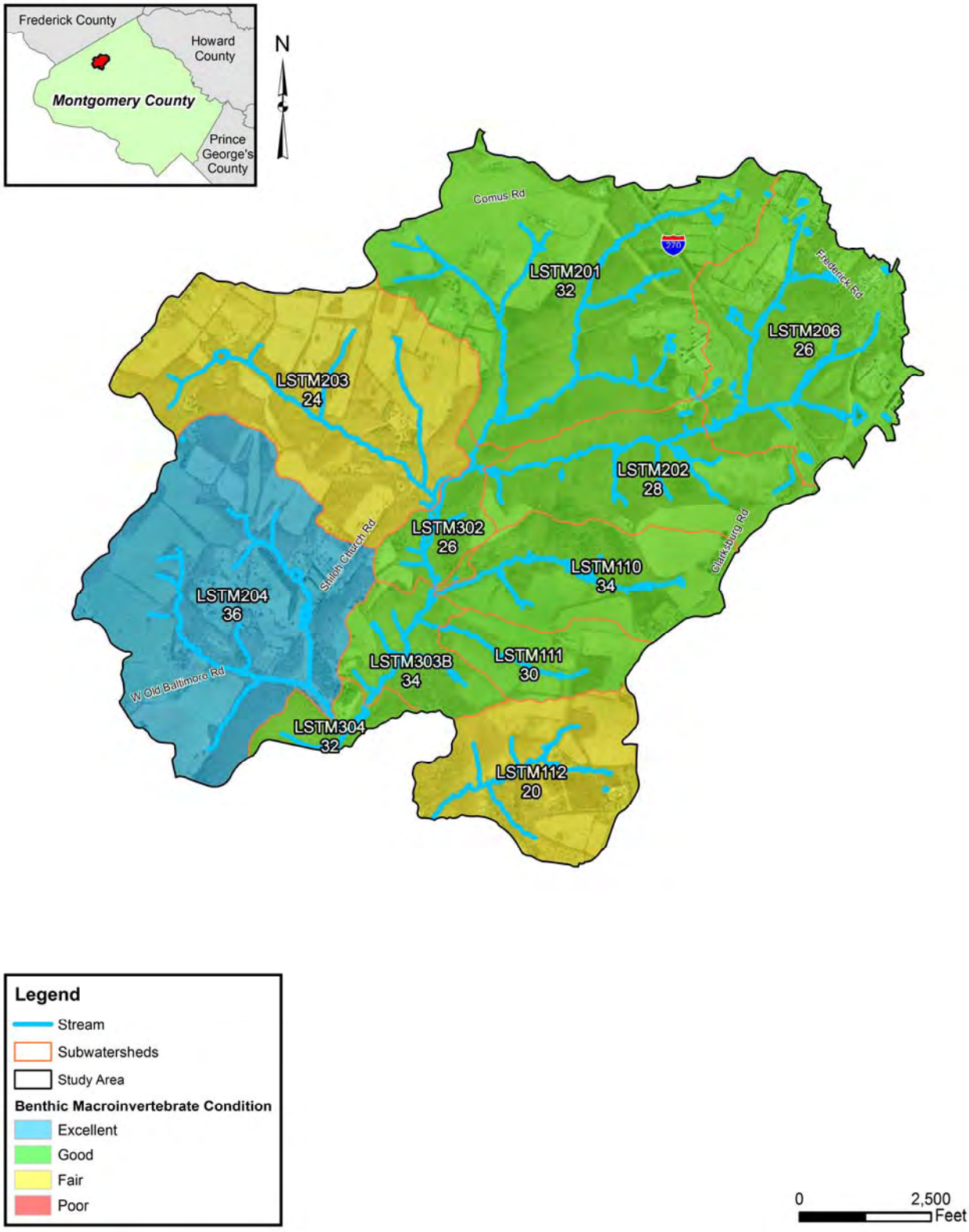


Figure 3.15. 2012 subwatershed benthic IBI rating.

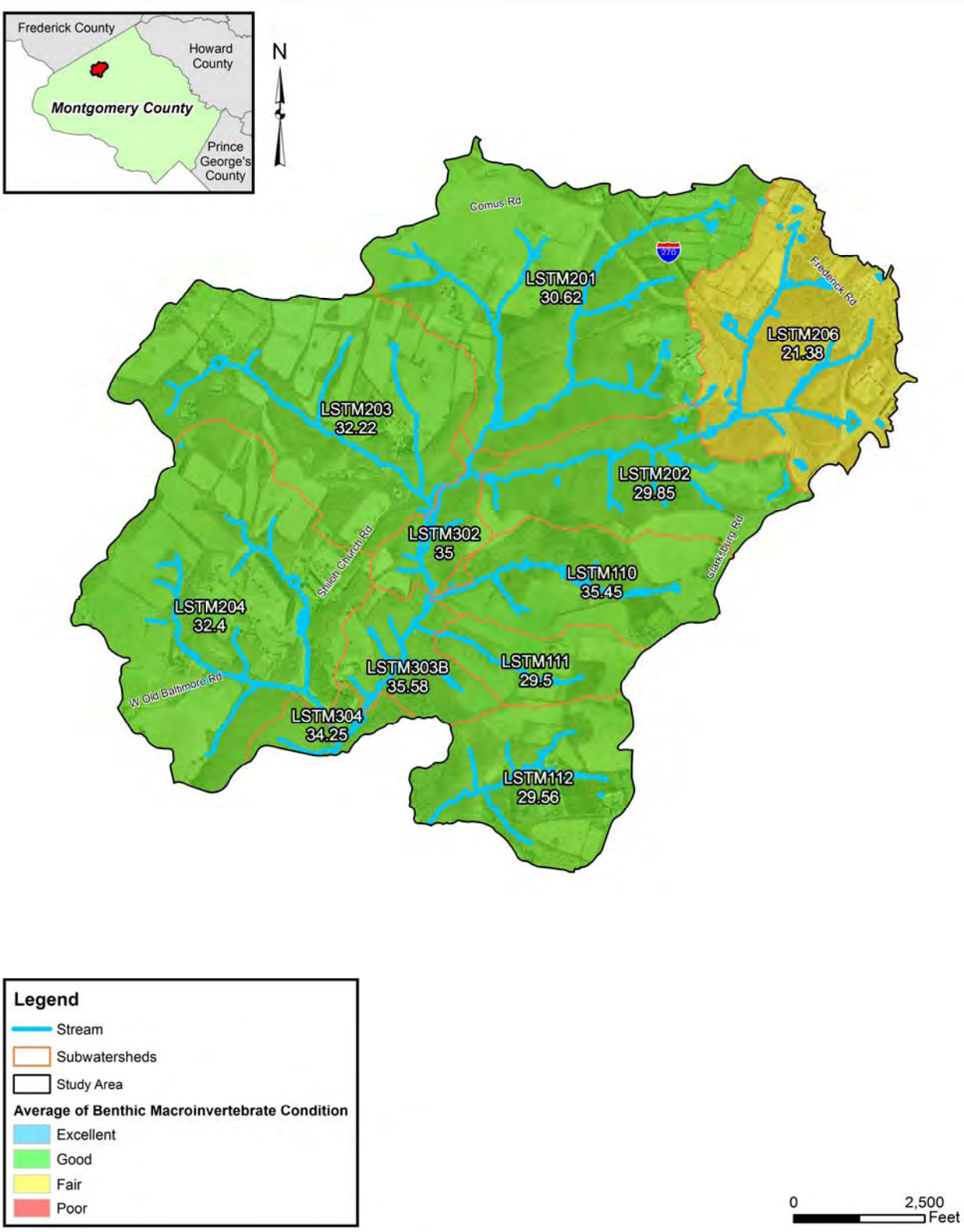


Figure 3.16. Average subwatershed benthic IBI rating (1994-2012).

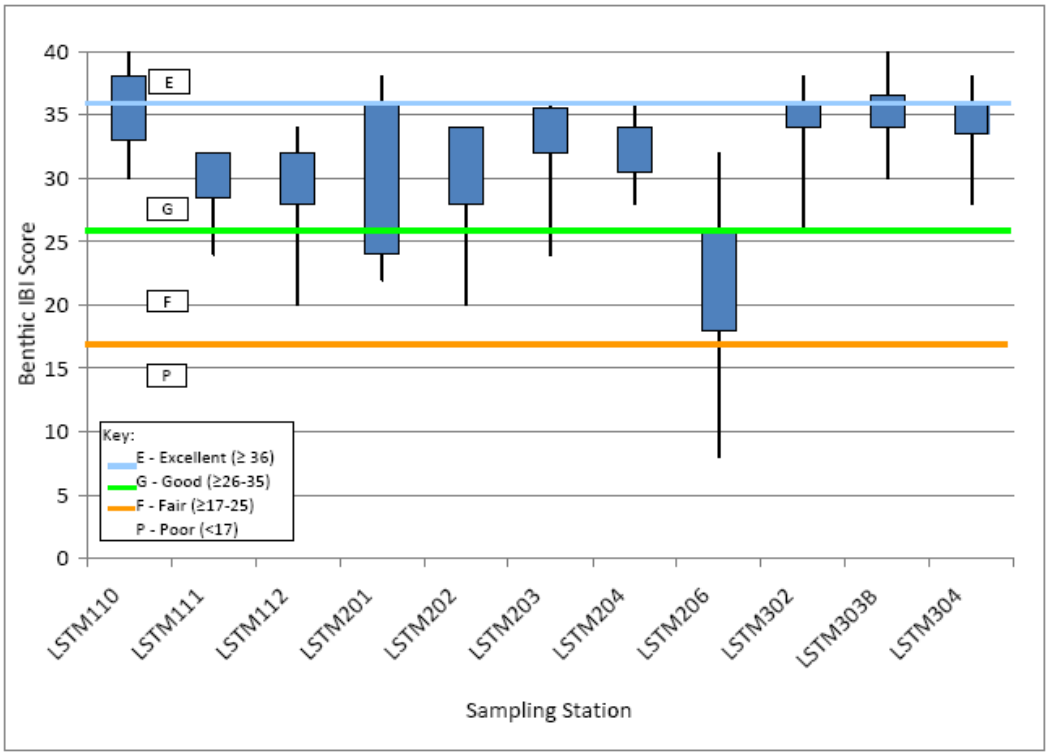


Figure 3.17. Ranges of composite Benthic IBI scores among the permanent sampling stations (1994-2012).

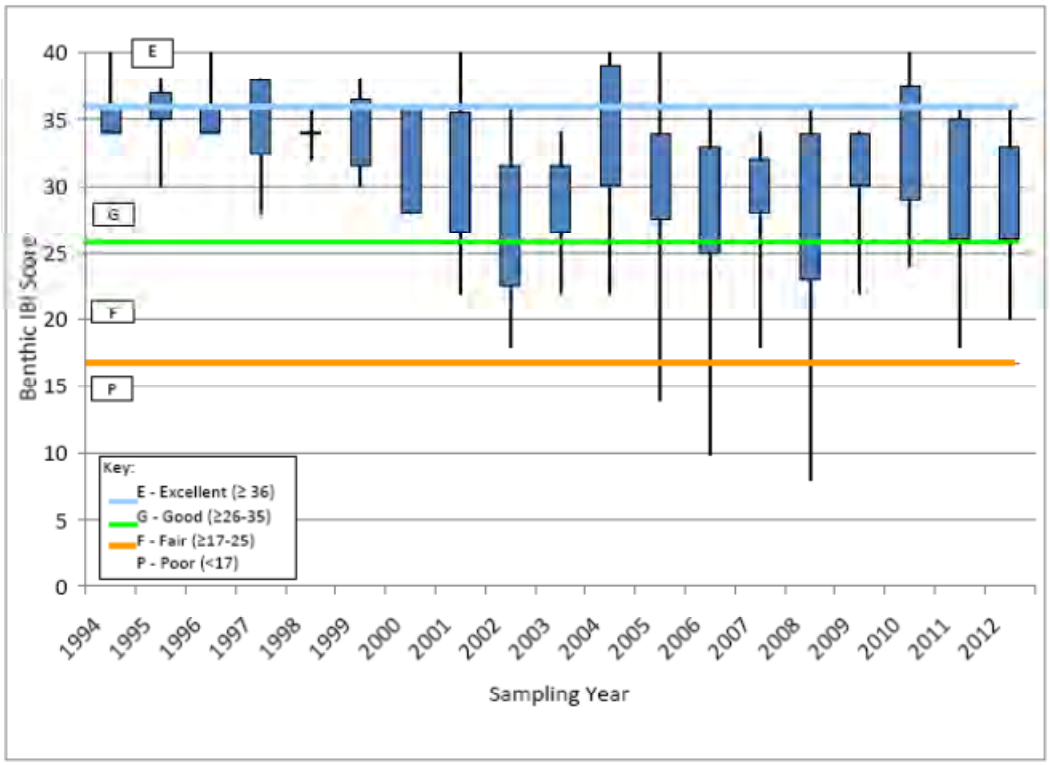


Figure 3.18. Variability among Benthic IBI scores at all sampling stations over time.

A number of observations related to the individual metrics time series data are discussed in Appendix D. Other than minor shifts in the benthic macroinvertebrate community structure, the community appears to be stable. The rates of change associated with any observed trends are generally slow and only likely to influence the overall Benthic IBI score over period of decades, if natural recovery does not occur. These trends indicate the tendency toward degradation if stressor levels are increased.

Habitat

Habitat was assessed by DEP staff using the qualitative rapid habitat assessment protocol described by Barbour and Stribling (Gibson, 1991). This method relies on visual inspection to assign numerical scores that represent the condition of each of ten habitat parameters. The 2012 habitat scores for each subwatershed are shown in Figure 3.19. Figure 3.20 shows the average of the 1994 – 2012 composite habitat scores for each subwatershed. A summary of the composite habitat scores at each station and over time is presented in Figures 3.21 and 3.22 respectively. These data indicate that the habitats of Ten Mile Creek are minimally to partially degraded (excellent/good) and generally score in the suboptimal range in individual parameters (Figure 3.21). Overall most stations scored within one standard deviation of the mean overall habitat score, with the exception of Station LSTM204. The deviation in Station LSTM204 can be attributed to poor scores for the riparian buffer parameter, which consequently dropped the overall score but not the overall condition category for the habitat score. These conclusions are corroborated by the MBSS Physical Habitat Index (Paul et al., 2003).

While most habitat parameters consistently scored in the good range, individual parameters related to sediment deposition and bank erosion scored marginal and likely influence the overall score. Embeddedness scores indicate that the preferred substrates (for most benthic organisms these are gravel, cobble and boulder) are choked with fine sediments surrounding 50-75% of the coarse grains and filling the interstitial voids. Additionally, sediment deposition scores reflect an intrusion of newly deposited fine sediments (gravel, sand and silt) occupying 30-50% of the bottom habitat. Marginal scores in bank erosion indicate a likely source of these fine sediments. The bank erosion scores indicate that 30-60% of the sample reach shows signs of erosion; however, the severity of this erosion was categorized as only minimal to moderate. Low suboptimal to marginal scores in the bank vegetation could also be attributed to the eroding banks.

As would be expected with a progressive problem like bank erosion, most of the stations show declining trends in the overall habitat score over time; however, the magnitude of the decline is only 1 to 2 total points/year in the overall score when the entire data set is analyzed (Figure 3.22). This trend may indicate that the watershed is stressed; however, several decades may elapse before the overall habitat condition degrades from suboptimal to marginal, which is also an adequate timeframe for the stream conditions to naturally recover or stabilize. Visual inspection of plots of the parameters versus time, which were not isolated and evaluated independently, indicate that the overall declining trend may be more severe in recent years (after 2005), but the significance of this was not tested (Figure 3.22).

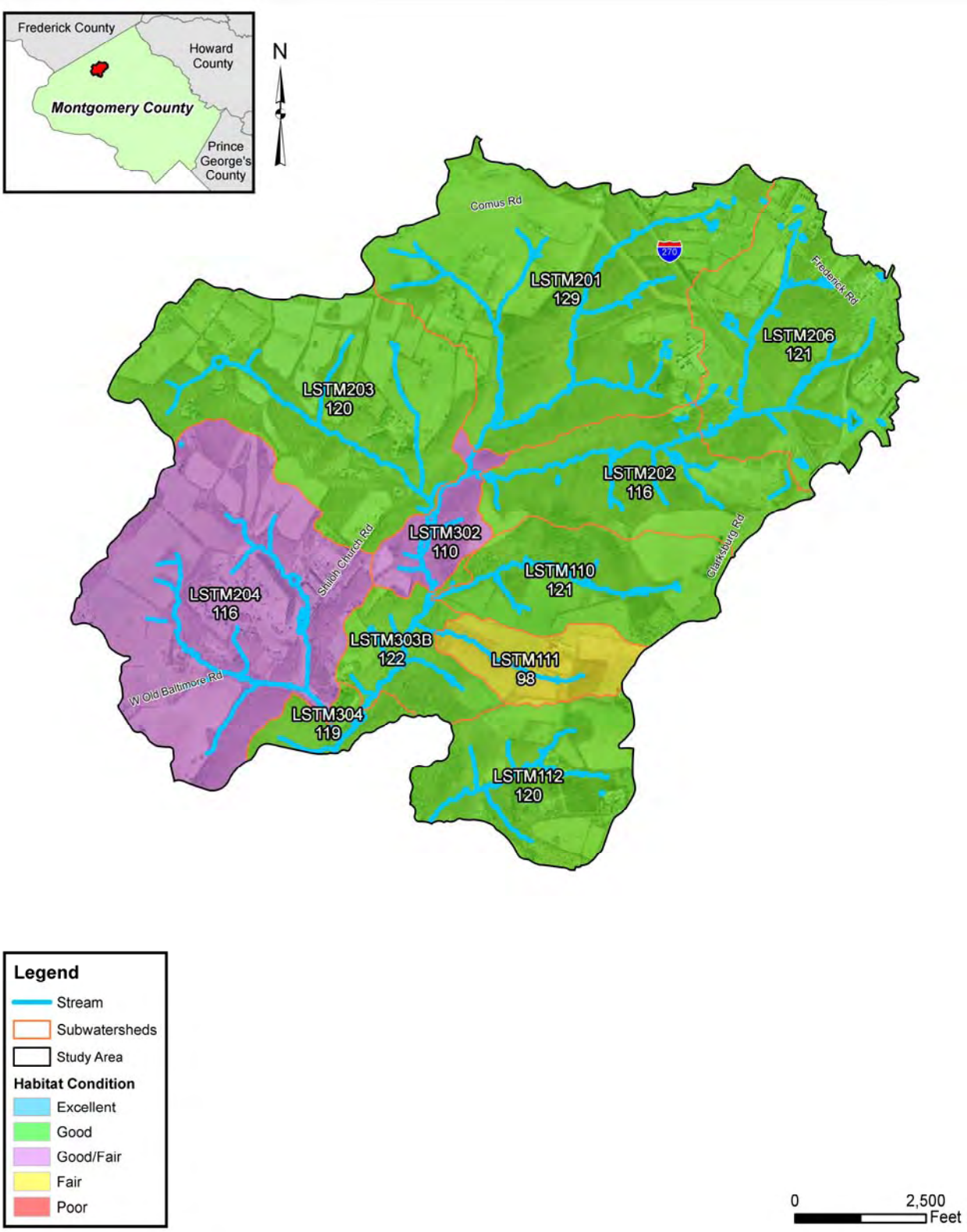


Figure 3.19. 2012 subwatershed habitat condition rating.

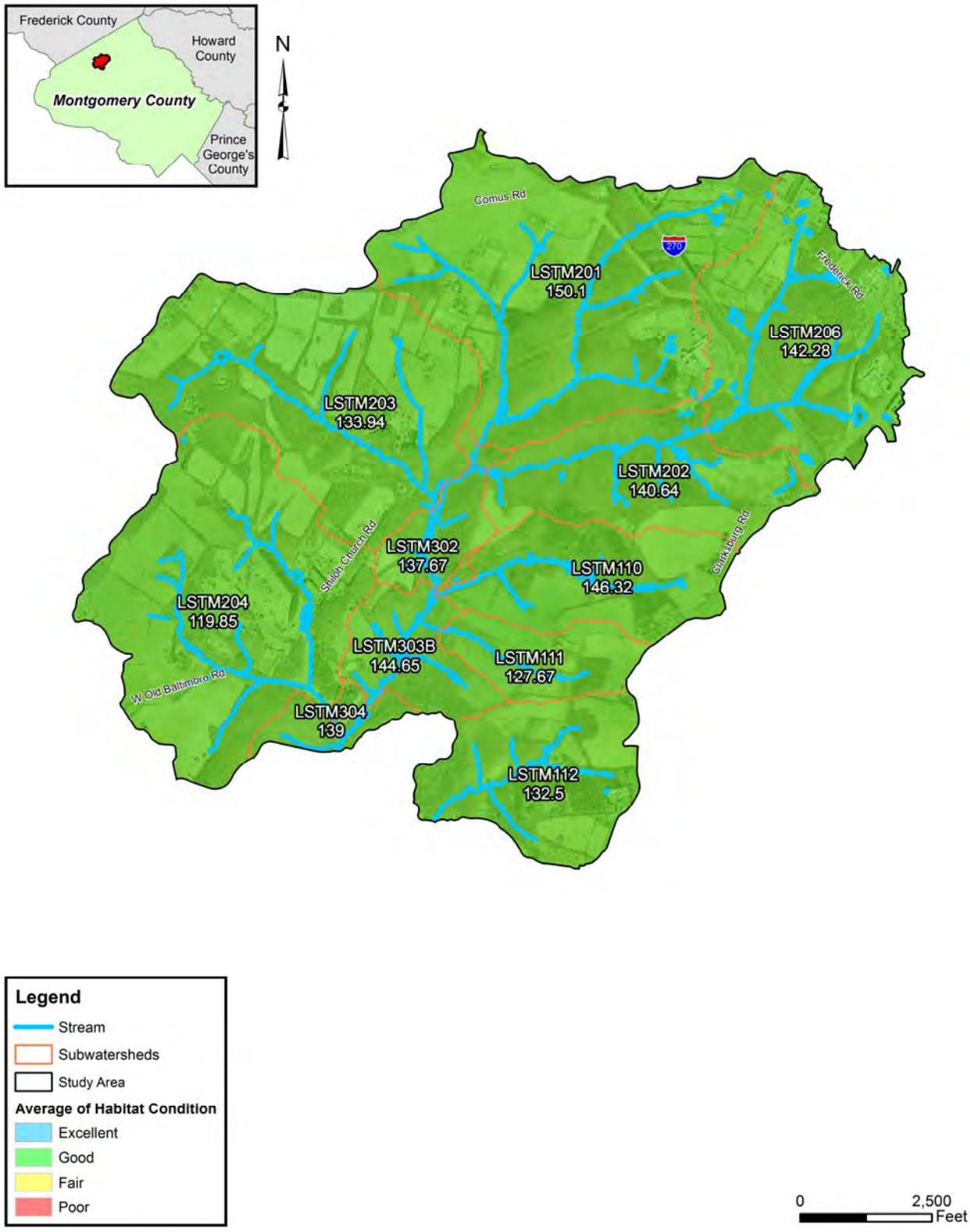


Figure 3.20. Average subwatershed habitat condition rating (1994-2012).

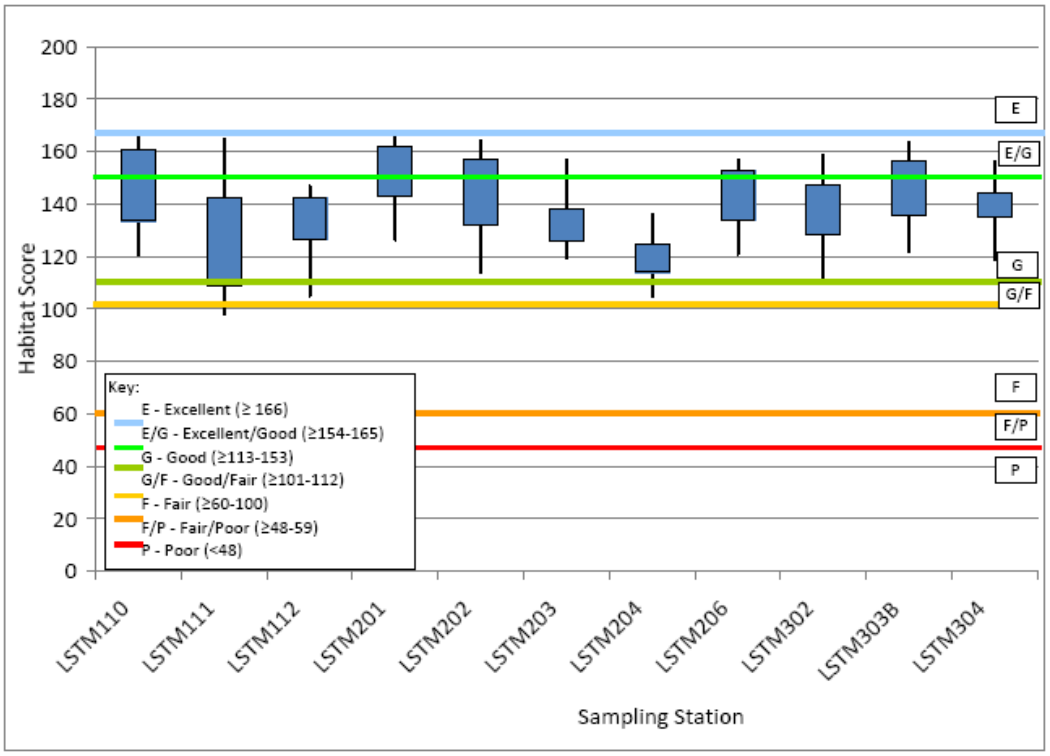


Figure 3.21. Ranges of composite habitat scores among the permanent sampling stations (1994-2012).

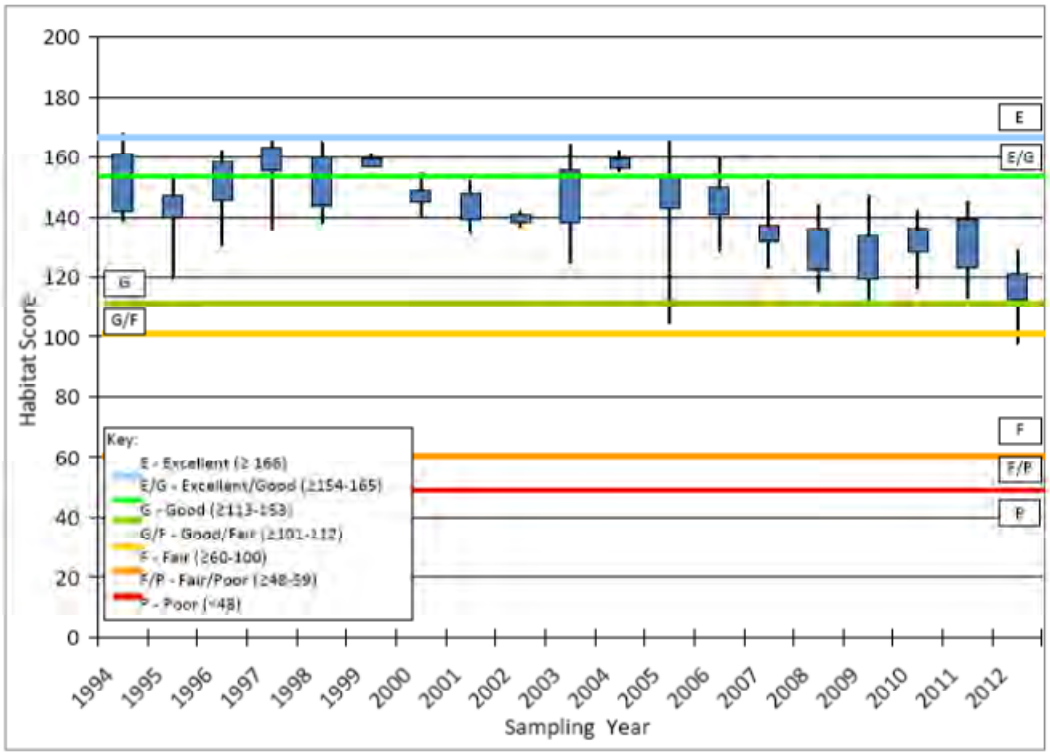


Figure 3.22. Variability among habitat scores at all sampling stations over time.

Fish

Fish communities were assessed by DEP staff during summer index periods of the respective sampling years in accordance with the Maryland Biological Stream Survey (MBSS) methods (Kayzak, 2001). The DEP Fish IBI evaluates 9 metrics which are averaged into an overall IBI score indicating the health of the fish community. Comparisons of these data to the statewide data sets developed by MBSS could not be used to corroborate these data because one or more of the metrics for this comparison was not readily available in the data provided.

The DEP Fish IBI indicates that overall the fish community within the Ten Mile Creek drainage is in good condition. Figure 3.23 shows the 2012 Fish IBI scores for each subwatershed, and Figure 3.24 shows the average of the 1994 – 2012 composite Fish IBI scores for each subwatershed. As shown in Figure 3.25, Station 206 and the third order or mainstem stations (LSTM 302, LSTM303B and LSTM304) scored lower than the second order stations. The lower scores in the third order stations could be due in part to how the Fish IBI is stratified based on stream order. The lower score in LSTM206, however, is likely more related to the watershed condition, since it is scored in the same way as the other stations. As discussed in previous sections, subwatershed LSTM206 contains the highest percent impervious cover and urban land uses, which could explain the lower overall score in the Fish IBI.

The one notable outlier in the data set is Station LSTM112, which was only sampled in 2007 and scored poor. Station LSTM112, is a first-order tributary and due to their watershed position, size and flow characteristics first-order tributaries typically lack the abundance and diversity necessary to be scored accurately by an IBI (Southerland et al. 2005).

Review of the time series data shown in Figure 3.26 indicates some of the variability in the sampling data over time. This variability is likely attributed to number of stations sampled between sample years 2000 and 2006. During this period, only LSTM206, LSTM303B and LSTM304, which generally scored lower in the fish IBI on average, were regularly sampled. Regimented sampling of all eight sampling stations for fish did not begin until sample year 2007. This more regimented sampling could explain the apparent recovery and/or stabilizing of the Fish IBI scores shown in Figure 3.26 post 2007.

A review of the time series data for the individual metrics comprising the DEP's Fish IBI is presented in Appendix D. While the time series data indicate some shifts in the overall community structure, the total fish diversity appears to be stable, as indicated by the composite Fish IBI shown in Figure 3.26.

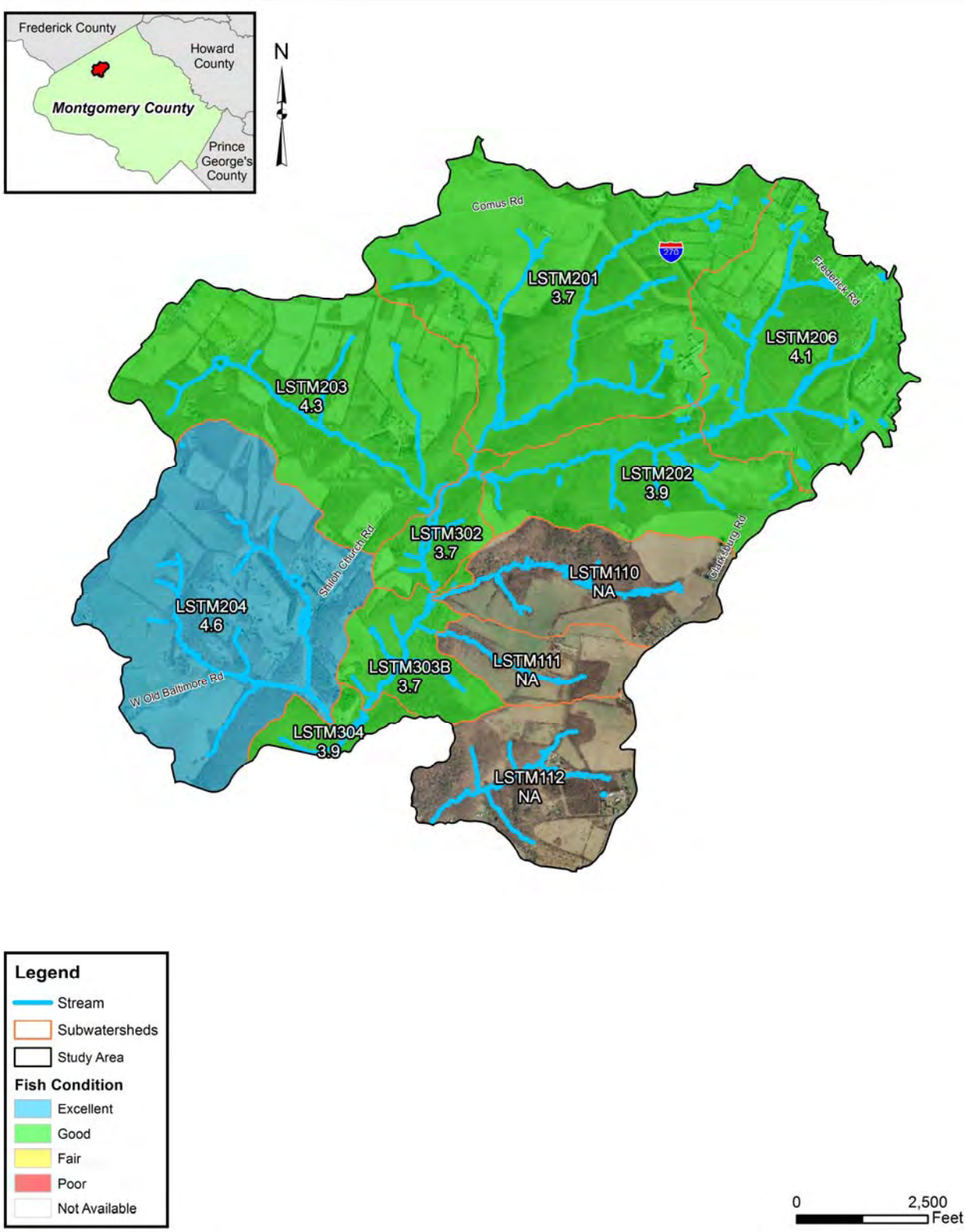


Figure 3.23. 2012 subwatershed fish IBI rating.

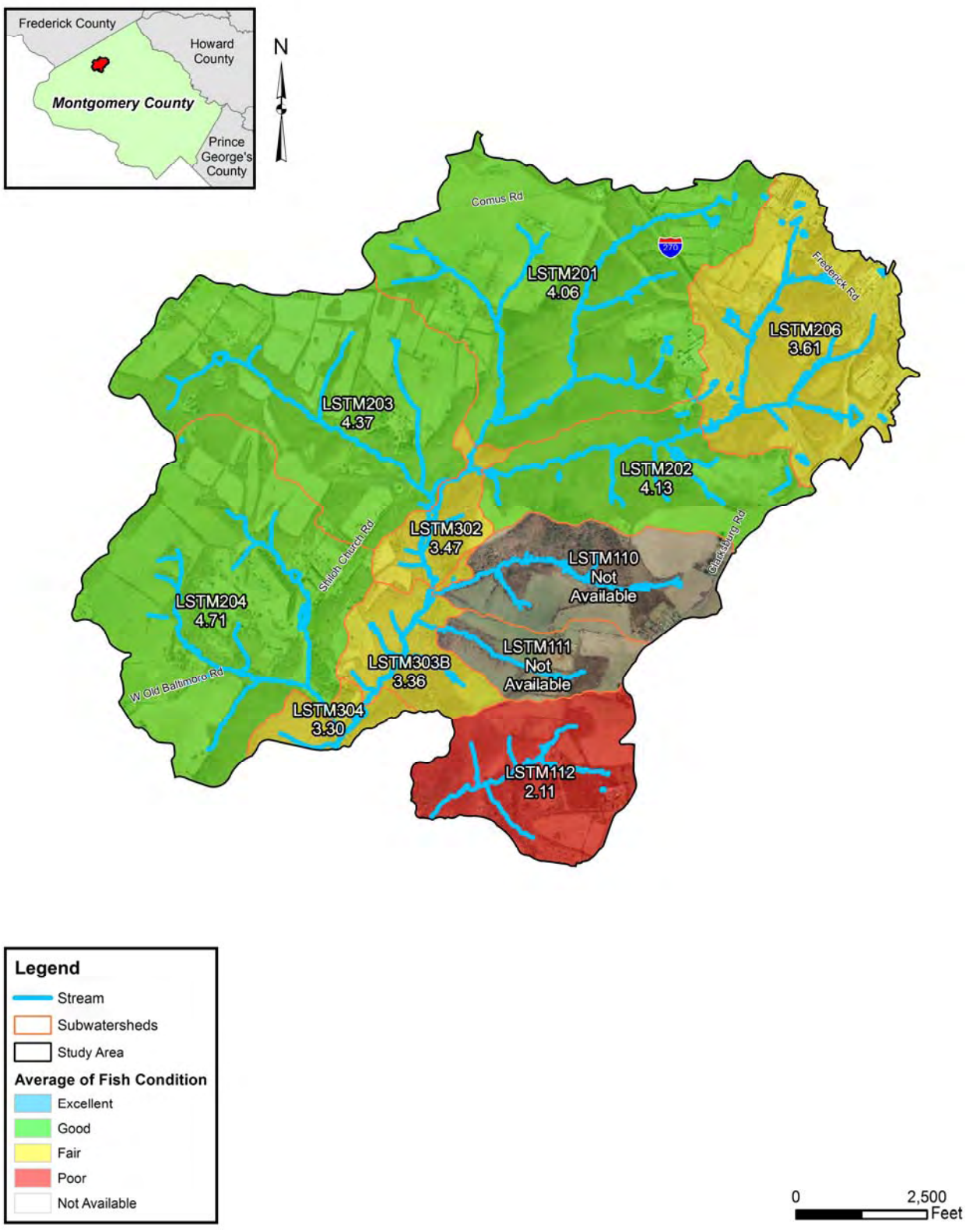


Figure 3.24. Average subwatershed fish IBI rating (1994-2012).

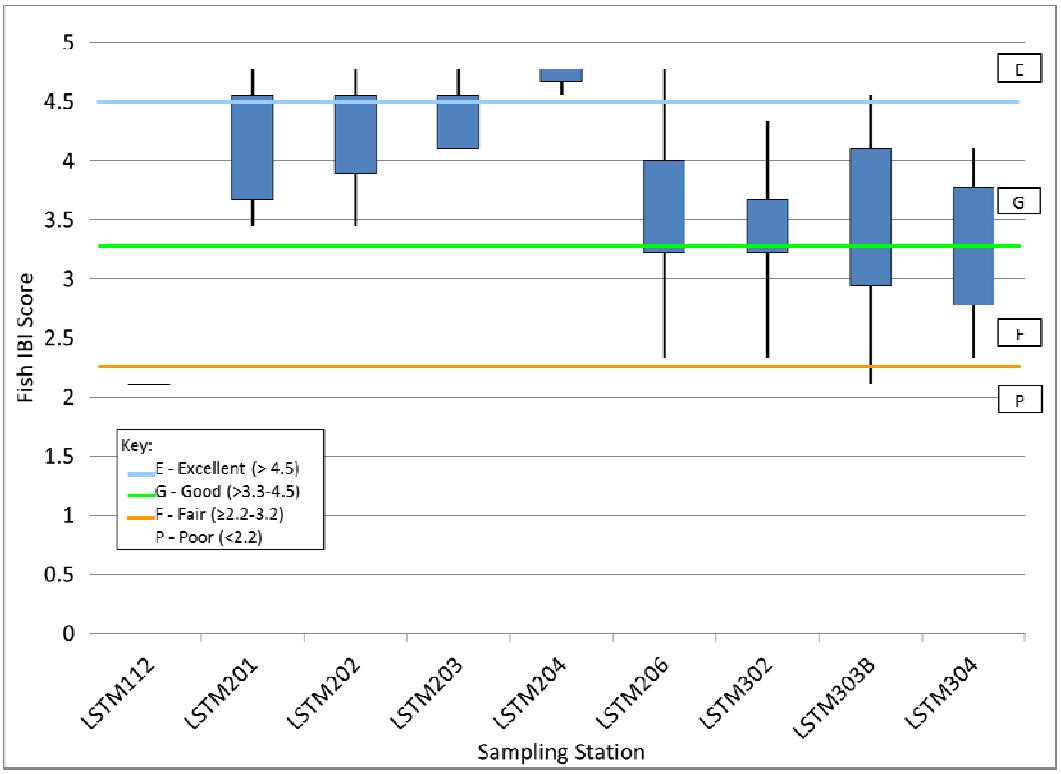


Figure 3.25. Ranges of composite Fish IBI scores among the permanent sampling stations (1994-2012).

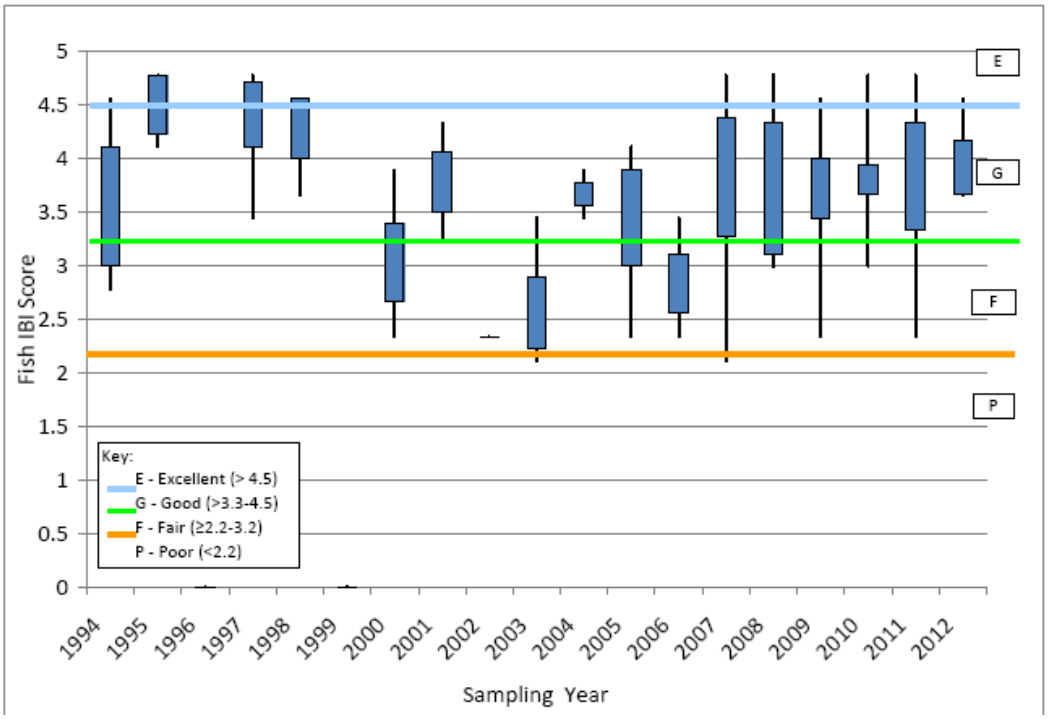


Figure 3.26. Variability among Fish IBI scores at all sampling stations over time.

Herptofauna

Reptile and amphibian, collectively called herptofauna, communities have been assessed by DEP since 2008. MBSS data suggest that herptofauna are sensitive to various environmental stressors including urbanization (Boward, Kayzak, Stranko, Hurd, & Prochaska, 1999). Consequently, Southerland et al. (2004) proposed a provisional Stream Salamander IBI to describe stream salamander communities relative to watershed condition; however, this IBI has not been able to effectively classify reference sites (Southerland and Rogers 2010). Southerland and Rogers (2010) attributed this to differences in sampling methodologies among sites and the number of reference sites where salamanders were not found. For these reasons, a formal stream salamander IBI is not available for comparison, but the presence or absence of herptofauna can still be indicative of watershed condition.

Within the Ten Mile Creek Watershed, a total of 22 herptofauna species were observed, which is indicative of less developed watersheds (Boward et al., 1999). A summary table of observed herptofauna is presented in Appendix D. Of the observed species, the slimy salamander (*Plethedon guttinosis*), a terrestrial/riparian species, found at station LSTM201 would be considered intolerant to degraded conditions. The slimy salamander preferred habitat is mature hardwood forest, and the slimy salamander along with most amphibians are sensitive to forest clearing and land use conversion (Petranka, 1998). Six of the species would be characterized as tolerant and the remaining 15 species would be considered sensitive. One or more of these sensitive species were observed at 10 of the 11 sample sites. The majority of these sensitive species require forested habitat (Stranko et al., 2010 and Petranka, 1998), and while many of these species are common, their distribution within the state is limited to relatively rural watersheds with low to moderate impervious cover between 3% and 25% (Boward et al., 1999). LSTM111 was the only site where sensitive species were absent, but two tolerant species were observed. The lack of sensitive species in this LSTM111 is likely related to the limited amount of preferred habitat (riparian forest) within the subwatershed and adjacent to the sampling station.

The presence of diverse community of herptofauna including a number of sensitive species is indicative a watershed that contains abundant and contiguous habitat. The large tracts of interior forest, springs, seeps, seasonal pools, and clean water within the watershed are necessary to support this community. Conservation and enhancement of contiguous blocks of preferred habitat, particularly riparian corridors, would be the primary management strategy for maintaining a diverse and healthy community of herptofauna (Petranka, 1998).

Biological Condition

The overall biological condition of the subwatersheds is determined by averaging the percent maximum IBI scores for the fish and benthic macroinvertebrates at each station (Keith Van Ness, personal communication, February 12, 2013). The 2012 biological conditions scores for each subwatershed are shown in Figure 3.27, and the average of the 1994 – 2012 biological condition scores for each subwatershed is presented in Figure 3.28. This index indicates that the overall biological condition of the Ten Mile Creek Watershed is good, as shown in Figure 3.29.

Time series data shown in Figure 3.30 indicates that the biological condition of the Ten Mile Creek sampling stations generally maintains a good classification, but shows a slight decline from high end of the good to the middle of the range, as observed in the Benthic IBI data. The biological condition is variable between sample years 2000 and 2006 when sampling was only performed at a limited number of stations, as discussed in the Fish section. The overall biological condition then stabilizes after 2007 as previously discussed.

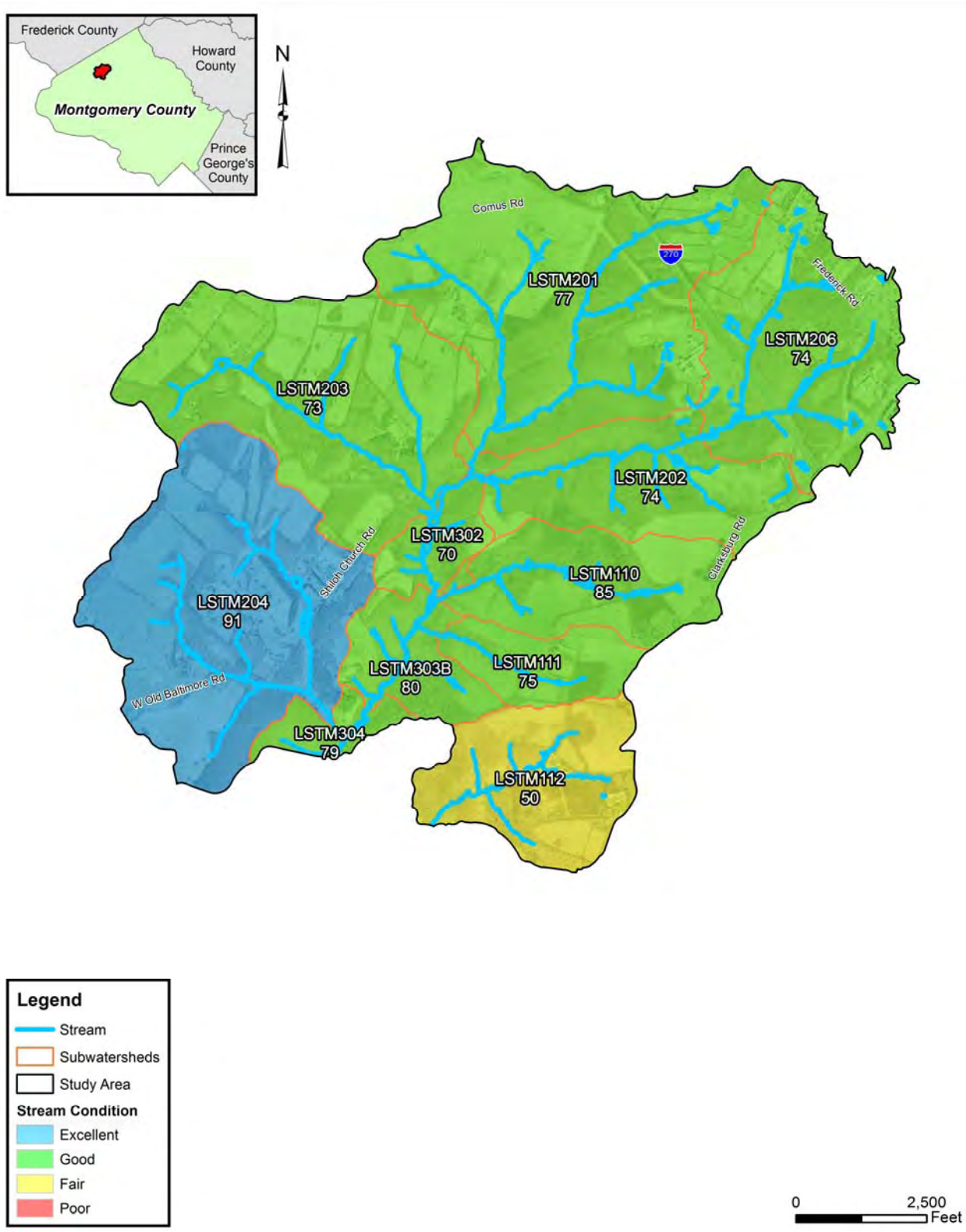


Figure 3.27. 2012 subwatershed biological condition rating.

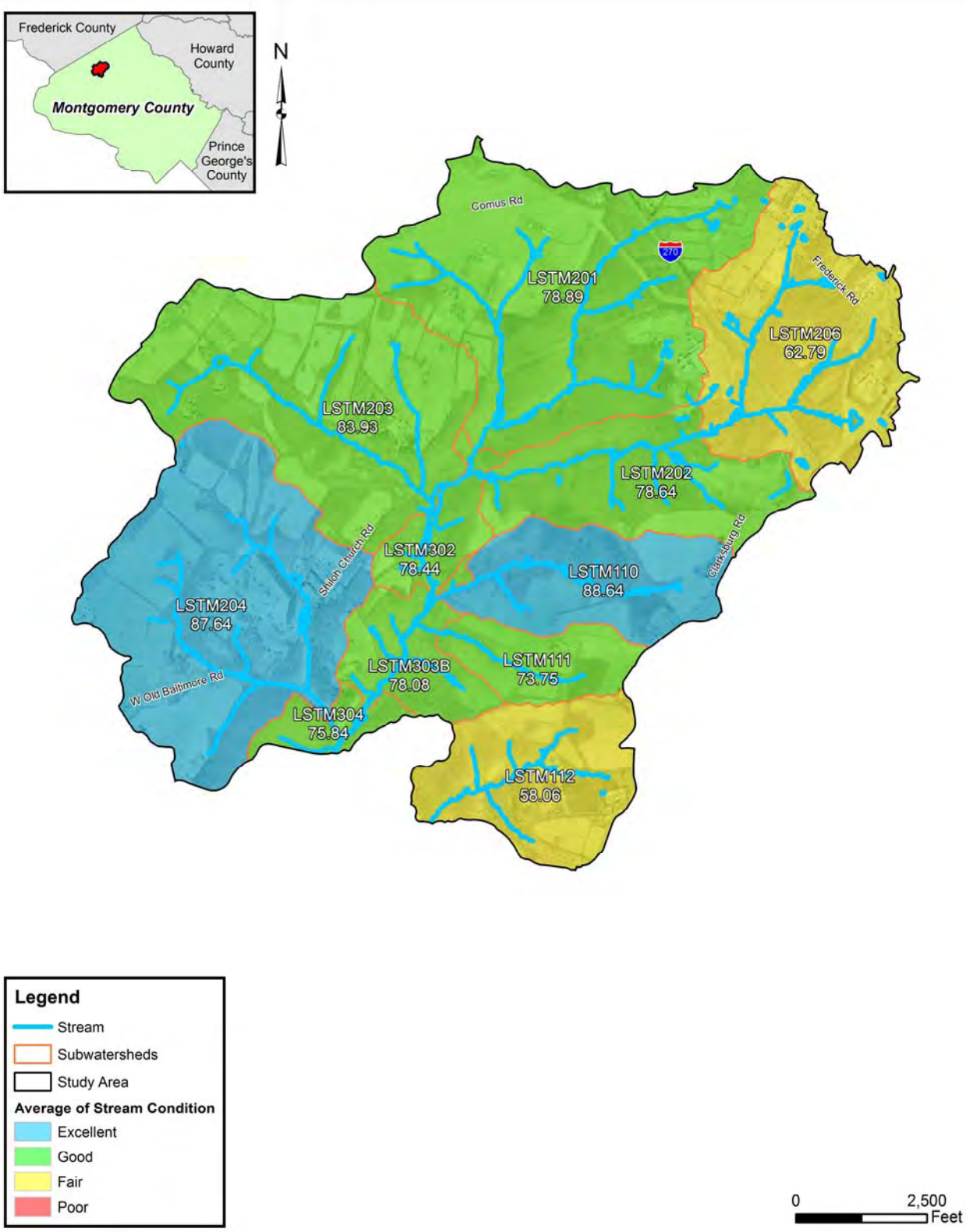


Figure 3.28. Average subwatershed biological condition rating (1994-2012).

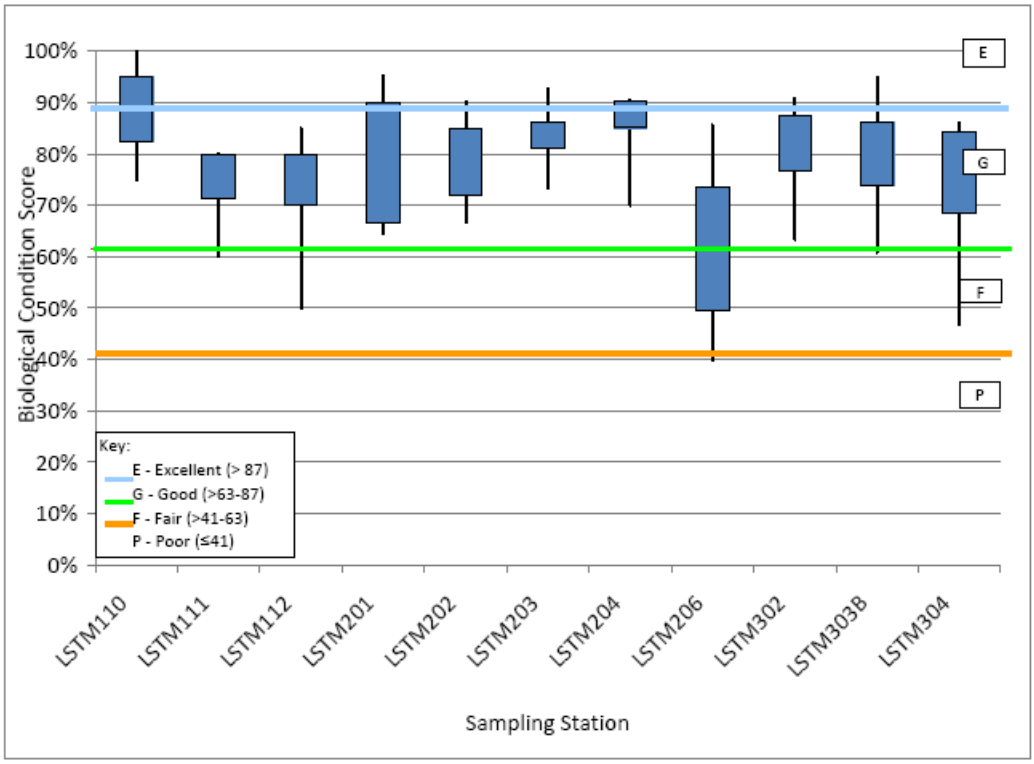


Figure 3.29. Ranges of composite Biological Condition scores among the permanent sampling stations (1994-2012).

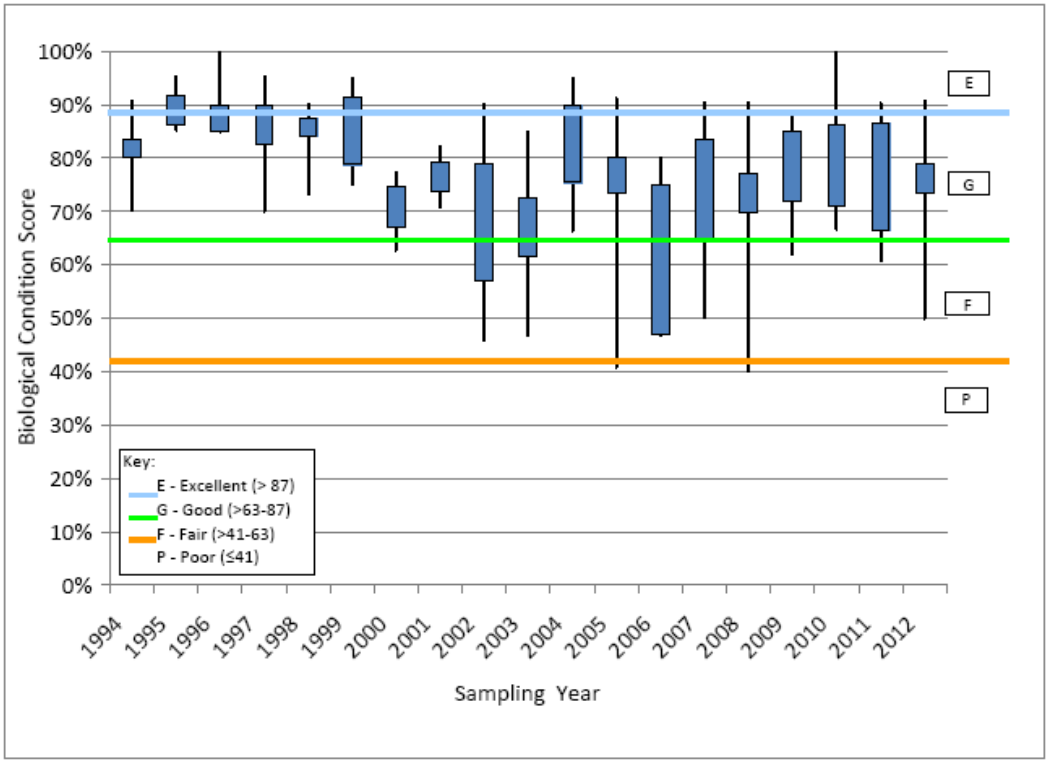


Figure 3.30. Variability among biological condition scores at all sampling stations over time.

3.9 Upland Habitat and Biology

Forest Cover

Typically in those undeveloped areas not in agriculture, the vegetation in the Ten Mile Creek study area is characterized as an upland or bottomland hardwood forest. The upland hardwood forest is particularly prevalent in the western portion of study area. It is described as a mature forest with abundant groundcover and a nearly complete canopy in upland and on hillslope landscape positions. Tuliptree (*Liriodendron tulipifera*), red maple (*Acer rubrum*), red oak (*Quercus rubra*), and hickory (*Carya sp.*) are the dominant canopy trees (Greenhorne & O'Mara, 1992). Bottomland hardwood forests are located along stream, floodplains and wetland areas within the watershed. The canopy coverage of the bottomland forests is dominated by red maple, American sycamore (*Platanus occidentalis*), black willow (*Salix nigra*), Green ash (*Fraxinus pennsylvanica*), tulip tree, hickory, black locust (*Robinia pseudoacacia*), black gum (*Nyssa sylvatica*), black cherry (*Prunus serotina*), and black walnut (*Juglans nigra*) in the overstory tree canopy. While concentrated in the western portion of the watershed, agricultural fields and pasture are found throughout the watershed (Greenhorne & O'Mara, 1992).

Montgomery County DEP recently mapped forest interior within the Ten Mile Creek watershed based on the following conditions: 1) a forest at least 50 acres in size with 10 or more acres of interior forest habitat or a forest greater than 300 feet from the nearest forest edge, or 2) a riparian forest with an average minimum width of 300 feet and at least 50 acres in size. These forest interiors that can support forest interior dwelling birds species (FIDS) that require large forest areas to breed and maintain viable populations (Jones, McCann, & McConville, 2000). See Figure 2.2 for the extent of forest interior in the Ten Mile Creek study area.

In addition MDNR has performed a statewide analysis of hubs and corridors "that are large and intact enough to provide a full range of environmental functions" (MDNR 2003). MDNR (2003) defines hubs as areas that consist of large contiguous tracts of forest land that are integral to the ecological health of the state and corridors as linear remnants of these vital habitats that form linkages among the hubs. As shown in Figures 3.31 and 3.32, the large tract of forest central to the Ten Mile Creek Watershed has been designated as a hub by MDNR. This figure also shows an important corridor extending north to Little Bennett Regional Park and south to Black Hills Regional Park, both MNDR designated hubs. Being in such proximity, these hubs each function to enhance the integrity and biodiversity of the adjacent habitats as a more contiguous unit. The crucial gaps documented in this resource are located at the northeastern tip of the subwatershed LSTM201 and at the boundary between LSTM302 and LSTM303B. The primary land use within these gaps is currently documented as bare ground and agriculture.

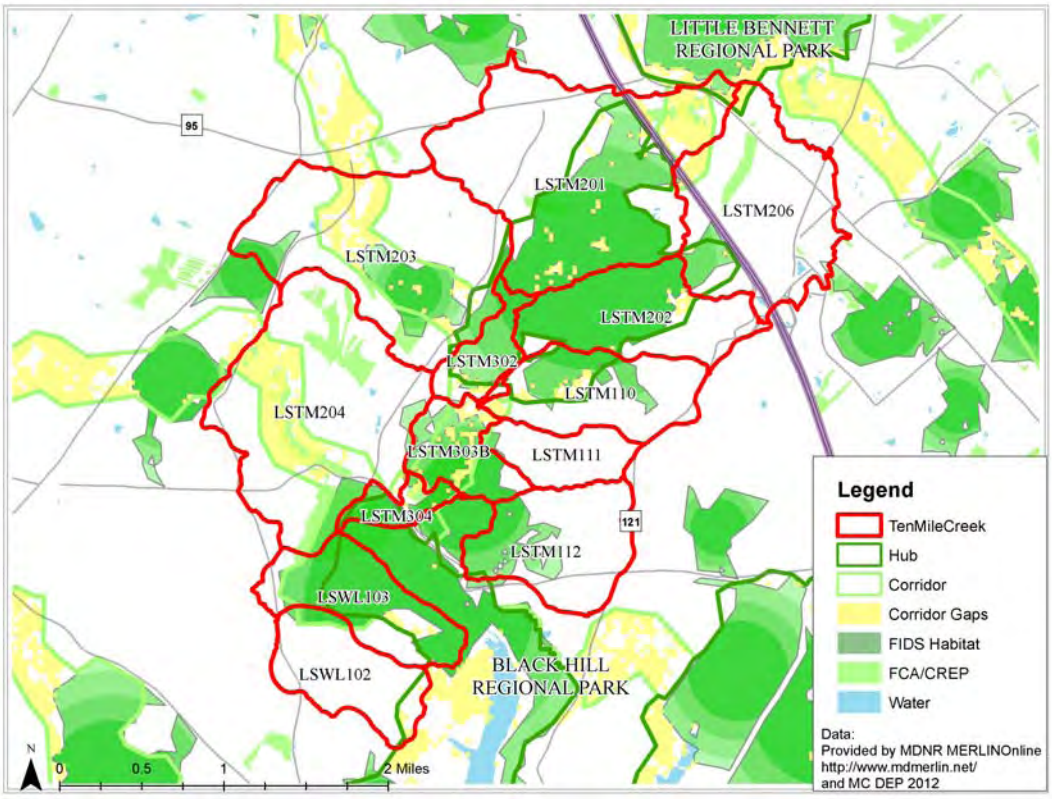


Figure 3.31. Overview of MDNR's hubs and corridors and forest connectivity data within the project area.

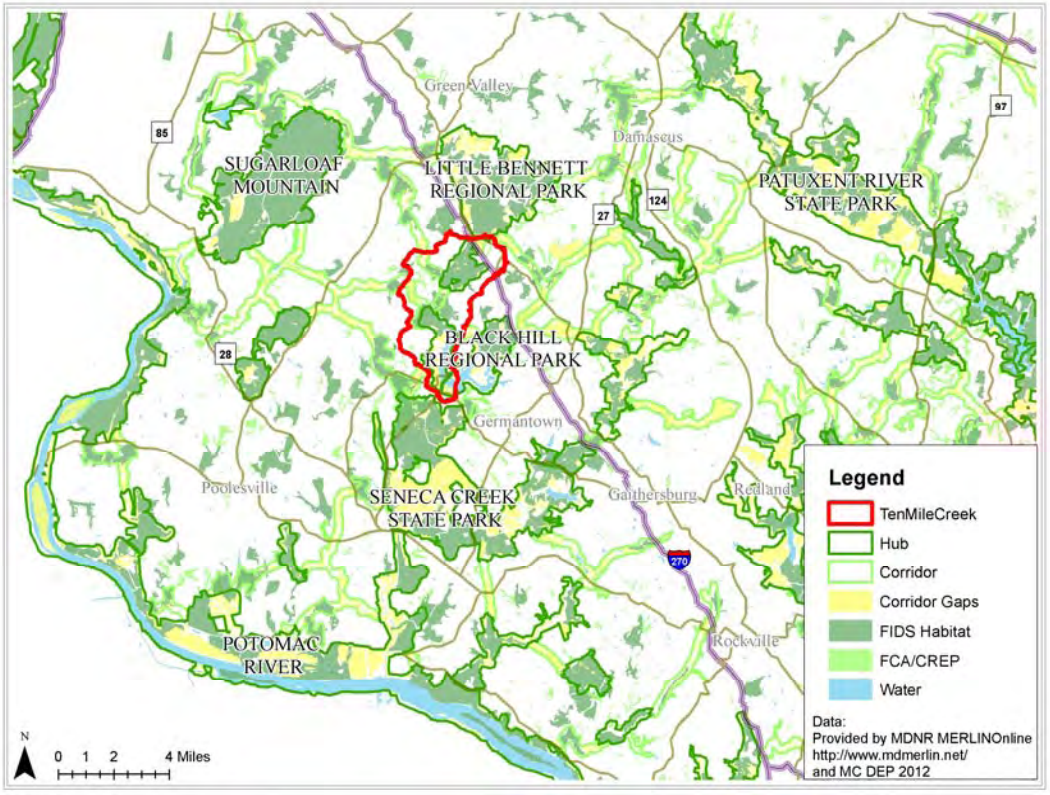


Figure 3.32. Regional overview of MDNR's hubs and corridors and forest connectivity data.

Wildlife

In the upper reaches of Ten Mile Creek beaver have developed a series of dams which provide deep, cool pools that act as refuge for fish, amphibians and reptiles during the drier summer months and habitat for wintering waterfowl and area wildlife in the winter months (Montgomery County Planning Department, 2009). In addition, "bird surveys in 2009 observed or heard 12 migratory nesting forest interior bird species in Stage 4 forest interior areas of Ten Mile Creek" (Montgomery County Planning Department, 2009).

Table 3.6 lists the wildlife documented in various habitats during an ecological field survey throughout the Clarksburg Planning Area by Greenhorne & O'Mara, Inc. (1992).

Table 3.6. Wildlife Documented in the Clarksburg Planning Area During the Clarksburg Environmental & Water Resources Study

Mammals throughout the Clarksburg Planning Area	
Whitetail deer (*Odocoileus virginianus*)	Eastern mole (*Scalopus aquaticus*)
Raccoon (*Procyon lotor*)	Woodchuck (*Marmota monax*)
Gray squirrel (*Sciurus carolinensis*)	Eastern chipmunk (*Tamias striatus*)
Red fox (*Vulpes vulpes*)	
Birds in Upland Hardwood Forest	
Downy woodpecker (*Picoides pubescens*)	Scarlet tanager (*Piranga olivacea*)
Red-bellied woodpecker (*Melanerpes carolinus*)	White-breasted nuthatch (*Sitta carolinensis*)
Tufted titmouse (*Parus bicolor*)	Whippoorwill (*Caprimulgus vociferous*)
Kentucky warbler (*Oporornis formosus*)	Eastern towhee (*Pipilo erythrophthalmus*)
Northern parula (*Parula americana*)	Red-tailed hawk (*Buteo jamaicensis*)
Northern cardinal (*Cardinalis cardinalis*)	Great crested flycatcher (*Myiarchus crinitus*)
Ovenbird (*Seiurus aurocapillus*)	
Birds in Bottomland Hardwood Forest	
Eastern wood pewee (*Contopus virens*)	Gray catbird (*Dumetella carolinensis*)
Carolina chickadee (*Poecile carolinensis*)	Red-eyed vireo (*Vireo olivaceus*)
Carolina wren (*Thryothorus ludoyicianus*)	American robin (*Turdus migratorius*)
Wood thrush (*Hylocichia mustelina*)	Barred owl (*Strix varia*)
Birds along Forest Edges and Open Areas	
Common yellowthroat (*Geothlypis trichas*)	Barn swallow (*Hirundo rustica*)
Red-winged blackbird (*Agelaius phoeniceus*)	American crow (*Corvus brachyrhynchos*)
Indigo bunting (*Passerina cyanea*)	Turkey vulture (*Cathartes aura*)
Northern flicker (*Colaptes auratus*)	American goldfinch (*Carduelis tristis*)
Herptile Species in Bottomland Hardwood Forests (Associated with streams, floodplains, and wetalnds)	
Pickerel frog (*Rana palustris*)	Ringneck snake (*Diadophis punctatus*)
American toad (*Bufo americanus*)	Eastern box turtle (*Terrapene carolina*)
Two-lined salamander (*Eurycea bislineata*)	Treefrog (*Hyla sp*.)

Source: (Greenhorne & O'Mara, Inc., 1992)

In addition, the Audubon Naturalist Society has observed or seen evidence of the following wildlife during sampling efforts in Ten Mile Creek watershed: salamanders, fish, frogs, deer, beavers,

woodpeckers, owls, songbirds, Great Blue herons, hawks, and vultures (Audubon Naturalist Society, 2012).

3.10 Rare, Threatened, and Endangered Species

A species information request letter regarding information on state rare, threatened and/or endangered plant and animal species within or near the Ten Mile Creek watershed was sent to MDNR Wildlife and Heritage Service in January 2013. As of the date of this report, a response letter was not yet received. According to the United States Fish and Wildlife Service (USFWS) Chesapeake Bay Field Office website, the watershed is located on a United States Geologic Survey (USGS) Topographic map designated "where no federally proposed or listed endangered or threatened species are known to occur." For this reason, an online certification letter is adequate for fulfilling the species information request to the USFWS (Appendix E). In addition, no endangered flora or fauna were identified during a 1990 environmental inventory conducted by Greenhorne & O'Mara, Inc. for Montgomery County Planning Department of M-NCPPC (Greenhorne & O'Mara, 1992).

4.0 COMMUNITY FEATURES

4.1 Historical Context

A letter requesting historic and archeological properties information within Ten Mile Creek watershed was sent to Maryland Historical Trust (MHT) in January 2013 (Appendix F). A MHT review letter dated February 8, 2013, (Appendix F) concluded there are "literally dozens of historical properties" and "several known archeological sites (both prehistoric and historic) as well as a number of archeologically sensitive areas likely to contain significant sites that have not yet been identified (Maryland Historical Trust, 2013)". The known historical features to note within Ten Mile Creek watershed include three rustic roads, West Old Baltimore Road ford crossing, cemeteries, Clarksburg School, Moneysworth Farm, Cephas Summers House, Clarksburg Historical District, and Tenmile Creek Valley Historical District (Figure 4.1).

The Rustic Road Program was enacted by Montgomery County to preserve historic and scenic roadways characteristics of the county's agricultural and rural origins. There are two categories of rustic roads – rustic road and exceptionally rustic road. The difference is that exceptional rustic roads "contribute significantly to the natural, agricultural, or historic characteristic of the County", "have unusual features found on few other roads", and "would be more negatively affected by improvements or modifications…than most other roads in the Rustic Road Program" (Montgomery County Department of Park and Planning, 1994). Three roads in the watershed are included in this program. Small portions of Peach Tree Road and Slidell Road within the watershed are classified as rustic roads. West Old Baltimore Road, that bisects the watershed from Clarksburg Road (MD 121) to Slidell Road, is classified as an exceptional rustic road (Montgomery County Planning Department, 2004).

A unique characteristic of West Old Baltimore Road is a ford crossing, a natural shallow point in the stream that can be crossed by vehicle or people, through Ten Mile Creek mainstem. This is one of a few fords remaining in Montgomery County.

Two historical cemeteries are located in Ten Mile Creek – one in the northeast and the other in the northwest – Clarksburg Methodist Church Cemetery and Thompson Family Cemetery. Clarksburg Methodist Church Cemetery is associated with the Clarksburg Methodist Church, established in 1788. Some of the slate grave markers are dated late 18th to early 19th century. The cemetery is located on Spire Street in the Clarksburg Historic District. Thompson Family Cemetery, circa 1873, is located west of Slidell Road just south of Comus Road (Montgomery County Planning Department & Montgomery County Department of Environmental Protection, 2013).

According to the 1994 Clarksburg Master Plan, the Master Plan for Historic Preservation has five individual sites and three Master Plan historical districts within the Clarksburg Study Area. Three individual sites – Clarksburg School, Moneysworth Farm, and Cephas Summers House – and Clarksburg Historic District are located entirely or partially within Ten Mile Creek watershed. Several additional historical resources, mostly houses and outbuildings within Ten Mile Creek watershed identified in the 1994 Master Plan that were being reviewed in conjunction with the Master Plan effort, received negative recommendations from the Historical Preservation Commission and the Master Plan (Montgomery County Department of Park and Planning, 1994).

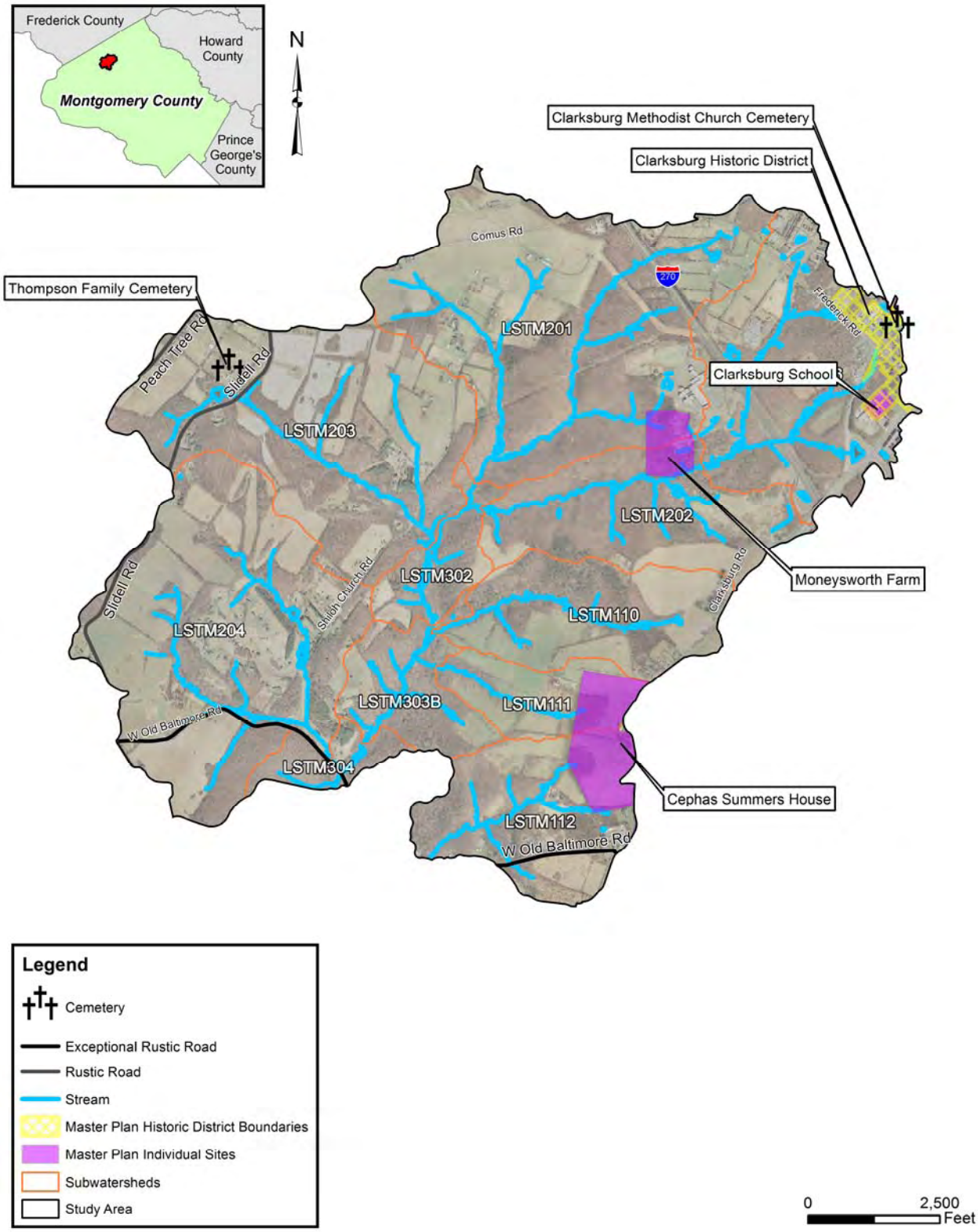


Figure 4.1. Historic and Cultural Sites

The National Register listed Clarksburg School, a two-room schoolhouse built in 1909, as located within the Clarksburg Historical District (Maryland Historical Trust, 2013; Montgomery County Department of Park and Planning, 1994). Moneysworth Farm, a MHT easement property, is located south of Frederick Road (MD 355) on the grounds of the Montgomery County Correctional Facility (Maryland Historical Trust, 2013; Montgomery County Department of Park and Planning, 1994). The Moneysworth Farm is a farmstead in which the original part of the house was built in 1783 with logs. Cephas Summers House, dating from the second quarter of the 19th century, is one of the earliest farmhouses in the Clarksburg area. The farmhouse, located west of Clarksburg Road, is an example of Greek Revival-style architecture (Montgomery County Department of Park and Planning, 1994; Montgomery County Planning Department & Montgomery County Department of Environmental Protection, 2013).

The National Register-eligible Clarksburg Historical District, located along Frederick Road (MD 355) in the northern part of Ten Mile Creek watershed, has residential and commercial buildings from the early 19th to early 20th century including the Clarksburg School (Maryland Historical Trust, 2013; Montgomery County Department of Park and Planning, 1994; Montgomery County Planning Department & Montgomery County Department of Environmental Protection, 2013). The Tenmile Creek Stream Valley Historical District is located between Route 121 and West Old Baltimore Road (Maryland Historical Trust, 1979). According to Maryland State archives compiled 1978-1979, the area contains potentially significant archeological sites (i.e. prehistoric Indian culture) and settlements of the eighteenth century (e.g., tobacco planters, a mill site include a pond, race, and house, a boarding house, etc.) (Maryland Historical Trust, 1979).

4.2 Existing Infrastructure

Utilities

Utilities are limited within the Ten Mile Creek study area. The County Correctional Facility pumps sewage to Gateway Center Drive. A few properties in the Historic District have access to sewer service via sewers in the Little Seneca watershed, some adjacent to the town center and a few west of Route 355 (Montgomery County Planning Department, 2009). The majority of residents within Ten Mile Creek watershed are on well water and septic systems.

Stormwater Management

Montgomery County has historically been very proactive in requiring stormwater management of developers, thus the existing development areas in Ten Mile Creek are largely controlled by best management practices (BMPs). Due to the various development periods, these BMPs vary according to their approval date and what was considered “state-of-the-practice” at the time of construction. Twenty BMPs are located in three of the Ten Mile Creek subwatersheds- LSTM201, LSTM206, and LSTM204 (Table 4.1 and Figure 4.2). In all, these BMPs service fifteen drainage areas, which are grouped in the Table. Eighteen are listed in the Montgomery County DEP urban stormwater BMP database. The urban stormwater BMP database maintained by DEP is generally used for the County to track BMPs within their jurisdiction for maintenance. Generally, there is a lag period between construction of a BMP, a period where the BMP is maintained by a developer or property owner, and when that BMP becomes County responsibility. At least two BMPs are currently not listed in the urban stormwater BMP database: a pond at the Clarksburg Detention Center, and a pond at the Stringtown Road Extension. These were added to Table 4.1 based on data from the SPA reports.

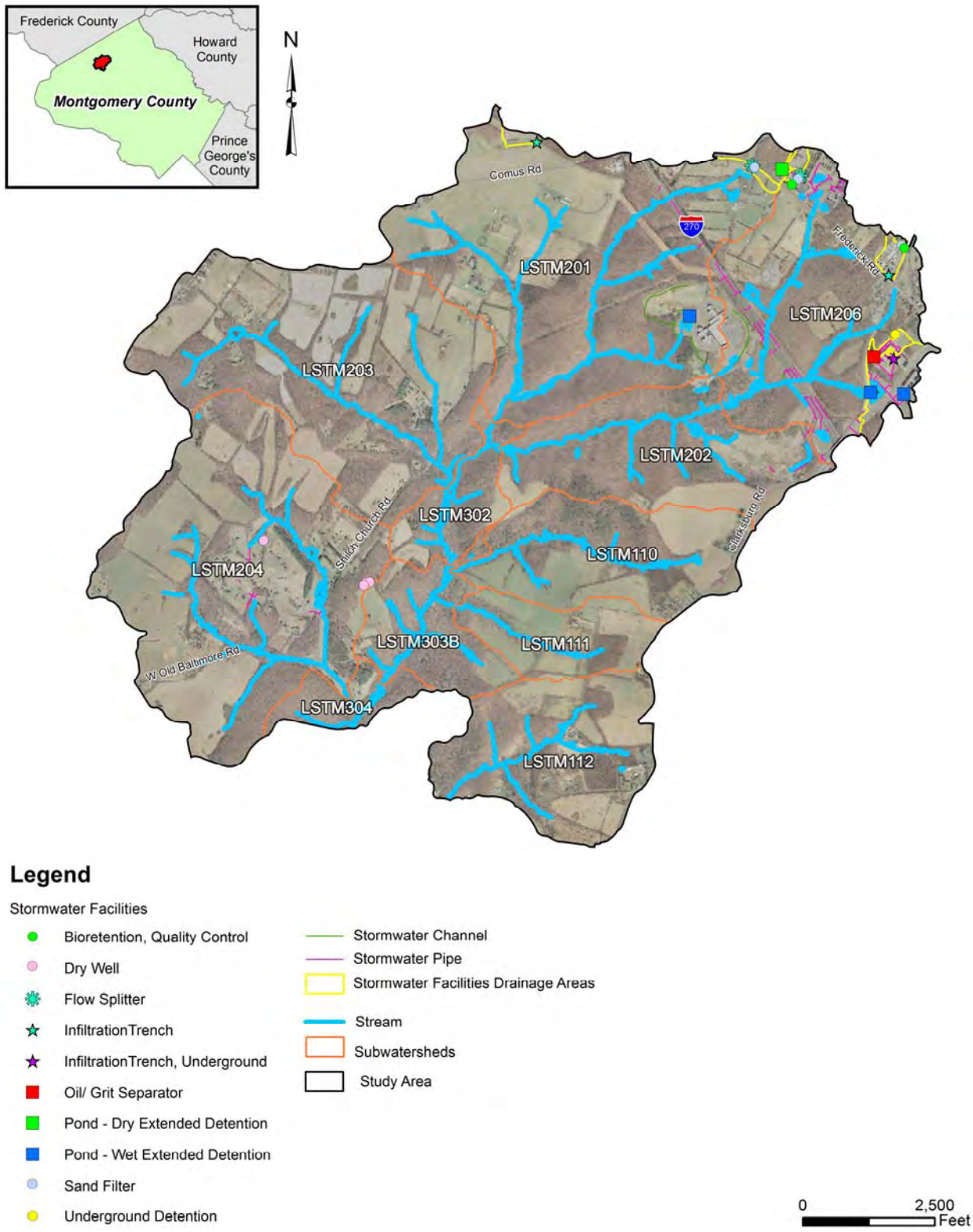


Figure 4.2. Existing Stormwater Infrastructure in the Ten Mile Creek Study Area

Table 4.1. Existing Stormwater Management Features in the Ten Mile Creek study area

Subwatershed	Structure Type	Approval Date	Drainage Area (acres)	Land Use
LSTM201	Flow Splitter to Sand Filter	2002	14.6	Route 355 Roadway
LSTM201	Infiltration Trench	2000	3.9	Garden of Remembrance Cemetery Roadway
LSTM201	Flow Splitter to Dry Pond w/ Extended Detention	1979	3.7	Little Bennett Regional Park Parking
LSTM201	Wet Pond w/ Extended Detention[1]	2002	35	Clarksburg Detention Facility (Institutional)
LSTM206	Flow Splitter to Sand Filter	1979	3.2	Little Bennett Regional Park Parking
LSTM206	Bioretention	2007	1.1	Woodcrest Phase 5 Medium-Density Residential
LSTM206	Infiltration Trench	1995	6.1	Clarksburg Nursery (Commercial)
LSTM206	Bioretention	2003	0.9	Clarksburg Ridge High-Density Residential
LSTM206	Sand Filter	2003	0.6	Clarksburg Ridge High-Density Residential
LSTM206	Wet Pond w/ Extended Detention	1989	34.5	Gateway 270 Corporate Park
LSTM206	Oil/grit Separator to Underground Detention	1992	3.8	Clarksburg Elementary School
LSTM206	Underground Infiltration trench	1974	0.3	Clarksburg Elementary School
LSTM206	Erosion & Sediment Control Pond, to be converted to a Wet Pond[2]	2012	12.9	Stringtown Road Extension & Gateway Commons
LSTM204	Dry Well	2007	0.09	Huffman Property Single Residence
LSTM204	Dry Well	2008	0.03	Branch Hill Single Residence

Source: DEP Urban Stormwater BMP Database, except for
1 Montgomery County Department of Environmental Protection, 2003
2 Montgomery County Department of Environmental Protection, 2012

The northern headwater area of Ten Mile Creek (subwatershed LSTM201) receives runoff from part of the Clarksburg Detention Center, Route 355, the Garden of Remembrance Cemetery, and the Little Bennett Regional Park. In some cases, a flow splitter is used to route first-flush events to infiltration practices, as is the case for the Route 355 and Little Bennett Regional Park facilities. The flow splitter at the Little Bennett Regional Park actually divides flow between the LSTM201 and LSTM206 subwatersheds. The pond at the Clarksburg Detention Center was re-constructed after construction of the jail, but was not listed in the DEP Urban Stormwater BMP database (Montgomery County Department of Environmental Protection, 2003). The stream has been impacted by the crossing and piped drainage associated with I-270. Sections of the Clarksburg Correctional Facility have also been channelized to improve drainage.

The eastern headwater area of Ten Mile Creek (subwatershed LSTM206) receives runoff from the new Stringtown Road widening west of Route 355, some commercial development in the I-270 Gateway Center area, portions of the Town Center development, a part of Gateway Commons, as well as runoff from portions of I-270. This subwatershed contains the highest density of stream crossings, piped drainage, and stormwater management facilities. Construction on the Stringtown Road Extension has been completed since November 2006, but the Sediment Basin BMP will not be converted to SWM until construction is completed at Gateway Commons, since the two properties both drain to this basin. The basin treats 12.9 acres of runoff from Stringtown Road Extension and Gateway Commons. It then discharges to an existing off-site stormwater management pond to the west of Gateway Center Drive (Montgomery County Department of Environmental Protection, 2012).

The western tributary area of Ten Mile Creek (subwatershed LSTM204) contains some low density residential development. Two of these private homes, Branch Hill and Huffman, have dry wells to manage runoff from their properties. Some limited piped drainage occurs associated with the residential development.

5.0 CONCLUSION

As presented in the preceding sections, the Ten Mile Creek study area exhibits many environmental characteristics that reflect overall healthy watershed conditions. Subwatershed characteristics within the study area are summarized in Table 5.1. Where conditions show indications of impairment, these tend to be associated with subwatersheds where development already exists.

In the next phases of planning analysis and development scenario testing, it will be important to assess potential impacts to key environmental features throughout the watershed. Spatial analysis overlaying development scenarios with key environmental features such as soils, slopes, wetlands, hydrology, and forest cover (supplemented by water quality and hydrologic modeling) will inform the Clarksburg Master Plan Limited Amendment process.

Table 5.1. Summary of Key Subwatershed Attributes

Subwatershed	Within SPA	Area (square miles)	Percent of Study Area	Contribution to Study Area's:					2012 Benthic IBI Rating
				Imperviousness	Forest Cover	Forest Interior	Wetlands	Erodible Soils	
LSTM110	Yes	0.3	7%	3%	7%	8%	2%	6%	Good
LSTM111	Yes	0.2	3%	1%	1%	0%	1%	3%	Good
LSTM206	Yes	0.6	12%	49%	11%	3%	15%	6%	Good
LSTM112	Partial	0.4	7%	5%	8%	6%	0%	13%	Fair
LSTM201	Partial	1.0	20%	19%	19%	25%	9%	11%	Good
LSTM202	Yes	0.4	8%	4%	12%	26%	6%	13%	Good
LSTM302	Partial	0.1	3%	0%	5%	9%	30%	4%	Good
LSTM303B	Partial	0.2	4%	0%	7%	10%	19%	5%	Good
LSTM203	No	0.8	16%	8%	14%	2%	11%	18%	Fair
LSTM204	No	0.8	18%	11%	13%	4%	3%	15%	Excellent
LSTM304	Partial	0.1	2%	0%	3%	7%	5%	5%	Good
TOTAL		**4.8**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	

REFERENCES

Athanas, C., Ph.D. & Associates, Inc., & Dewberry & Davis. (1997). Wetlands Study in Clarksburg, Maryland, Final Report, July. Maryland-National Capital Park and Planning Commission.

Audubon Naturalist Society. (2012). Audubon Naturalist Society monitoring at Ten Mile Creek. Notes accompanying field trip on December 13, 2012. Montgomery County, Maryland.

Boward, D.M., Kayzak, P.F., Stranko, S.A., Hurd, M.K., & Prochaska, T.P. (1999). From the mountains to the sea: the state of Maryland's freshwater streams (EPA 903-R-99-023). Maryland Department of Natural Resources, Monitoring and Nontidal Assessment Division, Annapolis, Maryland.

Cowardin, L.M., Carter, V., Golet, F.C., & LaRoe, E.T. (1979). Classification of Wetlands and Deepwater Habitats of the United States. United States Fish and Wildlife Service.

EIFAC Working Party on Water Quality Criteria for European Freshwater Fish. (1968). Water quality criteria for European freshwater fish. Report on extreme pH values and inland fisheries. European Inland Fisheries Advisory Commission. EIFAC tech. Pap., (4): 24p., 1968.

Gibson, G. (Ed.). (1991). Proceedings of a Symposium: Biological criteria: Research and regulation (EPA-440/5-91-005). Washington, D.C.: Office of Water, U.S. Environmental Protection Agency.

Greenhorne & O'Mara, Inc. (1992). Clarksburg Environmental & Water Resources Study. Prepared for Maryland-National Capital Park & Planning Commission, June 30th.

Hughes, R.M., Larsen, D.P. Larsen, & Omernik, J.M. (1986). Regional reference sites: A method for assessing stream potentials. Environmental Management 10, 629-635.

Jones, C., McCann J., & McConville, S. (2000). A guide to the conservation of forest interior dwelling birds in the Chesapeake Bay critical area. Critical Area Commission for the Chesapeake and Atlantic Coastal Bays. Annapolis, Maryland. Retrieved at http://www.dnr.state.md.us/irc/docs/00009691.pdf

Karr, J .R. (1981). Assessment of biotic integrity using fish communities. Fisheries 6(6), 21-27.

Kayzak, P. (2001). Maryland Biological Stream Survey sampling manual. Maryland Department of Natural Resources, Monitoring and Non-Tidal Assessment Division, Annapolis, MD.

Maryland Department of the Environment & Center for Watershed Protection. (2009). 2000 Maryland Stormwater Design Manual, Volumes I & II, Revised. Maryland Department of the Environment. Baltimore, MD.

Maryland Geological Survey. (1968). Geologic Map of Maryland. [Base map from Army Map Service sheets, 1:250,000.] Retrieved from http://www.mgs.md.gov/esic/geo/mon.html

Maryland Historical Trust. (1979). Inventory form for state historic sites survey. Retrieved from http://msa.maryland.gov/megafile/msa/stagsere/se1/se5/016000/016500/016558/pdf/msa_se5_16558.pdf.

Montgomery County Department of Environmental Protection (DEP). (2012). Special protection area program annual report 2010. Montgomery County Department of Environmental Protection, Department of Permitting Services, and Maryland-National Capital Park and Planning Commission.

Montgomery County Department of Environmental Protection (DEP). (2009). Special Protection Area Program Annual Report 2007. Montgomery County Department of Environmental Protection, Department of Permitting Services, and Maryland-National Capital Park and Planning Commission.

Montgomery County Department of Environmental Protection (DEP). (2003). Special Protection Area Program Annual Report 2002. Montgomery County Department of Environmental Protection, Department of Permitting Services, and Maryland-National Capital Park and Planning Commission.

Montgomery County Department of Park and Planning. (2000). Guidelines for environmental management of development in Montgomery County. Maryland-National Capital Park and Planning Commission. Silver Spring, MD.

Montgomery County Department of Park and Planning. (1994). Approved and Adopted Clarksburg Master Plan and Hyattstown Special Study Area. Maryland-National Capital Park and Planning Commission.

Montgomery County Planning Department. (2009). Attachment 1: Analysis of Current Conditions and Projected Development in Clarksburg Stage 4. Maryland - National Capital Park and Planning Commission. Silver Spring, Maryland. Retrieved at http://www.montgomeryplanningboard.org/agenda/2009/documents/20090709_attachment1-analysis_clarksburg_stage4.pdf

Montgomery County Planning Department. (2004). Rustic Roads Map. Maryland-National Capital Park and Planning Commission. Retrieved at http://www.montgomeryplanning.org/community/plan_areas/rural_area/rustic_roads.shtm

Montgomery County Planning Department & Montgomery County Department of Environmental Protection. (2013). *Ten Mile Creek GIS Data* [GIS Shapefiles].

National Climatic Data Center. (2010). [PDF document providing Summary of Monthly Normals 1981-2010]. National Oceanic and Atmospheric Administration Climate Data Online: Interactive Map Application. Retrieved at http://gis.ncdc.noaa.gov/map/viewer/#app=cdo

National Weather and Climate Center. (2002). Climate Information. United State Department of Agriculture. Natural Resources Conservation Service. Retrieved from http://www.wcc.nrcs.usda.gov/ftpref/support/climate/wetlands/md/24031.txt

Natural Resources Conservation Service. (2009). National engineering handbook, part 630 hydrology, chapter 7 hydrologic soil groups (210-VI-NEH). United States Department of Agriculture. Washington, DC.

Paul, M.J., Stribling, J.B., Klauda, R.J., Kayzak, P.F., Southerland, M.T., & Roth, N.E. (2003). A physical habitat index for freshwater wadeable streams in Maryland, final report (CBWP-MANTA-EA-03-4). Maryland Department of Natural Resources. Monitoring and Non-Tidal Assessment Division.

Petranka, J. A. (1998). Salamanders of the United States and Canada. Smithsonian Institution Press, Washington and London. 592 pages.
Reger, J.P. & Cleaves, E.T. (2008). Maryland Physiographic Map of Maryland. 1:100,000 scale. Maryland Geologic Survey. Retrieved from http://www.mgs.md.gov/coastal/maps/physio.html

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. (2013). [Soils map of Montgomery County, Maryland] Web Soil Survey - Montgomery County, Maryland. Retrieved from http://websoilsurvey.nrcs.usda.gov/.

Southerland, M.T., Jung, R.E., Baxter, D.P., Chellman, I.C., Mercurio, G., & Vølstad, J.H. (2004). Streamside salamanders as indicators of stream quality in Maryland. Applied Herpetology, 2, 23-46.

Southerland, M., & Rogers, G. (2010). Technical memorandum: validation of stream salamander IBI for Maryland: Analysis of 2007-2009 MBSS and Montgomery County data. Versar, Inc.

Southerland, M., Rogers G., Kline, M., Morgan, R., Boward, D., Kayzak, P., Klauda, R., & Stranko, S. (2005). Development of new fish and benthic macroinvertebrate indices of biotic integrity for Maryland streams. Maryland Department of Natural Resources. Annapolis, MD.

Stanko, S., Smith, S., Erb, L., Limpert, D. (2010). A key to the amphibians and reptiles of Maryland (12-10132011-532). Maryland Department of Natural Resources. Annapolis, MD.

United States Geological Survey. (2013). National Water Information System, data from USGS gage 01644390 Ten Mile Creek Near Boyds, MD. Retrieved from http://waterdata.usgs.gov/nwis/nwisman/?site_no=01644390&agency_cd=USGS

United States Environmental Protection Agency. (1976). Quality criteria for water. United States Environmental Protection Agency. Washington, D.C.

APPENDIX A. BIBLIOGRAPHY FOR THE TEN MILE CREEK WATERSHED ENVIRONMENTAL ANALYSIS FOR THE CLARKSBURG MASTER PLAN LIMITED AMENDMENT

TEN MILE CREEK WATERSHED ENVIRONMENTAL ANALYSIS FOR THE CLARKSBURG MASTER PLAN LIMITED AMENDMENT BIBLIOGRAPHY Updated March 29, 2013	
Category	**Bibliography**
ESD/ESC Review	Alberti, M., D. Booth, K. Hill, B. Coburn, and C. Avollo. The Impact of Urban Patterns of Aquatic Ecosystems: An Empirical Analysis in Puget Lowland Sub-Basins. Landscape Urban Planning, 80(4), 345-361
ESD/ESC Review	Alexander, R., E. Boyer, R. Smith, G. Schwarz and R. Moore, 2007. The role of headwater streams in downstream water quality. Journal of American Water Resources Association. 43(1): 41-59.
Clarksburg Planning Area	Athanas, C., Associates, Inc., & Dewberry & Davis. (1997). Wetlands study in Clarksburg, Maryland final report. Maryland-National Capital Park and Planning Commission.
Ten Mile Creek	Audubon Naturalist Society. (2012). Audubon Naturalist Society monitoring at Ten Mile Creek. Notes accompanying field trip on December 13, 2012. Montgomery County, Maryland.
Ten Mile Creek	Audubon Naturalist Society. (2013). ANS Site 32 monitoring comments tributary on Ten Mile Creek on the Mease Farm adjacent to West Old Baltimore Road. Received on January 3, 2013.
Ten Mile Creek	Audubon Naturalist Society. (2013). BIBI calculator from Dan Boward of DNR [Excel file]. Received on January 3, 2013.
Ten Mile Creek	Audubon Naturalist Society. (2013). BIBI Scores for both ANS Ten Mile Creek Sites, 1997-2012, all seasons [Excel file]. Received on January 3, 2013.
Ten Mile Creek	Audubon Naturalist Society. (2013). Characteristics of samples collected at both ANS Ten Mile Creek Sites [Excel file]. Received on January 3, 2013.
Ten Mile Creek	Audubon Naturalist Society. (2013). Dominant family by season, ANS station on mainstem of Ten Mile Creek, 2009-2012 [Excel file]. Received on January 3, 2013.
Ten Mile Creek	Audubon Naturalist Society. (2013). Dominant family by season, ANS station on tributary of Ten Mile Creek, 1997-2012 [Excel file]. Received on January 3, 2013.
Ten Mile Creek	Audubon Naturalist Society. (2013). Mainstem of Ten Mile Creen on the Mease Farm upstream of the ford on West Old Baltimore Road. Received on January 3, 2013.
Ten Mile Creek	Audubon Naturalist Society. (2013). Organisms collected at ANS station on mainstem on Ten Mile Creek, 2009-2012 [Excel file]. Received on January 3, 2013.
Ten Mile Creek	Audubon Naturalist Society. (2013). Organisms collected at ANS station on tributary on Ten Mile Creek, 1997-2012 [Excel file]. Received on January 3, 2013.
ESD/ESC Review	Belucci, C., 2007. Stormwater and Aquatic Life: Making the Connection Between Impervious Cover and Aquatic Life Impairments for TMDL Development in Connecticut Streams. Proceedings, TMDL 2007, 1003-1018
ESD/ESC Review	Benik, S.R., B.N. Wilson, D.D. Biesboer, B. Hanse, and D. Stenlund, 1998. The efficacy of erosion control products at a MN/DOT construction site. Paper No. 982156. American Society of Agricultural Engineers, St. Joseph, MI
ESD/ESC Review	Benik, S.R., B.N. Wilson, D.D. Biesboer, B. Hansen, and D. Stenlund, 2003. Evaluation of erosion control products using natural rainfall events. Journal of Soil and Water Conservation. 58.2 (March-April 2003): p98.

TEN MILE CREEK WATERSHED ENVIRONMENTAL ANALYSIS FOR THE CLARKSBURG MASTER PLAN LIMITED AMENDMENT BIBLIOGRAPHY Updated March 29, 2013	
Category	**Bibliography**
ESD/ESC Review	Bhardwaj, A.K., and R.A. McLaughlin, 2008. Energy dissipation and chemical treatment to improve stilling basin performance. Transactions of the ASABE. Vol. 51(5): 1645-1652 2008
Ten Mile & Little Seneca	Biohabitats Inc. Little Seneca watershed monitoring station cross section data Availability Summary [Excel file]. Created on January 3, 2013.
Ten Mile Creek	Biohabitats Inc. Ten Mile Creek subwatershed cross section data [Excel file]. Collected on December 21, 2012.
ESD/ESC Review	Booth, D. 2000. Forest cover, impervious surface area, and the mitigation of urbanization impacts in King County, WA. prepared for King County Water and Land Resource Division. University of Washington. Seattle, WA.
ESD/ESC Review	Booth, D., and C. Jackson. 1997. Urbanization of Aquatic Systems – Degradation Thresholds, Stormwater Detention, and the Limits of Mitigation. Journal of the American Water Resources Association. 22(5): 1077-1090
Watershed Science	Booth, D., and D. Hartley and R. Jackson. Forest Cover, Impervious-Surface Area, and the Mitigation of Stormwater Impacts. Journal of the American Water Resources Association. 38(3):836-845
ESD Effectiveness	Bradford A., A. Fata , B. Gharabaghi , J.Y. Li , G. MacMillan and R.P. Rudra, 2006. Evaluation of sediment control pond performance at construction sites in the Greater Toronto Area. Canadian Journal of Civil Engineering;Nov2006, Vol. 33 Issue 11, p1335
ESD/ESC Review	Brander, K., K. Owen and K. Potter, 2004. Modeled Impacts of Development Type on Runoff Volume and Infiltration Performance. Journal of the American Water Resources Association (2004): 961-969
ESD Effectiveness	Brander, K.E., Owen, K.E., & Potter, K.W. (2004). Modeled impacts of development type on runoff volume and infiltration performance. *Journal of the American Water Resources Association* (JAWRA) 40(4):961-969.
ESD/ESC Review	Britton, S.L., K.M. Robinson, and B.J. Barfield, 2001. Modeling the effectiveness of silt fence. Proceedings of the Seventh Federal Interagency Sedimentation Conference, March 25 to 29, 2001, Reno, Nevada
ESD/ESC Review	Burns, M., T. Fletcher, C. Walsh, A. Ladson and B. Hatt, 2012. Hydrologic shortcomings of conventional urban stormwater management and opportunities for reform. Landscape and Urban Planning 105 (2012) 230–240
Ten Mile Creek	C. Wiss with Audubon Naturalist Society (2013). Personal communication. Email: Additional documents RE: ANS Monitoring at Ten Mile Creek. Received on January 3, 2013.
ESD/ESC Review	Cameron, Diane, 2010. Protecting Ten Mile Creek Based on Watershed Science and Local Experience. Febrauary, 2010
ESD/ESC Review	Cameron, Diane, 2011. Implementing the Stormwater Management Act of 2007: Defining Pre-Development Forest Hydrology in the Maryland Piedmont and Beyond, (August 2011).
Watershed Science	Cappiella, K., Stack, W.P., Fraley-McNeal, L., Lane, C., & McMahon, G. (2012). Strategies for managing the effects of urban development on streams: U.S. Geological Survey Circular 1378, 69 p., available at http://pubs.usgs.gov/circ/1378/.

TEN MILE CREEK WATERSHED ENVIRONMENTAL ANALYSIS FOR THE CLARKSBURG MASTER PLAN LIMITED AMENDMENT BIBLIOGRAPHY Updated March 29, 2013	
Category	**Bibliography**
ESD/ESC Review	Cappiella, Karen, Stack, W.P., Fraley-McNeal, Lisa, Lane, Cecilia, and McMahon, Gerard, 2012, Strategies formanaging the effects of urban development on streams: U.S. Geological Survey Circular 1378, 69 p.
ESD/ESC Review	Carino, H.F., L.B. Faucette , J. Governo , R. Governo , C. F. Jordan and B.G. Lockaby, 2007. Evaluation of erosion control methods for storm water quality. Journal of Soil and Water Conservation Vol. 62. No. 6. November/December 2007
ESD/ESC Review	Center for Watershed Protection, 2003. Impacts of Impervious Cover on Aquatic Systems. Ellicott City, MD.
Montgomery County	Chesapeake Stormwater Network and Biohabitats, Inc. (2009). Montgomery task order #7 Subtask 1: Defining ESD to the MEP. Montgomery County Department of Environmental Protection.
Montgomery County	Chesapeake Stormwater Network and Biohabitats, Inc. (2011). Montgomery task order #7: Implementation plan guidance document. Montgomery County Department of Environmental Protection.
ESD/ESC Review	Cianfrani, C., W. Hession, and D. Rizzo, 2006. Watershed Imperviousness Impacts on Stream Channel Condition in S.E. Pennsylvania. Journal of the American Water Resources Association (JAWRA), 42(4): 941-956
ESD/ESC Review	Clausen, J., 2007. Jordan Cove Watershed Project Final Report, Department of Natural Resources Management and Engineering. University of Connecticut. Storrs, CT
ESD/ESC Review	Coleman, D., C. MacRae and E. Stein., 2005. Effects of Increases in Peak Flows and Imperviousness on the Morphology of Southern California Streams. Southern California Coastal Research Project, Costa Mesa, CA
ESD/ESC Review	Coles, J., T. Cuffney, G. McMahon, and K. Beaulieu, 2004. The Effects of Urbanization on the Biological, Physical and Chemical Characteristics of Coastal New England Streams.
ESD Effectiveness	Conservation Research Institute, 2005. Changing Cost Perceptions: An Analysis of Conservation Development. Prepared for: Illinois Conservation Foundation. Chicago, Ill.
Clarksburg Master Plan	County Council. (2012). Memorandum: Semi-annual report of the planning board - Clarksburg master plan. Addendum, Agenda item #8, October 9, 2012.
Biological Condition Gradient	Davies, S.P. & Jackson, S.K. (2006). The biological condition gradient: A descriptive model for interpreting change in aquatic ecosystems. Ecological Applications, 16(4), 2006, pp/ 1251-1266.
ESD Effectiveness	Davis, A., 2008. Field Performance of Bioretention: Hydrology Impacts. Journal of Hydrologic Engineering (June, 2008): 90-95
ESD/ESC Review	Debusk, K., W. Hunt and D. Line, 2011. Bioretention Outflow: Does It Mimic Nonurban Watershed Shallow Interflow? J. Hydrol. Eng.(16):274-279.
ESD Effectiveness	DeBusk, K.M., Hunt, W.F., and Line, D. E. (2011). Bioretention outflow: Does it mimic nonurban watershed shallow interflow? *Journal of Hydrologic Engineering* , ASCE, 16(3), 274–279. DOI: 10.1061/(ASCE)HE.1943-5584.0000315
Ten Mile Creek	Department of Environmental Protection. (2009). Environmentally sensitive features with buffers in Ten Mile Creek working draft. Montgomery County, Maryland.

TEN MILE CREEK WATERSHED ENVIRONMENTAL ANALYSIS FOR THE CLARKSBURG MASTER PLAN LIMITED AMENDMENT BIBLIOGRAPHY Updated March 29, 2013	
Category	**Bibliography**
ESD/ESC Review	Dietz, M. and J. Clausen, 2008. Stormwater runoff and export changes with development in a traditional and low impact subdivision. Journal of Environmental Management, 87:560–566
Clarksburg Planning Area	Dolan, M. (2013). MNCPPC Data for Clarksburg environmental studies: Data delivered by Jay Mukherjee. Maryland-National Capital Park & Planning Commission.
ESD/ESC Review	Eco Northwest, 2007. The Economics of Low-Impact Development:A Literature Review. Eugene, OR
ESD/ESC Review	Faucette, L.B., L.M. Risse, M.A. Nearing, J.W. Gaskin, and L.T. West. , 2004. Runoff, erosion, and nutrient losses from compost and mulch blankets under simulated rainfall. Journal of Soil and Water Conservation July/August 2004 vol. 59 no. 4 154-160
ESD/ESC Review	Faucette, L.B., R.A. Rowland , A.M. Sadeghi and K.A. Sefton, 2008. Sediment and phosphorus removal from simulated storm runoff with compost filter socks and silt fence. Journal of Soil and Water Conservation July/August 2008 vol. 63 no. 4 257-264
Biomonitoring	Fellows, C.S., Clapcott, J.E., Udy, J.W., Bunn, S.E., Harch, B.D., Smith, M.J., & Davies, P.M. (2006). Benthic metabolism as an indicator of stream ecosystem health. *Hydrobiologia* 572: 71– 87. doi:10.1007/s10750-005-9001-6
ESD/ESC Review	Felton, G. (circa 2007) Research Review of Nitrogen Losses from Turfgrass. Powerpoint Presentation by Gary Felton, Associate Professor, University of Maryland Agricultural Extension.
ESD/ESC Review	Fennessey,L. (undated) Hydrologic Budgets for Development Scale Areas in Pennsylvania.
Ten Mile Creek	Fick, G. (1994). Use attainability for Ten Mile Creek in Clarksburg, Maryland. First draft. Maryland-Nation Capital Park and Planning Commission, Environmental Planning Division. Silver Spring, MD.
ESD/ESC Review	Fifield, J, 2001. Designing Effective Sediment and Erosion Control for Construction Sites. Designing for Effective Sediment and Erosion Control on Construction Sites, Santa Barbara, CA: Forester Press. 2001
ESD/ESC Review	Freeman, M., C. Pringle, and R. Jackson. 2007. Hydrologic connectivity and the contribution of stream headwaters to ecological integrity at regional scales. Journal of the American Water Resources Association. 43(1): 5-14.
ESD/ESC Review	Gage, M. S., A. Spivar, and C.J. Paradise. 2004. Effects of Land Use and Disturbance on Benthic Insects in Headwater Streams Draining Small Watersheds North of Charlotte, NC. Southeastern Naturalist. 3(2): 345-358.
ESD/ESC Review	Galli, J. 1990. Thermal impacts associated with urbanization and stormwater best management practices. Metropolitan Washington Council of Governments. Washington, D.C.
ESD/ESC Review	Garrison et al., 2011. Rooftops to Rivers II: Green strategies for controlling stormwater and combined sewer overflows. Washington, DC
Biological Condition Gradient	Gerritsen, J. & Jessup, B. (2007). Identification of the biological condition gradient for freesonte (non-calcareous) streams of pennsylvania. United States Environmental Protection Agency. Pennsylvania Department of Environmental Protection.

TEN MILE CREEK WATERSHED ENVIRONMENTAL ANALYSIS FOR THE CLARKSBURG MASTER PLAN LIMITED AMENDMENT BIBLIOGRAPHY Updated March 29, 2013	
Category	**Bibliography**
Biological Condition Gradient	Gerritsen, J. & Leppo, E. (2005). Biological condition gradient for tiered aquatic life in New Jersey. United States Environmental Protection Agency. New Jersey Department of Environmental Protection.
Biological Condition Gradient	Gerritsen, J., Jessup, B., & Stamp, J. (2010). The New England biological condition gradient (BCG) and a model of benthic condition [PowerPoint file]. 34th Annual Meeting of the New England Association of Environmental Biologists.
Biological Assessments	Gibson, G. (Ed.). (1991). Proceedings of a Symposium: *Biological criteria: Research and regulation (EPA-440/5-91-005).* Washington, D.C.: Office of Water, U.S. Environmental Protection Agency.
ESD/ESC Review	Goetz, Scott J, et al. (2004) Integrated Analysis of Ecosystem Interactions With Land Use Change: The Chesapeake Bay Watershed. Ecosystems and Land Use Change, Geophysical Monograph 153. American Geophysical Union.
ESD/ESC Review	Goetz, Scott J, et al., (undated –estimated 2004-2005) Using IKONOS Imagery to Assess Impervious Surface Area, Riparian Buffers and Stream Health in the Mid-Atlantic Region, powerpoint presentation.
ESD/ESC Review	Goetz, Scott J, IKONOS imagery for resource management: Tree cover, impervious surfaces, and riparian buffer analyses in the mid-Atlantic region, (2003), Remote Sensing of the Environment 88, pp. 195-208. GoetzRemSensEnv.03
ESD/ESC Review	Gomi, T., R. Sidle, and J. Richardson. 2002. Understanding processes and downstream linkages of headwater systems. BioScience 53(10): 905-915.
Clarksburg Planning Area	Greenhorne & O'Mara, Inc. (1992). Clarksburg environmental & water resources Study: technical appendix. Maryland-National Capital Park & Planning Commission. Montgomery County Planning Department.
Clarksburg Planning Area	Greenhorne & O'Mara, Inc. (1992). Clarksburg environmental & water resource study: final report. Maryland-National Capital Park & Planning Commission. Montgomery County Planning Department.
Clarksburg Planning Area	Greenhorne & O'Mara, Inc. (1992). Map of ground water pollution potential, Little Seneca Lake watershed & Clarksburg planning area, Montgomery County, Maryland.
ESD/ESC Review	Gregory, J.H., M.D. Dukes, P.H. Jones, and G.L. Miller, 2006, Effect of urban soil compaction on infiltration rate. Journal of Soil and Water Conservation 61:3, 117-124 (2006)
ESD/ESC Review	Groffman, P. A. Dorset and P. Mayer, 2005. N processing within geomorphic structures in urban streams. Journal North American Benthological Society. 24(3): 613-625
ESD/ESC Review	Hayes, S.A., R.A. McLaughlin and D.L. Osmond, 2005. Polyacrylamide use for erosion and turbidity control on construction sites. Journal of Soil and Water Conservation 60(4):193-199
Clarksburg Planning Area	Hench, J. E., & Schmieler, T. (1991). Clarksburg master plan: Recommendations on natural and cultural resources and public park and recreation needs. Maryland-National Capital Park and Planning Commission. Department of Parks.
ESD/ESC Review	Holman-Dobbs, J., A. Bradley, and K. Potter. 2003. Evaluation of hydrologic benefits of infiltration based urban stormwater management. Journal of the American Water Resources Association 39(l):205-215.

TEN MILE CREEK WATERSHED ENVIRONMENTAL ANALYSIS FOR THE CLARKSBURG MASTER PLAN LIMITED AMENDMENT BIBLIOGRAPHY Updated March 29, 2013	
Category	**Bibliography**
ESD/ESC Review	Horner, R., H. Lim and S. Burges. 2003. Hydrologic monitoring of the Seattle ultra-urban stormwater management project. University of Washington. Department of Civil and Environmental Engineering. Water Resources Series. Technical Report 170.
ESD/ESC Review	Houlahan, J.E., and C.S. Findlay. 2003. The Effects of Adjacent Land Use on Wetland Amphibian Species Richness and Community Composition. Canadian Journal of Fisheries and Aquatic Sciences. 60(9): 1078-1094.
Biological Assessments	Hughes, R.M., Larsen, D.P., & Omernik, J.M. (1986). Regional reference sites: A method for assessing stream potentials. *Environmental Management* 10, 629-635.
ESD/ESC Review	Hunt, W. A. Jarret, J. Smith and L. Sharkey. 2006. Evaluating bioretention hydrology and nutrient removal at three field sites in North Carolina. Journal of Irrigation and Drainage Engineering. 6: 600-612.
ESD/ESC Review	Hunt, W. and W. Lord. 2006. Bioretention performance, design, construction, and maintenance. North Carolina Cooperative Extension Service. Urban Waterways. AG-588-05.
ESD/ESC Review	Hursh, Charles R, 1944.Water Storage Limitations in Forest Soil Profiles, Soil Science Society of America, Proceedings, Vol. 8, (1944)
ESD/ESC Review	Islam, M.M., D. Taphorn, and H. Utrata-Halcomb, 1998. Current performance of sediment basins & sediment yield measurement of construction sites in unincorporated Hamilton County, Ohio. Hamilton County Soil and Water Conservation District, 1998
ESD/ESC Review	Jarrett, A, 1996. Sediment basin evaluation and design improvements. Final completion report. Hillsborough, N.C.: Orange County Board of Commissioners
ESD/ESC Review	Jarrett, A. , 1999. Designing sedimentation basins for better sediment capture. Orange County Board of Commissioners
ESD/ESC Review	Jones, M.P. and W.F. Hunt. 2009. Bioretention Impact on Runoff Temperature in Trout Sensitive Waters.Journal of Environmental Engineering, 135(8): 577-585.
ESD/ESC Review	Jones, M.P. and W.F. Hunt. 2010. Effect of Stormwater Wetlands and Wet Ponds on Runoff Temperature in Trout Sensitive Waters. Journal of Irrigation and Drainage Engineering. 136(9): 656-661.
ESD/ESC Review	Jones, M.P., W.F. Hunt, and R.J. Winston. 2012. Effect of Urban Catchment Composition on Runoff Temperature. Journal of Environmental Engineering. 138(12): 1231-1236.
ESD/ESC Review	Jones, R., A. Norton and D. Morgan. 1996. Bioassessment of BMP effectiveness in mitigating stormwater impacts on aquatic biota. in Effects of Watershed Development and Management on Aquatic Ecosystems. Proceedings ASCE ERF Conference. Snowbird, UT.
ESD/ESC Review	Kalainesan, S., R.D. Neufeld, R. Quimpo, and P. Yodnane, 2008. Integrated methodology of design for construction site sedimentation basins. Journal of Environmental Engineering, Vol. 134, No. 8, August 2008, pp. 619-627
Biological Assessments	Karr, J .R. (1981). Assessment of biotic integrity using fish communities. *Fisheries* 6(6), 21-27.
ESD/ESC Review	Kays, E.L. (undated) Relationship of Forest Destruction and Soil Disturbance to Increased Flooding in the Suburban North Carolina Piedmont.

TEN MILE CREEK WATERSHED ENVIRONMENTAL ANALYSIS FOR THE CLARKSBURG MASTER PLAN LIMITED AMENDMENT BIBLIOGRAPHY Updated March 29, 2013	
Category	**Bibliography**
Biological Assessments	Kayzak, P. (2001). Maryland biological stream survey sampling manual. Maryland Department of Natural Resources, Monitoring and Non-Tidal Assessment Division, Annapolis, MD.
ESD/ESC Review	Kennen, J., K. Murray and K. Beaulieu. Determining hydrologic factors that influence stream macroinvertebrate assemblages in the northeastern US. Ecohydrol. 3, 88–106 (2010)
ESD/ESC Review	King County Science and Stormwater Services Sections., 2012. Stormwater Retrofit Analysis and Recommendations for Juanita Creek Basin in the Lake Washington Watershed Ecology.
ESD/ESC Review	King, R. M. Baker, D. Whigham, D. Weller and K. Hurd. 2005. Spatial considerations for linking watershed land cover to ecological indicators in streams. Ecological Applications. 15: 137-153.
Biomonitoring	King, R.S., Baker, M.E., Kazyak, P.F., & Weller, D.E. (2011). How novel is too novel? Stream community thresholds at exceptionally low levels of catchment urbanization. *Ecological Applications* , 21(5), 1659-1678.
ESD/ESC Review	King, Ryan S, How Novel is too Novel? Stream Community Thresholds at Exceptionally Low Levels of Catchment Urbanization, Ecol Appl 21.1659-1678 (1)
ESD/ESC Review	Kloss, 2006. Rooftops to Rivers: Green Strategies for Controlling Stormwater and CSOs. Washington, DC
ESD/ESC Review	Legg, A. R. Bannerman and J. Panuska. 1996. Variation in the relation of runoff from residential lawns in Madison, Wisconsin. USGS Water Resources Investigations Report 96-4194.
ESD/ESC Review	Lichter J. and P. Lindsey. 1994. Soil compaction and site construction: assessment and case studies. The Landscape Below Ground. International Society of Arborculture
ESD/ESC Review	Line, D.E., 2007. Monitoring the effects of highway construction in the Sedgefield Lakes Watershed. North Carolina Department of Transportation Report Number FHWA/NC/2006-07
ESD/ESC Review	Line, D.E., and N.M. White, 2001. Efficiencies of temporary sediment traps on two North Carolina construction sites. Transactions of the ASABE. Vol. 44(5): 1207-1215 . @2001
ESD/ESC Review	Line, D.E., and N.M. White, 2007. Effects of development on runoff and pollutant export. Water Environment Research, Volume 79, Number 2, February 2007 , pp. 185-190(6)
ESD/ESC Review	Loperfido, J.V., and Hogan, D.M., 2012, Effects of Urban Stormwater-Management Strategies on Stream-Water Quantity and Quality: U.S. Geological Survey Fact Sheet 2012–3079, 2 p., available at http://pubs.usgs.gov/fs/2012/3079.
ESD/ESC Review	Lowrance, Richard, Water Quality Functions of Riparian Forest Buffers in Chesapeake Bay Watersheds, Lowrance et al WQ Functions of Riparian Forest Buffers in Chesapeake Bay Watersheds
ESD/ESC Review	Maryland Department of Natural Resources (2012), River/Stream Management Strategy, Guiding Principles. http://www.dnr.state.md.us/streams/pdfs/RiverStream_MgtStrat_GuidingPrinciples_092612.pdf
ESD/ESC Review	Maryland Department of Natural Resources (undated) Impacts of Impervious Cover on Maryland Streams. Stream Health Fact Sheet. http://www.dnr.state.md.us/streams/pdfs/ImperviousFactSheet.pdf

TEN MILE CREEK WATERSHED ENVIRONMENTAL ANALYSIS FOR THE CLARKSBURG MASTER PLAN LIMITED AMENDMENT BIBLIOGRAPHY Updated March 29, 2013	
Category	**Bibliography**
Maryland	Maryland Department of the Environment & Center for Watershed Protection. (2009). 2000 Maryland Stormwater Design Manual, Volumes I & II, Revised. Maryland Department of the Environment. Baltimore, MD.
Little Seneca Lake	Maryland Department of the Environment. (2006). Water quality analysis of eutrophication for Little Seneca lake, Montgomery County, MD. Water Protection Division, U.S. Environmental Protection Agency, Region III. Philadelphia, PA.
Environmental Site Design	Maryland Department of the Environment. (2012). Environmental site design and innovative technology. Maryland Deparment of the Environment. Water Management Administration.
Ten Mile Creek	Maryland Historical Trust. (1979). Inventory form for state historic sites survey. Retrieved from http://msa.maryland.gov/megafile/msa/stagsere/se1/se5/016000/016500/016558/pdf/msa_se5_16558.pdf
ESD/ESC Review	Maxted, J.R., McCready, C.H., and Scarsbrook, M.R. 2005. Effects of small ponds on stream water quality and macroinvertebrate communities. New Zealand Journal of Marine and Freshwater Research 39:1069-1084.
ESD/ESC Review	McCaleb, M. M. and R. A. McLaughlin, 2008. Sediment trapping by five different sediment detention devices on construction sites. Transactions of the ASABE. 51(5): 1613-1621. @2008
ESD/ESC Review	Mclaughlin R. A., S.E. King and G.D. Jennings, 2009. Improving construction site runoff quality with fiber check dams and polyacrylamide. Journal of Soil and Water Conservation March/April 2009 vol. 64 no. 2 144-154
ESD/ESC Review	McLaughlin, R.A, 2009. Water quality improvements using modified sediment control systems on construction sites. Transactions of the ASABE 2009, vol. 52, No. 6, pp.1859-1867
ESD/ESC Review	Meyer, J. L., et al., (2003) Where rivers are born: The scientific imperative for defending small streams and wetlands. Washington, DC: Sierra Club and American Rivers.
ESD/ESC Review	Meyer, J., D. Strayer, J. Wallace, S. Eggert, G. Helfman and N. Leonard. 2007. The contribution of headwater streams to biodiversity in river networks.Journal of American Water Resources Association 43(1): 86-103
ESD/ESC Review	Miltner, R, D. White, and C. Yoder. 2004. The Biotic Integrity of Streams in Urban and Suburbanized Landscapes. Landscape and Urban Planning. 69.
Modeling	Mohamoud, Y.M. (2006). *An integrative watershed modeling framework (IWMF) for ecosystem sustainability assessment* [PowerPoint slides]. Science Forum, Washington D.C.
Modeling	Mohamoud, Y.M. (2006). *Modeling urban development impacts with HSPF model* [PowerPoint slides]. United States Environmental Protection Agency. National Exposure Research Laboratory.
ESD/ESC Review	Montgomery County Department of Environmental Protection (MCDEP). 2003. Countywide Stream Protection Strategy, 2003 Update.

TEN MILE CREEK WATERSHED ENVIRONMENTAL ANALYSIS FOR THE CLARKSBURG MASTER PLAN LIMITED AMENDMENT BIBLIOGRAPHY Updated March 29, 2013	
Category	**Bibliography**
Montgomery County	Montgomery County Department of Environmental Protection. (2012). Habitat Monitoring. Montgomery County Government. Retrieved from http://www6.montgomerycountymd.gov/dectmpl.asp?url=/content/dep/water/monHabitat.asp
Clarksburg Planning Area	Montgomery County Department of Environmental Protection. (2013). All Little Bennett rain data [Excel files]. Received on January 7, 2013.
Ten Mile & Little Seneca	Montgomery County Department of Environmental Protection. (2013). Benthics [Excel file]. Received on January 8, 2013.
Clarksburg Planning Area	Montgomery County Department of Environmental Protection. (2013). Black Hills - all rain data [Excel files]. Received on January 7, 2013.
Ten Mile & Little Seneca	Montgomery County Department of Environmental Protection. (2013). Fish [Excel file]. Received on January 8, 2013.
Ten Mile & Little Seneca	Montgomery County Department of Environmental Protection. (2013). PhysChem [Excel file]. Received on January 10, 2013.
Ten Mile & Little Seneca	Montgomery County Department of Environmental Protection. (2013). PhysChem [Excel file]. Received on January 10, 2013.
Ten Mile Creek, Little Seneca, & Cabin Branch	Montgomery County Department of Environmental Protection. (2013). Spring & summer habitat assessment [Excel files]. Received on January 11, 2013.
Ten Mile Creek	Montgomery County Department of Environmental Protection. (2013). Ten Mile Creek - Synoptic flow study [Excel, JPEG, & ESRI ArcMap files]. Received on January 10, 2013.
Ten Mile & Little Seneca	Montgomery County Department of Environmental Protection. (2013). Ten Mile Creek - water temperature data [Excel, JPEG, & ESRI ArcMap files]. Received on January 10, 2013.
Ten Mile Creek	Montgomery County Department of Environmental Protection. (2013). Ten Mile Creek cross section data - 2013 [Excel files]. Received on January 11, 2013.
Ten Mile & Little Seneca	Montgomery County Department of Environmental Protection. (2013). TenMile_WQ_DataRequest-Jenny [Excel & PDF files]. Received on January 10, 2013.
Ten Mile & Little Seneca	Montgomery County Department of Environmental Protection. (2013). TenMileHerpData [Word, Excel, & Access Database files]. Received on January 10, 2013.
Little Seneca	Montgomery County Department of Environmental Protection. Little Seneca monitoring atation LSLS104 cross section data [Excel file]. Received on January 3, 2013.
Little Seneca	Montgomery County Department of Environmental Protection. Little Seneca subwatershed monitoring station LSLS109 cross section data [Excel file]. Received on January 3, 2013.
Ten Mile Creek	Montgomery County Department of Environmental Protection. Ten Mile Creek subwatershed monitoring station cross section data [Excel file]. Received on January 3, 2013.
Clarksburg Study Area	Montgomery County Department of Park and Planning. (1994). Approved and adopted Clarksburg master plan and Hyattstown special study area. Maryland-National Capital Park and Planning Commission.
Montgomery County	Montgomery County Department of Park and Planning. (2000). Guidelines for environmental management of development in Montgomery County. Maryland-National Capital Park and Planning Commission. Silver Spring, MD.

TEN MILE CREEK WATERSHED ENVIRONMENTAL ANALYSIS FOR THE CLARKSBURG MASTER PLAN LIMITED AMENDMENT BIBLIOGRAPHY Updated March 29, 2013	
Category	**Bibliography**
Little Seneca Reservoir	Montgomery County Planning Department. (2013). Little Seneca Reservoir water quality monitoring results 2010-2012 [PDF files]. Received on January 31, 2013.
ESD/ESC Review	Moore, A. and M. Palmer. 2005. Invertebrate diversity in agricultural and urban headwater streams. Ecological Applications. 15: 1169-1177.
ESD/ESC Review	Moore, T., S. Hutchinson, and R. Christianson. 2011. A qualitative assessment tool for ecologically based stormwater systems. Ecological Engineering. 10 pp. In Press
ESD/ESC Review	Morgan, R.P., and S.F. Cushman. 2005. Urbanization Effects on Stream Fish Assemblages in Maryland, USA. J. N. Am. Benthol. Soc. 24(3): 643-655.
ESD/ESC Review	National Research Council, 2009. Urban Stormwater Management in the United States. 611 pp.
Hydrologic Soil Groups	Natural Resources Conservation Service. (2009). National engineering handbook, part 630 hydrology, chapter 7 hydrologic soil groups (210-VI-NEH). United States Department of Agriculture. Washington, DC.
ESD/ESC Review	O'Driscoll et al. (2010). Urbanization Effects on Watershed Hydrology and In-Stream Processes in the Southern United States. Water 2010, pp 605-648. www.mdpi.com/2073-4441/2/3/605/pdf
ESD/ESC Review	Ourso, R., and A. Frenzel. 2003. Identification of Linear and Threshold Responses in Streams along a Gradient of Urbanization in Anchorage, Alaska. Hydrobiologia. 501: 117-131.
ESD/ESC Review	Page, N. and P. Lilly, 2010. Analysis of Streamflow, Water Quality, and Benthic Community Changes in North Creek (1999–2009). Prepared for: City of Surrey, British Columbia
Watershed Science	Palmer, M.A. (2009). Reforming watershed restoration: Science in need of application and applications in need of science. *Estuaries and Coasts* 32:1–17; DOI 10.1007/s12237-008-9129-5
ESD/ESC Review	Philips, R., C. Clausen, J. Alexpoulus, B. Morton, S. Zaremba and M. Cote. 2003. BMP research in a low-impact development environment: the Jordan Cove Project. Stormwater. 6(1):1- 11.
ESD/ESC Review	Pitt, R. and J. Lantrip. 2000. Infiltration through disturbed urban soils. Applied Modeling of Urban Water Systems (Volume 8) Monograph Series of Modeling: Stormwater Impacts. CHI. Guelph, Canada
ESD/ESC Review	Pitt, R., T. Brown and R. Morchque. 2004. National Stormwater Quality Database. Version 2.0. University of Alabama and Center for Watershed Protection. Final Report to U.S. Environmental Protection Agency.
Biological Condition Gradient	Pond, G. (2004). Biological condition gradient: Hypothetical example scenario. A headwater stream catchment in the Appalachian coal field region, Commonwealth of Kentucky. Kentucky Department of Environmental Protection. Division of Water.
Eastern Ten Mile Creek Watershed	Potomac Investment Associates & Roger & Associates, Inc. (1992). Bennett, King, & Shiloh properties land use sewer service & environmental protection proposals for a portion of the eastern Ten Mile Creek watershed. Benet, King, Shiloh Properties.
ESD/ESC Review	Public Service Commission of Wisconsin (2011) Environmental Impacts of Transmission Lines. See pp. 21-26. http://psc.wi.gov/thelibrary/publications/electric/electric10.pdf

TEN MILE CREEK WATERSHED ENVIRONMENTAL ANALYSIS FOR THE CLARKSBURG MASTER PLAN LIMITED AMENDMENT BIBLIOGRAPHY Updated March 29, 2013	
Category	**Bibliography**
MD Geology	Reger, J. & Cleaves, E.T. (2008). Explanatory text for the Maryland physiographic map of Maryland (version MDPHYS2003.2). Open-File Report 08-03-1. Maryland Geologic Survey. Retrieved from http://www.mgs.md.gov/coastal/maps/physio.html
MD Geology	Reger, J. & Cleaves, E.T. (2008). Maryland physiographic map of Maryland. Maryland Geologic Survey. Retrieved from http://www.mgs.md.gov/coastal/maps/physio.html
ESD/ESC Review	Reice, S. 2000. Regulating Sedimentation and Erosion Control into Streams: What Really Works and Why. In: National Conference for Urban Water Resource Management and Protection. Chicago, IL. Pp. 291-295
Erosion and Sediment Control	Reice, S.R. & Carmin, J. (2000). Regulating sedimentation and erosion control into streams: What really works and why? Presented from *Conference on Tools for Urban Resource Management and Protection.* Chicago, Illinois.
Watershed Science	Rojas, M., Manglik, A., Wiss, C., & Cameron, D. (2013). Additional key reports and papers related to urbanization impacts on streams, and low impact development studies. Audubon Naturalist Society. Received on January 28, 2013.
ESD/ESC Review	Roseen, R. et al.. 2011. Forging the Link: Linking the Economic Benefits of Low Impact Development and Community Decisions.
ESD/ESC Review	Roy, A., B. Freeman and M. Freeman. 2006. Riparian influences on stream fish assemblage structure on urbanizing streams. Landscape Ecology.
ESD/ESC Review	Roy, A., M. Freeman, B. Freeman, S. Wenger, J. Meyer, W. Ensign. 2006. Importance of Riparian Forests in Urban Catchments Contingent on Sediment and Hydrologic Regimes. Environmental Management. 37(4): 523-539
ESD/ESC Review	Rubbo, M.J., and J.M. Kiesecker. 2005. Amphibian Breeding Distribution in an Urbanized Landscape. Conservation Biology. 19: 504-511
ESD/ESC Review	Schueler, T. 2008. Chesapeake Stormwater Network (CSN) Technical Bulletin No. 3, Implications of the Impervious Cover Model: Stream Classification, Urban Subwatershed Management and Permitting (2008)
ESD/ESC Review	Schueler, T. "The Compaction of Urban Soils." The Practice of Watershed Protection. eds. T. Schueler and H. Holland. Center for Watershed Protection. Ellicott City, MD.
ESD/ESC Review	Schueler, T. and C. Lane. 2012. Recommendations of the Expert Panel to Define Removal Rates for New State Stormwater Performance Standards. Chesapeake Stormwater Network, Ellicott City, MD
Stormwater	Schueler, T., & Lane, C. (2012). Recommendations of the expert panel to define removal rates for new state stormwater performance standards. Chesapeake Stormwater Network.
ESD/ESC Review	Schueler, Thomas R, Fraley-McNeal, L. and Cappiella, L. (2009) Is Impervious Cover Still Important? Review of Recent Research, Journal of Hydrologic Engineering, ASCE April 2009, pp. 309-315.
ESD/ESC Review	Schwartz, S., 2010. Effective Curve Number and Hydrologic Design of Pervious Concrete Storm-Water Systems. Journal of Hydrologic Engineering. June, 2010: 465-474

TEN MILE CREEK WATERSHED ENVIRONMENTAL ANALYSIS FOR THE CLARKSBURG MASTER PLAN LIMITED AMENDMENT BIBLIOGRAPHY Updated March 29, 2013	
Category	**Bibliography**
ESD/ESC Review	Schweizer, P.E., and G.R. Matlack. 2003. Annual Variation in Fish Assemblages of Watersheds with Stable and Changing Land Use. The American Midland Naturalist. 153: 203-308.
ESD/ESC Review	Snyder, C.D., J.A. Young, R. Villela, and D.P. Lemarie. 2003. Influences of Upland and Riparian Land Use on Stream Biotic Integrity. Landscape Ecology 18: 647-664.
Biomonitoring	Snyder, M.N., Goetz, S.J., & Wright, R.K. (2005). Stream Health Rankings Predicted by Satellite Derived Land Cover Metrics. *Journal of the American Water Resources Association* (JAWRA) 41(3):659-677.
Montgomery County	Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. (2013). [Soils map of Montgomery County, Maryland] *Web Soil Survey - Montgomery County, Maryland* . Retrieved from http://websoilsurvey.nrcs.usda.gov/.
Biological Assessments	Southerland, M., & Rogers, G. (2010). Technical memorandum: validation of stream salamander IBI for Maryland: Analysis of 2007-2009 MBSS and Montgomery County data. Versar, Inc.
Biological Assessments	Southerland, M.T., Jung, R.E., Baxter, D.P., Chellman, I.C., Mercurio, G., & Vølstad, J.H. (2004). Streamside salamanders as indicators of stream quality in Maryland. *Applied Herpetology,* 2, 23-46.
ESD/ESC Review	Sprague, L., R. Zueling and. J. Dupree. 2006. Effect of urban development on stream ecosystems along the Front Range of the Rocky Mountains, Colorado and Wyoming, USGS Scientific Investigations Report 2006-5101A 139 pp.
ESD/ESC Review	St. John, J. 2011. Montgomery County Streams: Change and Restoration. Powepoint Presentaion available at: http://www.dnr.state.md.us/streams/pdfs/SS2011Presentations/6%20St%20John.pdf
Ten Mile Creek	St. John, J. (2009). Ten Mile environmental sensitive area mapping - notes. Montgomery County Department of Environmental Protection.
Ten Mile Creek	St. John, J. (2012). Ten Mile Creek data. Montgomery County Department of Environmental Protection.
Modeling	Staley, N.A., Wynn, T.M.,& Benham, R.L. Modeling channel erosion at the watershed scale: A comparison of GWLF, SWAT, and CONCEPTS. Virginia Polytechnic Institute and State University.
Modeling	U.S. Environmental Protection Agency. (2010). Chesapeake Bay Phase 5.3 Community Watershed Model. EPA 903S10002 - CBP/TRS-303-10. U.S. Environmental Protection Agency, Chesapeake Bay Program Office, Annapolis MD.
Water Quality	United States Environmental Protection Agency. (1976). Quality criteria for water. United States Environmental Protection Agency. Washington, D.C.
Modeling	United States Environmental Protection Agency. (2010). Causal analysis/diagnosis decision information system (CADDIS). Office of Research and Development, Washington, D.C. Retrieved at http://www.epa.gov.caddis. Last updated September 23, 2010.
Biological Assessments	United States Environmental Protection Agency. (2011). A primer on using biological assessments to support water quality management. EPA 810-R-11-01.

TEN MILE CREEK WATERSHED ENVIRONMENTAL ANALYSIS FOR THE CLARKSBURG MASTER PLAN LIMITED AMENDMENT BIBLIOGRAPHY Updated March 29, 2013	
Category	**Bibliography**
ESD/ESC Review	Urban, M., D. Skelly, D. Burchsted, W. Price and S. Lowry. 2006. Stream communities across a rural-urban landscape gradient. Diversity and Distributions. 12: 337-350
ESD Effectiveness	US EPA and LID Center. (2000). Low impact development (LID): A literature review. EPA-841-B-00-005. Office of Water, Washington, D.C., 41 pp.
ESD/ESC Review	US EPA and LID Center. 2000. Low Impact Development (LID): A Literature Review. EPA-841-B-00-005. Office of Water, Washington, D.C., 41 pp.
ESD/ESC Review	Van Sickle, J., J. Baker, A. Herlihy, P. Bayley, S. Gregory, P. Haggerty, L. Ashkenas, J. Li. 2004. Projecting the Biological Condition of Streams Under Alternative Scenarios of Human Land Use. Ecological Applications. 14: 368-380.
Little Seneca	Versar. (2011). Dry Seneca Creek & Little Seneca Creek pre-assessment report. Montgomery County Department of Environmental Protection.
ESD/ESC Review	Walsh, C, K. Waller, J. Gehling and R. MacNally. 2007. Riverine invertebrate assemblages are degraded more by catchment urbanization than riparian deforestation. Freshwater Biology. Early on-line edition
ESD/ESC Review	Walsh, C.J. 2004. Protection of In-Stream Biota from Urban Impacts: Minimize Catchment Imperviousness or Improve Drainage Design? Marine and Freshwater Research 55: 317-326.
ESD/ESC Review	Wardynski, B.J., R.J. Winston, W.F. Hunt. 2013. Internal water storage enhances exfiltration and thermal load reduction from permeable pavement in the North Carolina mountains. Journal of Environmental Engineering. (In Press - February 2013).
Little Seneca Reservoir	Washington Suburban Sanitary Commission (WSSC) Environmental Group. (2010). Draft Little Seneca Reservoir water quality monitoring plan.Washington Suburban Sanitary Commission.
Maryland DNR Green Infrastructure	Weber, T. (2003). Maryland's green infrastructure assessment: A comprehensive strategy for land conservation and restoration. Maryland Department of Natural Resources. Annapolis, MD.
ESD/ESC Review	Winston, R.J., W.F. Hunt, and W.G. Lord. 2011. Thermal Mitigation of Urban Stormwater by Level Spreader - Vegetative Filter Strips. Journal of Environmental Engineering. 137(8), 707-716.
ESD/ESC Review	Winter, T. 2007. The role of groundwater in generating streamflow in headwater areas and in maintaining baseflow. Journal of American Water Resources Association. 43(1): 15-25.
ESD/ESC Review	Wolin, J.A. and P. Mackeigan, P. 2005. Human Influence Past and Present – Relationship of Nutrient and Hydrologic Conditions to Urban Wetland Macrophyte Distribution. Ohio Journal of Science. 105(5): 125-132.
ESD/ESC Review	Woltemade, Christopher J., 2010. Impact of Residential Soil Disturbance on Infiltration Rate and Stormwater Runoff. Journal of the American Water Resources Association (JAWRA) 46(4): 700-711.
ESD/ESC Review	Xian, M. Crane and J. Su. 2006. An Analysis of Urban Development and its Environmental Impact on the Tampa Bay Watershed, Journal of Environmental Management.

TEN MILE CREEK WATERSHED EVIRONMENTAL ANALYSIS FOR THE CLARKSBURG MASTER PLAN LIMITED AMENDMENT GIS DATA SOURCES Updated March 6, 2013	
Category	**Data Sources**
Overall Figure Data	**Study Area**. FinalData_ToUse_BC.gdb\Subwatersheds_StudyArea. Created from Original_Data\mp_boundary_one\mp_boundary_one.shp based on direction from Montgomery Co. DEP, Feb 8, 2013.
Overall Figure Data	**Ten Mile Creek Boundary**. Original_Data\DEP\TenMileCreek_OCT2012.gdb\TMC
Overall Figure Data	**Subwatersheds**. FinalData_ToUse_BC.gdb\Station_DA_BCupdated. Created from Original_Data\DEP\TenMileCreek_OCT2012.gdb\ STATION_DA based on direction from Montgomery Co. DEP, Feb 8, 2013.
Overall Figure Data	**Streams**. FinalData_ToUse_BC.gdb\TMC_HYDRO_FINAL. Created from Original_Data\TenMileCreek_HYDRO_FINAL.gdb\TMC_HYDRO_FINAL to correct ephemeral streams, add one missing stream and create centerlines for streams having duplicate lines.
Individual Maps	
2012 Benthic Macroinvertebrate Conditions	Created from DEP data summaries compiled by Biohabitats Mar 6, 2013.
2012 Fish Conditions	Created from DEP data summaries compiled by Biohabitats Mar 6, 2013.
2012 Habitat Condition	Created from DEP data summaries compiled by Biohabitats Mar 6, 2013.
2012 Stream Condition	Created from DEP data summaries compiled by Biohabitats Mar 6, 2013.
Average of Benthic Macroinvertebrate Conditions	Created from DEP data summaries compiled by Biohabitats Feb 13, 2013.
Average of Fish Conditions	Created from DEP data summaries compiled by Biohabitats Feb 13, 2013.
Average of Habitat Condition	Created from DEP data summaries compiled by Biohabitats Feb 13, 2013.
Average of Stream Condition	Created from DEP data summaries compiled by Biohabitats Feb 13, 2013.
Erodible Soils	**Erodible Soils.** Data\Erodible_Soil_Clip_MUNAMEdesc.shp. Created from Original_Data\MNCPPC\Clarksburg Data.mdb\Erodible_soils96 and NRCS data.
Habitat, Biological, and Geomorphic Stream Monitoring Sites	**Monitoring Stations.** Original_Data\Biohab_Jan2013\BIOHABIT_JAN_2013.gdb\station (Inactive stations LSTM106, LSTM301, LSTM303A, LSTM10 and LS3638212 not shown)
Historic and Cultural Sites	**Cemeteries**. Original_Data\MNCPPC\Clarksburg Data.mdb\Historic Preservation\GISADMIN_Montco_Cem_2007
Historic and Cultural Sites	**Rustic Roads.** Original_Data\Data Transfer 010813.mdb\Rustic_Roads

Historic and Cultural Sites	**Master Plan Historic District Boundary**. Original_Data\MNCPPC\Clarksburg Data.mdb\Historic Preservation\GISADMIN_mp_historic_district_bound
Historic and Cultural Sites	**Master Plan Individual Sites**. Original_Data\MNCPPC\Clarksburg Data.mdb\Historic Preservation\ GISADMIN_mp_individual_sites
Key Hydrologic Features	**USGS Stream Gage**. Data\RiverGauge_Projected83.shp from: http://waterdata.usgs.gov/md/nwis/nwismap/?site_no=01644390&agency_cd=USGS
Key Hydrologic Features	**Hydrologic Feature Points (West Side**). Manipulated_Data-ZN\WestSide_TMC_Feat_Pnt.shp. Created from Original_Data\TenMileCreek_West_NRI.gdb\TenMileCreek_West_NRI\TMC_FEAT_PNT by removing duplicate ephemeral streams)
Key Hydrologic Features	**Hydrologic Feature Points (East Side).** Original_Data\DEP\12-05-12 MNCPPC & Biohab - Ten Mile Mapping Data\DATA\New Feature Reference & Field Points\FeaturePoints.shp (Features grouped into springs, seeps, pools, wetlands in symbology)
Key Hydrologic Features	**Wetlands.** FinalData_ToUse_BC.gdb\Wetlands_combined. Created from DEP\12-05-12 MNCPPC & Biohab - Ten Mile Mapping Data- Existing Wetlands97Update, New_TenMile_Wetlands_06-03-09, and Original_Data\TenMileCreek_HYDRO_FINAL.gdb\TMC_HYDRO_FINAL
Key Hydrologic Features	**Existing 100-yr Floodplain.** Original_Data\MNCPPC\Clarksburg Data.mdb\ GISADMIN_floodplains_county
Land Use	**2007 Land Use Classifications**. LandcoverNew_02152013.gdb\ Landcover2007_updatedBC_Clipped. Created from Original_Data\ Clarksburg Data.mdb\GISADMIN_MC_Landcover_byShed, modified based on direction from M-NCPPC.
Landcover	**Forest Conservation Easement**. Original_Data\MNCPPC\Clarksburg Data.mdb\GISADMIN_forest_conservation_easements
Landcover	**Impervious Features**. Original_Data\Latest Impervious Layer.gdb\ Imperviousness_012213
Landcover	**Forest**. Original_Data\MNCPPC\Clarksburg Data.mdb\ GISADMIN_forest_2008
Landcover	**Forest Interior**. Original_Data\DEP\12-05-12 MNCPPC & Biohab - Ten Mile Mapping Data\DATA\Existing Forest Cover & Interior Forest\TenMile_Forest_Interior_05-15-09
Ten Mile Creek Watershed	**Special Protection Areas**. Original_Data\MNCPPC\Clarksburg Data.mdb\GISADMIN_special_protection_areas
Soils	**Soil Classification Layer**. Original_Data\MNCPPC\Clarksburg Data.mdb\GISADMIN_soils
Existing Stormwater Facilities	**Stormwater Facilities**. Original_Data\DEP\TenMileCreek_OCT2012.gdb\ TMC\TMC_SWFAC and Montgomery Co. DEP BMP information.

Existing Stormwater Facilities	**Stormwater Facilities Drainage Areas**. Original_Data\DEP\TenMileCreek _OCT2012.gdb\TMC\TMC_SWFAC_DA
Existing Stormwater Facilities	**Storm Channel (County)**. Original_Data\Biohab_Jan2013\BIOHABIT_ JAN_2013.gdb\StormDrain\County_CH
Existing Stormwater Facilities	**Storm Channel (DPS).** Original_Data\Biohab_Jan2013\BIOHABIT _JAN_2013.gdb\StormDrain\DPS_CH
Existing Stormwater Facilities	**Storm Pipe (State).** Original_Data\Biohab_Jan2013\BIOHABIT_ JAN_2013.gdb\StormDrain\State_P
Existing Stormwater Facilities	**Storm Pipe (County).** Original_Data\Biohab_Jan2013\BIOHABIT _JAN_2013.gdb\StormDrain\County_P
Existing Stormwater Facilities	**Storm Pipe (DPS).** Original_Data\Biohab_Jan2013\BIOHABIT_ JAN_2013.gdb\StormDrain\DPS_P
Topography	**Index Contour Line.** Original_Data\MNCPPC\Clarksburg Data.mdb\contours2ft
Subwatershed Imperviousness	Color coding provided by Biohabitats Feb 28, 2013 based on Impervious Features in Original_Data\Latest Impervious Layer.gdb\ Imperviousness_012213
Little Seneca Lake Drainage Area	**Drainage Areas**. Original_Data\Seneca Lake Subwatershed\Seneca Lake Subwatershed.shp and Original_Data\DEP\TenMileCreek_OCT2012.gdb \TMC
Spatial Data Analyses	
Data Analysis: Land Use Analysis	**Forest 2008**. Original_Data\MNCPPC\Clarksburg Data.mdb\ GISADMIN_forest_2008
Data Analysis: Land Use Analysis	**Impervious Features**. Original_Data\Latest Impervious Layer.gdb\ Imperviousness_012213
Data Analysis: Land Use Analysis	**Erodible Soils.** Data\Erodible_Soil_Clip_MUNAMEdesc.shp. Created from Original_Data\MNCPPC\Clarksburg Data.mdb\Erodible_soils96 and NRCS data.
Data Analysis: Land Use Analysis	**Soils.** FinalData_ToUse_BC.gdb\Soils_Clipped. Created from MNCPPC\Clarksburg Data.mdb - GISADMIN_soils_1996 soils survey and NRCS data.
Data Analysis: Land Use Analysis	**Subwatersheds**. FinalData_ToUse_BC.gdb\Station_DA_BCupdated. Created from Original_Data\DEP\TenMileCreek_OCT2012.gdb\ STATION_DA
Data Analysis: Land Use Analysis	**Land Use.** LandcoverNew_02152013.gdb\Landcover2007_updatedBC _Clipped. Created from Original_Data\ Clarksburg Data.mdb\GISADMIN _MC_Landcover_byShed, modified based on direction from M-NCPPC.
Data Analysis: Stream Analysis	**Streams**. FinalData_ToUse_BC.gdb\TMC_HYDRO_FINAL. Created from Original_Data\TenMileCreek_HYDRO_FINAL.gdb\TMC_HYDRO_FINAL to correct ephemeral streams, add one missing stream and create centerlines for streams having duplicate lines.
Data Analysis: Stream	**Subwatersheds**. FinalData_ToUse_BC.gdb\Station_DA_BCupdated.

Analysis	Created from Original_Data\DEP\TenMileCreek_OCT2012.gdb\ STATION_DA
Data Analysis: Stream Analysis	**Monitoring Stations**. Original_Data\Biohab_Jan2013\BIOHABIT _JAN_2013.gdb\station
Data Analysis: Hydrologic Feature Count	**Hydrologic Feature Points (West Side).** Manipulated_Data-ZN\WestSide_TMC_Feat_Pnt.shp. Created from Original_Data\TenMileCreek_West_NRI.gdb\TenMileCreek_West_NRI\TMC_FEAT_PNT by removing duplicate ephemeral streams)
Data Analysis: Hydrologic Feature Count	**Hydrologic Feature Points (East Side).** Original_Data\DEP\12-05-12 MNCPPC & Biohab - Ten Mile Mapping Data\DATA\New Feature Reference & Field Points\FeaturePoints.shp (Features grouped into springs, seeps, pools, wetlands in symbology)

APPENDIX B. DETAILED SOIL MAP UNIT DESCRIPTION

Detailed Soil Map Units Descriptions

According to USDA Natural Resources Conservation Service (NRCS) Soil Survey mapping, the study area within Ten Mile Creek, approximately 3,050 acres of land, is mapped with fifteen soil map units excluding water (Soil Survey Staff, 2013). The dominant soil map units include Brinklow-Blocktown channery silt loams, 8 to 15 percent slopes (16C), Linganore-Hyattstown channery silt loams, 8 to 15 percent slopes (9C), Brinklow-Blocktown channery silt loams, 3 to 8 percent slopes (16B), and Linganore-Hyattstown channery silt loams, 3 to 8 percent slopes (9B) at 17.9%, 16.2%, 15.6%, and 13.9% of the study area, respectively.

Linganore and Hyattstown soil series making up the 9B and 9C map units are well drained soils on nearly level ridge crests and side slopes of ridges and dissected landscapes. Both soil series formed in residuum, or in place, weathered from phyllite. Linganore is moderately deep with a restrictive layer of paralithic bedrock ranging from 20 to 40 inches from the soil surface, while Hyattstown is shallow with a restrictive layer of paralithic bedrock ranging from 10 to 20 inches from the soil surface. Paralithic implies the bedrock at that depth can be dug with difficulty with hand tools. Both map units also have a channery silt loam surface texture. This indicates the surface soil has more than 15 percent channers or thin, flat rock fragments in the soil surface layer or topsoil. The particle-size class, or the grain size classification, of both series is loamy-skeletal meaning the soil has 35 percent of more rock fragments by volume throughout the soil profile (Soil Survey Staff, 2013).

Brinklow and Blocktown soil series making up the 16B and 16C map units are well drained soils on ridges and side slopes of dissected landscapes. While both soil series formed in residuum weathered from phyllite and schist, Brinklow also formed in soil creep matierals, or soil that has moved slowly down-slope. Brinklow is moderately deep with a restrictive layer of lithic bedrock ranging from 20 to 40 inches from the soil surface, while Blocktown is shallow with a restrictive layer of paralithic bedrock ranging from 10 to 20 inches from the soil surface. Lithic refers to hard bedrock that is not able to be dug with hand tools. Similar to map units 9B and 9C, 16B and 16C have a channery silt loam surface texture indicating the surface soil has more than 15 percent channers in the topsoil. Blocktown soil series' particle-size class, or the grain size classification, is loamy-skeletal (Soil Survey Staff, 2013).

In general, Ten Mile Creek mainstem and its tributaries were mapped using the soil maps units Glenville silt loam, 0 to 3 percent slopes (5A), Glenville silt loam, 3 to 8 percent slopes (5B), Baile silt loam, 0 to 3 percent slopes (6A), and Hatboro silt loam, 0 to 3 percent slopes, frequently flooded (54A). The soil map unit 54A was mapped along Ten Mile Creek mainstem and its tributaries with existing floodplains. Soil map unit 6A was mapped along tributaries with narrow floodplains bounded by steep slopes and soil map units 5A and 5B were mapped in the tributary headwaters. These soils map units mapped along the stream are either poorly drained or moderately well drained and formed in alluvium, soil deposited by flowing water, or colluvium, soil accumulated by the action of gravity (Soil Survey Staff, 2013).

APPENDIX C. HYDROLOGY: USGS DAILY MEAN FLOWS & MONTGOMERY COUNTY DEP'S TEN MILE CREEK SYNOPTIC FLOW

Appendix C. Hydrology - USGS Daily Mean Flows

USGS 01644390 TEN MILE CREEK NEAR BOYDS, MD

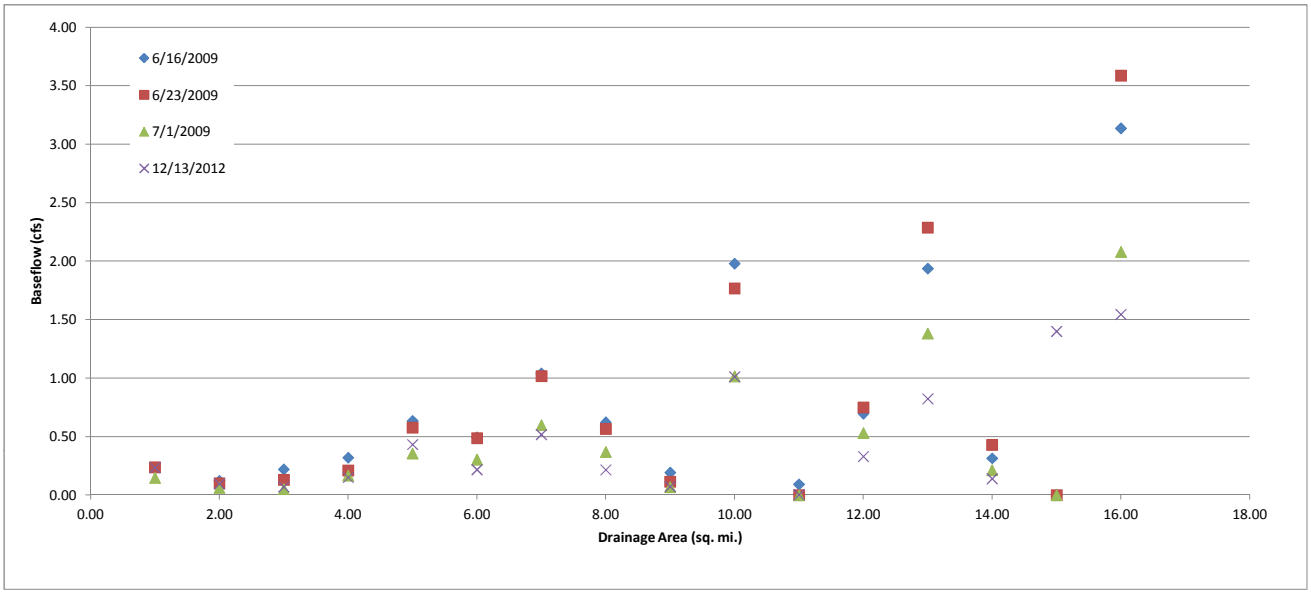
Time Series: Daily Statistics

00060, Discharge, cubic feet per second,

Mean of daily mean values for each day for 2 - 2 years of record in, cfs (Calculation Period 2010-10-01 -> 2012-09-30)

Day of month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3.8	2.9	18	4	5.4	28	0.81	0.62	0.64	16	4.2	10
2	3.7	9.3	7.4	3.5	4.9	9.9	0.77	0.48	0.7	11	3.7	5.2
3	3.4	5.5	8.6	3.2	4.5	3.3	1.3	0.48	3.4	4.5	3.4	4
4	3.1	4	5.8	3	6.8	2.6	0.95	0.47	1.1	4.5	5.6	3.6
5	3.3	4.3	4.9	5.9	4.5	2.3	0.8	0.42	13	3.2	4	3.4
6	3.2	5.6	58	3.9	4	2	0.72	0.57	21	2.7	3.1	3.7
7	3	5.3	21	3.4	3.8	1.8	0.68	1.5	18	2.5	2.8	36
8	2.8	5.1	8.2	3.9	3.5	1.7	2	0.77	348	2.2	2.7	16
9	2.7	4.1	6.5	4.1	3.5	1.5	6.1	2.1	11	2.1	2.6	7
10	2.7	3.5	49	3.5	3.3	1.4	1	3	7.3	2	2.6	5.5
11	2.9	3.7	18	3.4	2.7	1.4	1.5	0.79	4.7	2	2.5	4.9
12	13	3.3	8.2	16	2.6	1.6	1.3	0.56	4.1	2.3	2.4	5.4
13	7.4	3	6.4	14	2.6	1.5	1.2	0.52	3.7	59	2.3	5.2
14	5.1	5.5	5.6	5.9	4.9	1.5	0.94	13	6.2	26	2.3	4.2
15	4.2	4.2	5	4.7	13	1.2	0.77	3.7	6.2	7.6	2.3	4
16	3.4	4	6.7	37	7	1.2	0.71	0.87	3.4	4.9	6	3.6
17	3.6	4	4.8	16	4.7	1.5	0.66	0.63	2.9	4.2	5.8	3.5
18	3.6	3.6	4.4	7.5	5.4	1.6	0.6	0.64	3.8	3.7	3.3	3.3
19	3.5	3.3	4.1	7.6	4.8	1.2	3.7	1.6	3.1	9.9	2.8	3.2
20	3.5	3	4.1	6.4	4	1.4	2	1.7	2.5	7.2	2.5	3
21	3.4	3	4.4	5.2	3.9	1.1	1.2	1.1	2.3	3.9	2.8	3.2
22	3	3.2	4	6.4	3.3	1.1	0.89	0.74	2.2	3.3	18	4
23	3.2	3	4	7.4	3.7	1	0.71	0.61	4.1	3	32	24
24	3.7	3	5.5	15	3.4	0.94	0.76	0.6	3	2.8	6.5	5.4
25	3	12	4.7	9.2	2.9	0.88	1.1	0.69	2.3	2.7	4.8	4.5
26	3	4.7	3.9	5.9	2.4	0.82	0.78	1.6	2.3	2.7	4.2	4
27	3.9	3.8	3.5	7.5	2.4	0.85	0.62	1.5	2.4	9.6	4	10
28	3.3	4.7	3.4	20	2.7	0.78	0.58	5.3	3.2	3.2	3.7	6.5
29	3	134	3.3	8.1	2.6	0.79	0.53	1.1	2.6	6.8	7.4	4.6
30	3		3.3	5.8	2.8	1.3	0.48	0.78	2.2	8.2	4.9	4.2
31	2.9		3.5		2		0.63	0.65		5.3		4
Average:	3.8	8.9	9.6	8.2	4.1	2.6	1.2	1.6	16.4	7.4	5.2	6.7

Appendix C. Hydrology - Montgomery County DEP's Ten Mile Creek Synoptic Flow										
	2009 Date			2012 Date	CUMUL Drainage Area (SF)	CUMUL Drainage Area (sq mi)	COMMENTS	Sample Point	Latitude	Longitude
Sample Point	6/16/2009	6/23/2009	7/1/2009	12/13/2012						
1	0.23	0.24	0.15	0.23	175.3	0.27	West Fork- above LSTM206	1	39.23483	77.28985
2	0.12	0.10	0.06	0.10	168.7	0.26	East Fork- above LSTM206	2	39.23604	77.29008
3	0.22	0.13	0.05	0.07	310.5	0.49	East Fork- above LSTM201	3	39.23486	77.30431
4	0.32	0.21	0.17	0.15	275.0	0.43	West Fork- above LSTM201	4	39.23515	77.30636
5	0.63	0.58	0.36	0.43	616.7	0.96	LSTM202	5	39.23181	77.3079
6	0.49	0.49	0.30	0.22	614.5	0.96	LSTM201	6	39.23255	77.3081
7	1.04	1.02	0.60	0.52	1242.4	1.94	Below confluence of LSTM201 and 202	7	39.23042	77.31016
8	0.62	0.57	0.37	0.22	482.7	0.75	LSTM203	8	39.23014	77.31046
9	0.19	0.12	0.07	0.07	203.9	0.32	LSTM110	9	39.22593	77.3083
10	1.98	1.77	1.01	1.01	2015.2	3.15	LSTM302 (below LSTM110)	10	39.2244	77.31127
11	0.09	-	-	0.00	105.2	0.16	LSTM111	11	39.22371	77.31147
12	0.70	0.75	0.53	0.33	543.8	0.85	LSTM204	12	39.21837	77.31731
13	1.94	2.29	1.38	0.82	2241.2	3.50	LSTM303B	13	39.21847	77.31602
14	0.31	0.43	0.21	0.14	243.9	0.38	LSTM112	14	39.21164	77.31152
-	-	-	-	1.4	-	-	USGS Gage	15	39.21043	77.31069
15	3.14	3.59	2.08	1.55	3195.0	4.99	Below bridge			
15a	3.32	2.96	-	1.33	-	-	Below bridge- close loop			



APPENDIX D. AQUATIC HABITAT AND BIOLOGY

Appendix D Aquatic Habitat and Biology

The following sections outline the sampling methodologies and summarize the individual metrics, narrative IBI scores and trends over the 19 years of data provided by DEP. A summary table of available data and IBI scores for the respective sampling efforts are presented in this Appendix.

1.0 Habitat

Habitat was assessed by DEP staff using the qualitative rapid habitat assessment protocol described by Barbour and Stribling (Gibson, 1991). This method scores the condition of each of ten habitat parameters from 0 to 20 according to the criteria in Table D-1.The individual scores are summed to provide the composite habitat score which assigned a condition score (Excellent to Poor) according to the criteria in Table D-1a The habitat parameters include the following:

- Instream cover
- Epifaunal substrate
- Embeddedness
- Channel alteration
- Sediment deposition
- Riffle frequency
- Channel flow status
- Bank vegetation
- Bank stability
- Riparian buffer

Table D-1. Habitat assessment scoring criteria	
Condition category	Score
Optimal	20-16
Suboptimal	15-11
Marginal	10-6
Poor	5-0
Source: Barbour and Stribling (Gibson, 1991)	

Table D-1a. Cumulative habitat assessment scoring criteria	
Condition category	Score
Excellent	≥ 166
Excellent/Good	≥154-165
Good	≥113-153
Good/Fair	≥101-112
Fair	≥60-100
Fair/Poor	≥48-59
Poor	<48
Source: Keith Van Ness, personal communication, January 10, 2013.	

Since 2005, DEP has been supplementing these habitat data with the MBSS spring and summer habitat assessments forms (MDNR 2010 and previous versions) to be comparable to statewide datasets. These supplemental data include the following:

Appendix D
Habitat

- Severity and extent of bank erosion
- Composition of bars and substrate
- Exotic plant
- Adjacent land use
- Stream character
- Riparian vegetation type
- Number of woody debris

The MBSS raw habitat scores are converted to scaled metrics and averaged for an overall PHI score for each site as described by Paul et al. (2003). Table D-2 presents the MBSS habitat scoring criteria.

Table D-2. MBSS Habitat assessment scoring criteria

PHI Score	Narrative Rating
81.0 – 100.0	Minimally Degraded
66.0 – 80.9	Partially Degraded
51.0 – 65.9	Degraded
0.0 – 50.9	Severely Degraded

Source: Barbour and Stribling (Gibson, 1991)

The following tables the present the available habitat assessment data at each station for the respective sampling year.

	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Avg.
2005	NA	NA	NA	NA	NA	85	NA	76	76	**79**
2006	NA	NA	NA	NA	NA	NA	NA	NA	79	**79**
2007	93	93	96	90	35	87	83	80	NA	**82**
2008	NA	83	77	79	35	84	70	79	NA	**73**
2009	NA	85	80	86	42	87	77	84	NA	**77**
2010	NA	81	84	84	41	87	77	86	79	**77**
2011	NA	89	81	87	46	85	NA	85	68	**77**
2012	NA	84	81	77	34	73	69	77	75	**71**
Avg.	**93**	**86**	**83**	**84**	**39**	**84**	**75**	**81**	**75**	**77**
R-square	*NA*	*0.14*	*0.22*	*0.22*	*0.07*	***0.30***	***0.37***	*0.22*	*0.22*	***0.38***
Slope	*NA*	*-0.01*	*-0.02*	*-0.01*	*0.01*	*-0.01*	*-0.02*	*0.01*	*-0.01*	*-0.01*
N	*1.00*	*6.00*	*6.00*	*6.00*	*6.00*	*7.00*	*5.00*	*7.00*	*5.00*	*8.00*

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

Appendix D

DEP Habitat Scores for Individual Metrics

Instream cover

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994	NA	NA	NA	16.00	8.00	NA	NA	NA	13.00	13.00	13.00	**12.60**
1995	NA	NA	NA	15.50	13.50	13.00	11.00	NA	14.33	13.50	13.00	**13.40**
1996	17.00	NA	NA	15.00	16.00	14.00	8.00	NA	16.00	13.00	13.00	**14.00**
1997	15.50	NA	NA	13.33	14.33	NA	12.00	15.00	16.67	15.33	16.33	**14.81**
1998	15.00	NA	NA	14.00	12.00	NA	NA	14.00	NA	13.50	15.00	**13.92**
1999	NA	NA	NA	13.00	15.00	NA	NA	16.00	NA	15.00	NA	**14.75**
2000	NA	NA	NA	NA	NA	NA	NA	15.00	14.00	13.00	13.50	**13.88**
2001	NA	NA	NA	NA	NA	NA	NA	17.00	NA	14.00	NA	**15.50**
2002	NA	NA	NA	NA	NA	NA	NA	15.00	NA	13.00	NA	**14.00**
2003	15.00	NA	NA	15.00	16.00	12.00	10.00	13.50	15.50	13.50	13.00	**13.72**
2004	8.00	NA	NA	NA	NA	NA	NA	15.50	NA	15.50	NA	**13.00**
2005	NA	16.00	8.00	NA	NA	NA	NA	13.00	NA	14.00	15.00	**13.20**
2006	6.00	NA	11.00	NA	NA	NA	NA	15.00	NA	16.00	13.00	**12.20**
2007	13.00	NA	10.50	13.00	12.00	11.00	8.50	13.00	12.00	14.00	NA	**11.89**
2008	NA	NA	8.00	16.50	13.50	13.00	11.50	14.50	16.50	15.50	NA	**13.63**
2009	9.00	NA	8.00	15.00	12.00	12.50	11.00	14.50	11.00	17.00	NA	**12.22**
2010	12.00	NA	14.00	14.00	14.00	12.00	9.00	15.00	14.50	15.50	11.50	**13.15**
2011	11.00	8.00	11.00	14.50	14.50	10.50	11.00	13.50	17.00	16.50	13.50	**12.82**
2012	8.00	4.00	8.00	11.50	9.50	11.50	8.00	13.50	10.50	14.00	14.00	**10.23**
Average	**11.77**	**9.33**	**9.81**	**14.33**	**13.10**	**12.17**	**10.00**	**14.56**	**14.25**	**14.46**	**13.65**	**13.31**
R-square	***0.49***	***0.96***	*0.02*	*0.09*	*0.00*	***0.49***	*0.03*	*0.20*	*0.07*	***0.36***	*0.04*	***0.34***
Slope	*-0.44*	*-1.58*	*0.13*	*-0.06*	*-0.02*	*-0.12*	*-0.04*	*-0.10*	*-0.08*	*0.14*	*-0.04*	*-0.12*
N	*11.00*	*3.00*	*8.00*	*13.00*	*13.00*	*9.00*	*10.00*	*16.00*	*12.00*	*19.00*	*12.00*	*19.00*

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

Appendix D

DEP Habitat Scores for Individual Metrics

Epibenthic substrate

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994	NA	NA	NA	16.00	11.00	NA	NA	NA	11.00	11.00	16.00	**13.00**
1995	NA	NA	NA	15.00	14.00	15.50	14.00	NA	16.67	14.50	13.00	**14.67**
1996	14.00	NA	NA	17.00	16.00	16.00	18.00	NA	14.00	13.00	15.00	**15.38**
1997	17.00	NA	NA	15.33	18.00	NA	19.00	17.00	13.33	15.00	16.00	**16.33**
1998	17.00	NA	NA	15.00	12.00	NA	NA	13.00	NA	14.50	11.00	**13.75**
1999	NA	NA	NA	14.00	14.00	NA	NA	15.00	NA	14.00	NA	**14.25**
2000	NA	NA	NA	NA	NA	NA	NA	12.00	13.00	10.50	10.50	**11.50**
2001	NA	NA	NA	NA	NA	NA	NA	12.00	NA	7.00	NA	**9.50**
2002	NA	NA	NA	NA	NA	NA	NA	13.00	NA	13.00	NA	**13.00**
2003	16.00	NA	NA	12.00	14.00	12.00	17.00	16.50	14.00	15.50	14.00	**14.56**
2004	18.00	NA	NA	NA	NA	NA	NA	11.00	NA	14.50	NA	**14.50**
2005	NA	16.00	7.00	NA	NA	NA	NA	12.50	NA	12.50	12.00	**12.00**
2006	14.00	NA	15.00	NA	NA	NA	NA	15.00	NA	15.00	12.00	**14.20**
2007	16.00	NA	14.00	16.00	13.00	19.00	17.00	14.00	16.50	15.00	NA	**15.61**
2008	NA	NA	16.00	17.00	15.00	15.00	14.00	16.00	12.00	13.00	NA	**14.75**
2009	12.00	NA	17.00	11.00	10.00	17.50	14.50	16.00	13.00	14.50	NA	**13.94**
2010	14.00	NA	16.00	15.00	15.00	16.50	17.00	17.50	16.50	14.50	14.50	**15.65**
2011	16.00	16.00	16.00	16.00	11.00	14.50	15.50	13.00	15.00	15.50	14.00	**14.77**
2012	10.00	11.00	12.00	11.50	13.50	11.50	15.50	12.00	11.00	14.50	13.00	**12.32**
Average	**14.91**	**14.33**	**14.13**	**14.68**	**13.58**	**15.28**	**16.15**	**14.09**	**13.83**	**13.53**	**13.42**	**13.88**
R-square	*0.27*	***0.37***	*0.18*	*0.11*	*0.06*	*0.01*	*0.12*	*0.00*	*0.00*	*0.11*	*0.03*	*0.00*
Slope	*-0.22*	*-0.47*	*0.56*	*-0.10*	*-0.08*	*-0.04*	*-0.09*	*0.03*	*0.01*	*0.12*	*-0.05*	*0.01*
N	*11.00*	*3.00*	*8.00*	*13.00*	*13.00*	*9.00*	*10.00*	*16.00*	*12.00*	*19.00*	*12.00*	*19.00*

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

Appendix D

DEP Habitat Scores for Individual Metrics

Embeddedness

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994	NA	NA	NA	17.00	16.00	NA	NA	NA	20.00	16.00	10.00	**15.80**
1995	NA	NA	NA	13.50	15.00	14.00	12.00	NA	12.00	13.00	11.67	**13.02**
1996	12.00	NA	NA	16.00	14.00	14.00	15.00	NA	13.00	13.00	11.00	**13.50**
1997	15.00	NA	NA	16.33	17.67	NA	17.00	16.50	15.33	15.67	16.33	**16.23**
1998	15.00	NA	NA	16.00	14.50	NA	NA	14.00	NA	14.00	14.00	**14.58**
1999	NA	NA	NA	16.00	16.00	NA	NA	16.00	NA	14.00	NA	**15.50**
2000	NA	NA	NA	NA	NA	NA	NA	16.00	15.00	14.50	14.00	**14.88**
2001	NA	NA	NA	NA	NA	NA	NA	13.00	NA	16.00	NA	**14.50**
2002	NA	NA	NA	NA	NA	NA	NA	13.00	NA	17.00	NA	**15.00**
2003	15.00	NA	NA	13.00	18.00	14.50	15.00	13.50	15.00	15.50	18.00	**15.28**
2004	13.00	NA	NA	NA	NA	NA	NA	15.00	NA	16.00	NA	**14.67**
2005	NA	15.00	8.00	NA	NA	NA	NA	15.00	NA	16.50	17.00	**14.30**
2006	17.00	NA	11.00	NA	NA	NA	NA	15.00	NA	17.00	16.00	**15.20**
2007	11.00	NA	13.00	14.00	12.00	12.00	14.00	12.00	15.00	15.00	NA	**13.11**
2008	NA	NA	13.00	12.50	10.50	11.50	10.50	11.00	11.00	10.50	NA	**11.31**
2009	12.00	NA	14.00	6.00	10.00	12.00	10.50	9.50	10.50	12.50	NA	**10.78**
2010	7.00	NA	14.00	11.50	11.50	9.50	12.50	10.50	9.50	12.00	11.50	**10.95**
2011	10.00	12.00	8.00	9.00	10.50	14.00	12.50	14.50	8.00	11.50	11.00	**11.00**
2012	8.00	6.00	11.00	11.00	7.50	10.00	11.00	11.50	8.00	9.50	8.00	**9.23**
Average	**12.27**	**11.00**	**11.50**	**13.22**	**13.32**	**12.39**	**13.00**	**13.50**	**12.69**	**14.17**	**13.21**	**13.62**
R-square	***0.40***	***0.70***	*0.01*	***0.64***	***0.66***	***0.43***	***0.37***	***0.44***	***0.57***	*0.21*	*0.02*	***0.54***
Slope	*-0.34*	*-1.01*	*0.12*	*-0.39*	*-0.39*	*-0.19*	*-0.20*	*-0.30*	*-0.39*	*-0.18*	*-0.06*	*-0.27*
N	*11.00*	*3.00*	*8.00*	*13.00*	*13.00*	*9.00*	*10.00*	*16.00*	*12.00*	*19.00*	*12.00*	*19.00*

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

Appendix D

DEP Habitat Scores for Individual Metrics

Channel Alterations

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994	NA	NA	NA	17.00	17.00	NA	NA	NA	18.00	16.00	15.00	**16.60**
1995	NA	NA	NA	16.50	18.00	19.00	15.33	NA	17.33	17.50	16.67	**17.19**
1996	19.00	NA	NA	18.00	17.00	18.00	19.00	NA	18.00	18.00	18.00	**18.13**
1997	19.00	NA	NA	18.33	19.00	NA	19.00	19.00	18.67	19.00	17.00	**18.63**
1998	18.00	NA	NA	18.00	19.00	NA	NA	18.50	NA	18.50	17.00	**18.17**
1999	NA	NA	NA	19.00	18.00	NA	NA	18.00	NA	18.00	NA	**18.25**
2000	NA	NA	NA	NA	NA	NA	NA	18.00	17.50	17.00	18.00	**17.63**
2001	NA	NA	NA	NA	NA	NA	NA	18.00	NA	18.00	NA	**18.00**
2002	NA	NA	NA	NA	NA	NA	NA	18.50	NA	17.00	NA	**17.75**
2003	18.00	NA	NA	16.00	19.00	16.00	14.00	16.50	17.00	16.50	18.00	**16.78**
2004	20.00	NA	NA	NA	NA	NA	NA	18.00	NA	18.00	NA	**18.67**
2005	NA	18.00	13.00	NA	NA	NA	NA	16.50	NA	17.00	18.00	**16.50**
2006	18.00	NA	17.00	NA	NA	NA	NA	17.00	NA	18.00	18.00	**17.60**
2007	19.00	NA	18.00	19.00	19.00	18.00	17.00	19.00	17.00	18.00	NA	**18.22**
2008	NA	NA	18.00	18.00	16.00	17.00	17.50	18.50	17.50	18.50	NA	**17.63**
2009	19.00	NA	18.00	17.50	16.50	19.00	16.50	18.00	16.50	18.00	NA	**17.67**
2010	18.00	NA	17.00	18.50	17.00	18.00	18.00	17.00	17.00	18.50	18.00	**17.70**
2011	19.00	18.00	19.00	17.50	18.50	17.50	18.50	19.00	18.00	18.00	18.00	**18.27**
2012	18.00	16.00	18.00	18.00	17.00	18.50	18.00	17.50	16.00	17.50	17.50	**17.45**
Average	**18.64**	**17.33**	**17.25**	**17.79**	**17.77**	**17.89**	**17.28**	**17.94**	**17.38**	**17.74**	**17.43**	**17.73**
R-square	*0.02*	***0.37***	***0.45***	*0.05*	*0.06*	*0.01*	*0.01*	*0.03*	***0.38***	*0.05*	***0.36***	*0.00*
Slope	*-0.02*	*-0.19*	*0.50*	*0.03*	*-0.04*	*-0.01*	*0.03*	*-0.03*	*-0.07*	*0.03*	*0.08*	*0.00*
N	*11.00*	*3.00*	*8.00*	*13.00*	*13.00*	*9.00*	*10.00*	*16.00*	*12.00*	*19.00*	*12.00*	*19.00*

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Appendix D

DEP Habitat Scores for Individual Metrics

Sediment Deposition

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994	NA	NA	NA	16.00	11.00	NA	NA	NA	16.00	17.00	14.00	**14.80**
1995	NA	NA	NA	11.00	11.50	12.00	11.67	NA	12.67	10.50	9.67	**11.29**
1996	13.00	NA	NA	14.00	12.00	13.00	11.00	NA	13.00	13.00	13.00	**12.75**
1997	14.50	NA	NA	14.67	13.67	NA	15.00	13.50	15.33	13.67	13.67	**14.25**
1998	14.00	NA	NA	15.00	11.00	NA	NA	12.50	NA	9.50	10.00	**12.00**
1999	NA	NA	NA	15.00	12.00	NA	NA	14.00	NA	12.00	NA	**13.25**
2000	NA	NA	NA	NA	NA	NA	NA	15.50	13.50	13.50	12.00	**13.63**
2001	NA	NA	NA	NA	NA	NA	NA	17.00	NA	16.00	NA	**16.50**
2002	NA	NA	NA	NA	NA	NA	NA	11.00	NA	16.00	NA	**13.50**
2003	16.00	NA	NA	15.00	15.00	15.00	15.00	11.50	15.00	15.50	15.00	**14.78**
2004	13.00	NA	NA	NA	NA	NA	NA	15.00	NA	15.50	NA	**14.50**
2005	NA	17.00	8.00	NA	NA	NA	NA	15.50	NA	16.00	15.00	**14.30**
2006	15.00	NA	9.00	NA	NA	NA	NA	15.00	NA	14.00	10.00	**12.60**
2007	8.00	NA	10.50	15.00	10.00	9.00	12.00	12.00	11.50	10.00	NA	**10.89**
2008	NA	NA	14.00	13.00	11.00	10.00	14.50	11.00	8.00	9.00	NA	**11.31**
2009	11.00	NA	12.00	11.00	8.00	10.50	7.00	11.50	8.00	10.00	NA	**9.89**
2010	7.00	NA	10.00	13.00	12.50	9.50	10.00	10.00	10.50	8.00	9.50	**10.00**
2011	6.00	8.00	12.00	14.50	10.50	9.00	8.50	15.50	6.00	8.50	6.50	**9.55**
2012	12.00	6.00	7.00	12.00	9.50	9.00	8.50	7.00	7.50	10.50	7.00	**8.73**
Average	**11.77**	**10.33**	**10.31**	**13.78**	**11.36**	**10.78**	**11.32**	**12.97**	**11.42**	**12.54**	**11.28**	**12.55**
R-square	***0.40***	***1.00***	*0.00*	*0.13*	*0.17*	***0.52***	*0.26*	*0.19*	***0.72***	*0.22*	***0.32***	***0.38***
Slope	*-0.37*	*-1.55*	*0.05*	*-0.09*	*-0.11*	*-0.24*	*-0.22*	*-0.24*	*-0.42*	*-0.25*	*-0.26*	*-0.23*
N	*11.00*	*3.00*	*8.00*	*13.00*	*13.00*	*9.00*	*10.00*	*16.00*	*12.00*	*19.00*	*12.00*	*19.00*

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

Appendix D

DEP Habitat Scores for Individual Metrics

Riffle frequency

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994	NA	NA	NA	13.00	11.00	NA	NA	NA	20.00	16.00	16.00	**15.20**
1995	NA	NA	NA	15.00	13.50	16.50	15.67	NA	17.00	16.00	15.33	**15.57**
1996	18.00	NA	NA	14.00	17.00	16.00	19.00	NA	18.00	14.00	18.00	**16.75**
1997	18.50	NA	NA	16.00	17.33	NA	18.00	17.00	17.00	16.67	17.00	**17.19**
1998	17.00	NA	NA	17.00	15.50	NA	NA	16.50	NA	16.00	12.00	**15.67**
1999	NA	NA	NA	15.00	15.00	NA	NA	17.00	NA	15.00	NA	**15.50**
2000	NA	NA	NA	NA	NA	NA	NA	17.50	15.00	14.50	14.00	**15.25**
2001	NA	NA	NA	NA	NA	NA	NA	18.00	NA	8.00	NA	**13.00**
2002	NA	NA	NA	NA	NA	NA	NA	15.50	NA	11.00	NA	**13.25**
2003	18.00	NA	NA	15.00	17.00	15.50	16.00	16.50	14.50	15.00	16.00	**15.94**
2004	18.00	NA	NA	NA	NA	NA	NA	17.00	NA	17.00	NA	**17.33**
2005	NA	18.00	8.00	NA	NA	NA	NA	15.00	NA	16.00	16.00	**14.60**
2006	15.00	NA	18.00	NA	NA	NA	NA	15.00	NA	17.00	16.00	**16.20**
2007	15.00	NA	16.50	18.00	13.00	16.00	18.00	17.00	16.00	14.50	NA	**16.00**
2008	NA	NA	17.00	17.00	12.50	15.00	15.00	18.50	13.00	13.00	NA	**15.13**
2009	16.00	NA	17.00	18.00	14.00	14.00	17.00	17.50	15.00	15.50	NA	**16.00**
2010	18.00	NA	19.00	17.50	18.00	16.50	17.00	19.00	15.50	14.50	15.00	**17.00**
2011	17.00	17.00	17.00	18.50	17.50	15.50	16.50	17.00	19.00	15.50	9.00	**16.32**
2012	18.00	19.00	17.00	17.00	14.50	14.50	17.00	17.50	14.00	15.00	17.00	**16.41**
Average	**17.14**	**18.00**	**16.19**	**16.23**	**15.06**	**15.50**	**16.92**	**16.97**	**16.17**	**14.75**	**15.11**	**15.70**
R-square	*0.09*	*0.02*	***0.32***	***0.67***	*0.02*	*0.28*	*0.06*	*0.06*	*0.27*	*0.00*	*0.08*	*0.03*
Slope	*-0.07*	*0.03*	*0.78*	*0.21*	*0.05*	*-0.07*	*-0.05*	*0.06*	*-0.16*	*-0.01*	*-0.11*	*0.04*
N	*11.00*	*3.00*	*8.00*	*13.00*	*13.00*	*9.00*	*10.00*	*16.00*	*12.00*	*19.00*	*12.00*	*19.00*

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Appendix D

DEP Habitat Scores for Individual Metrics

Channel flow characteristics

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994	NA	NA	NA	18.00	16.00	NA	NA	NA	8.00	18.00	14.00	**14.80**
1995	NA	NA	NA	16.00	11.50	8.50	17.00	NA	12.00	12.50	13.33	**12.98**
1996	19.00	NA	NA	18.00	15.00	15.00	19.00	NA	9.00	18.00	13.00	**15.75**
1997	15.50	NA	NA	15.67	14.67	NA	16.00	12.00	12.33	14.00	13.67	**14.23**
1998	17.00	NA	NA	15.00	12.00	NA	NA	12.50	NA	13.50	14.00	**14.00**
1999	NA	NA	NA	15.00	13.00	NA	NA	14.00	NA	16.00	NA	**14.50**
2000	NA	NA	NA	NA	NA	NA	NA	14.00	10.00	12.50	14.50	**12.75**
2001	NA	NA	NA	NA	NA	NA	NA	13.00	NA	6.00	NA	**9.50**
2002	NA	NA	NA	NA	NA	NA	NA	14.50	NA	12.00	NA	**13.25**
2003	15.00	NA	NA	12.00	15.00	11.00	14.00	14.00	13.00	14.00	15.00	**13.67**
2004	16.00	NA	NA	NA	NA	NA	NA	15.50	NA	15.50	NA	**15.67**
2005	NA	13.00	13.00	NA	NA	NA	NA	12.50	NA	14.50	11.00	**12.80**
2006	13.00	NA	11.00	NA	NA	NA	NA	13.00	NA	15.00	11.00	**12.60**
2007	9.00	NA	13.00	13.00	10.00	12.00	12.50	14.00	8.50	12.00	NA	**11.56**
2008	NA	NA	15.00	10.00	9.50	9.50	11.00	11.00	8.50	9.00	NA	**10.44**
2009	14.00	NA	15.00	8.50	9.50	8.00	14.00	8.50	8.00	9.00	NA	**10.50**
2010	9.00	NA	13.00	10.50	8.50	9.00	15.00	8.00	8.50	8.00	11.00	**10.05**
2011	18.00	9.00	12.00	12.50	12.00	9.50	12.50	13.50	13.00	10.50	10.00	**12.05**
2012	11.00	6.00	8.00	9.00	9.00	8.50	10.50	10.00	7.50	8.50	7.50	**8.68**
Average	**14.23**	**9.33**	**12.50**	**13.32**	**11.97**	**10.11**	**14.15**	**12.50**	**9.86**	**12.55**	**12.33**	**12.62**
R-square	***0.34***	***0.91***	*0.15*	***0.83***	***0.59***	*0.25*	***0.69***	*0.26*	*0.06*	***0.38***	***0.65***	***0.49***
Slope	*-0.35*	*-0.88*	*-0.36*	*-0.44*	*-0.30*	*-0.18*	*-0.34*	*-0.23*	*-0.08*	*-0.37*	*-0.28*	*-0.26*
N	*11.00*	*3.00*	*8.00*	*13.00*	*13.00*	*9.00*	*10.00*	*16.00*	*12.00*	*19.00*	*12.00*	*19.00*

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

Appendix D

DEP Habitat Scores for Individual Metrics

Left bank vegetation

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994	NA	NA	NA	9.00	8.00	NA	NA	NA	4.00	9.00	8.00	**7.60**
1995	NA	NA	NA	9.00	8.00	6.00	4.33	NA	7.00	7.50	7.67	**7.07**
1996	7.00	NA	NA	8.00	8.00	9.00	4.00	NA	6.00	7.00	4.00	**6.63**
1997	8.50	NA	NA	8.67	7.33	NA	4.00	7.00	8.67	9.00	7.33	**7.56**
1998	8.00	NA	NA	9.00	6.00	NA	NA	7.00	NA	7.50	8.00	**7.58**
1999	NA	NA	NA	9.00	9.00	NA	NA	7.00	NA	9.00	NA	**8.50**
2000	NA	NA	NA	NA	NA	NA	NA	7.00	8.50	8.50	8.50	**8.13**
2001	NA	NA	NA	NA	NA	NA	NA	5.00	NA	8.00	NA	**6.50**
2002	NA	NA	NA	NA	NA	NA	NA	6.50	NA	6.00	NA	**6.25**
2003	7.00	NA	NA	7.00	8.00	5.50	6.00	4.50	7.00	6.00	8.00	**6.56**
2004	8.00	NA	NA	NA	NA	NA	NA	8.00	NA	8.00	NA	**8.00**
2005	NA	9.00	7.00	NA	NA	NA	NA	6.50	NA	7.50	8.00	**7.60**
2006	9.00	NA	6.00	NA	NA	NA	NA	5.00	NA	8.00	8.00	**7.20**
2007	5.00	NA	6.00	7.00	6.00	5.00	4.50	4.00	5.00	6.00	NA	**5.39**
2008	NA	NA	6.00	5.00	5.50	5.50	4.50	4.50	5.50	5.00	NA	**5.19**
2009	6.00	NA	7.00	5.50	4.00	5.50	4.50	5.50	4.50	4.00	NA	**5.17**
2010	5.00	NA	5.00	5.50	5.00	5.50	3.00	4.00	4.50	5.00	6.00	**4.85**
2011	5.00	4.00	5.00	4.50	4.00	4.50	3.00	3.50	9.00	4.50	5.00	**4.73**
2012	5.00	3.00	5.00	5.50	3.50	4.50	2.50	4.50	3.00	3.50	3.50	**3.95**
Average	**6.68**	**5.33**	**5.88**	**7.13**	**6.33**	**5.67**	**4.03**	**5.59**	**6.06**	**6.79**	**6.83**	**6.55**
R-square	***0.49***	***1.00***	***0.54***	***0.88***	***0.74***	***0.57***	*0.17*	***0.53***	*0.08*	***0.64***	*0.20*	***0.57***
Slope	*-0.19*	*-0.85*	*-0.25*	*-0.24*	*-0.24*	*-0.16*	*-0.06*	*-0.21*	*-0.08*	*-0.25*	*-0.12*	*-0.18*
N	*11.00*	*3.00*	*8.00*	*13.00*	*13.00*	*9.00*	*10.00*	*16.00*	*12.00*	*19.00*	*12.00*	*19.00*

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

Appendix D

DEP Habitat Scores for Individual Metrics

Right bank vegetation

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994	NA	NA	NA	9.00	8.00	NA	NA	NA	4.00	9.00	7.00	**7.40**
1995	NA	NA	NA	8.00	8.00	5.00	4.33	NA	7.00	7.50	5.67	**6.50**
1996	7.00	NA	NA	8.00	10.00	7.00	4.00	NA	6.00	7.00	7.00	**7.00**
1997	8.50	NA	NA	9.00	7.67	NA	4.00	7.00	8.00	9.00	6.00	**7.40**
1998	8.00	NA	NA	9.00	7.00	NA	NA	8.00	NA	8.00	6.00	**7.67**
1999	NA	NA	NA	9.00	9.00	NA	NA	7.00	NA	9.00	NA	**8.50**
2000	NA	NA	NA	NA	NA	NA	NA	7.50	8.00	8.50	5.50	**7.38**
2001	NA	NA	NA	NA	NA	NA	NA	7.00	NA	8.00	NA	**7.50**
2002	NA	NA	NA	NA	NA	NA	NA	6.50	NA	6.00	NA	**6.25**
2003	7.00	NA	NA	5.00	9.00	5.50	6.00	5.00	7.00	6.00	8.00	**6.50**
2004	8.00	NA	NA	NA	NA	NA	NA	8.00	NA	8.00	NA	**8.00**
2005	NA	9.00	7.00	NA	NA	NA	NA	6.50	NA	7.50	6.00	**7.20**
2006	9.00	NA	6.00	NA	NA	NA	NA	5.00	NA	8.00	8.00	**7.20**
2007	5.00	NA	5.50	6.00	7.00	5.00	4.50	5.00	4.00	5.00	NA	**5.22**
2008	NA	NA	7.00	5.00	5.50	4.50	4.50	4.00	6.00	5.00	NA	**5.19**
2009	5.00	NA	6.00	5.50	5.00	6.00	4.00	4.00	6.00	5.50	NA	**5.22**
2010	6.00	NA	5.00	5.50	5.50	4.50	3.50	3.50	5.00	5.00	4.00	**4.75**
2011	4.00	4.00	5.00	5.50	5.00	3.50	3.50	5.00	9.00	4.50	4.00	**4.82**
2012	4.00	3.00	4.00	4.50	5.00	4.00	4.00	3.50	3.50	3.50	4.00	**3.91**
Average	**6.50**	**5.33**	**5.69**	**6.85**	**7.05**	**5.00**	**4.23**	**5.78**	**6.13**	**6.84**	**5.93**	**6.51**
R-square	***0.53***	***1.00***	***0.65***	***0.80***	***0.67***	***0.43***	*0.05*	***0.72***	*0.03*	***0.65***	*0.29*	***0.57***
Slope	*-0.23*	*-0.85*	*-0.34*	*-0.24*	*-0.21*	*-0.11*	*-0.03*	*-0.28*	*-0.04*	*-0.25*	*-0.12*	*-0.17*
N	*11.00*	*3.00*	*8.00*	*13.00*	*13.00*	*9.00*	*10.00*	*16.00*	*12.00*	*19.00*	*12.00*	*19.00*

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

Appendix D

DEP Habitat Scores for Individual Metrics

Left bank stability

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994	NA	NA	NA	8.00	5.00	NA	NA	NA	4.00	8.00	8.00	**6.60**
1995	NA	NA	NA	7.50	6.00	7.00	6.33	NA	6.00	6.50	7.00	**6.62**
1996	8.00	NA	NA	8.00	8.00	7.00	6.00	NA	7.00	9.00	4.00	**7.13**
1997	8.00	NA	NA	8.33	6.67	NA	5.00	6.00	7.67	8.67	7.67	**7.25**
1998	8.00	NA	NA	8.00	6.00	NA	NA	6.50	NA	8.00	8.00	**7.42**
1999	NA	NA	NA	8.00	7.00	NA	NA	6.00	NA	9.00	NA	**7.50**
2000	NA	NA	NA	NA	NA	NA	NA	6.00	6.00	8.00	8.50	**7.13**
2001	NA	NA	NA	NA	NA	NA	NA	5.00	NA	9.00	NA	**7.00**
2002	NA	NA	NA	NA	NA	NA	NA	5.00	NA	5.00	NA	**5.00**
2003	8.00	NA	NA	7.00	6.00	6.50	4.00	3.50	6.50	7.00	7.00	**6.17**
2004	9.00	NA	NA	NA	NA	NA	NA	6.50	NA	7.50	NA	**7.67**
2005	NA	7.00	7.00	NA	NA	NA	NA	5.50	NA	7.00	8.00	**6.90**
2006	8.00	NA	6.00	NA	NA	NA	NA	4.00	NA	7.00	8.00	**6.60**
2007	6.00	NA	8.50	6.00	5.00	7.00	5.00	4.00	6.00	7.00	NA	**6.06**
2008	NA	NA	7.00	6.00	3.50	5.50	4.00	4.00	1.50	5.50	NA	**4.63**
2009	8.00	NA	9.00	5.00	3.00	6.50	4.00	3.50	4.00	4.00	NA	**5.22**
2010	6.00	NA	7.00	5.00	6.50	5.50	4.00	3.50	6.00	6.00	6.50	**5.60**
2011	6.00	3.00	8.00	5.50	4.00	5.00	4.00	4.50	7.00	7.50	4.00	**5.32**
2012	5.00	3.00	6.00	6.00	4.00	4.50	3.00	3.00	5.00	4.00	3.50	**4.27**
Average	**7.27**	**4.33**	**7.31**	**6.79**	**5.44**	**6.06**	**4.53**	**4.78**	**5.56**	**7.04**	**6.68**	**6.32**
R-square	***0.46***	***0.98***	*0.00*	***0.85***	***0.42***	***0.59***	***0.76***	***0.62***	*0.06*	***0.42***	*0.20*	***0.49***
Slope	*-0.15*	*-0.60*	*0.01*	*-0.17*	*-0.14*	*-0.12*	*-0.14*	*-0.19*	*-0.06*	*-0.18*	*-0.13*	*-0.13*
N	*11.00*	*3.00*	*8.00*	*13.00*	*13.00*	*9.00*	*10.00*	*16.00*	*12.00*	*19.00*	*12.00*	*19.00*

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

Appendix D

DEP Habitat Scores for Individual Metrics

Right bank stability

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994	NA	NA	NA	9.00	9.00	NA	NA	NA	4.00	9.00	4.00	**7.00**
1995	NA	NA	NA	7.00	7.50	6.00	6.33	NA	6.67	8.00	5.33	**6.69**
1996	8.00	NA	NA	6.00	9.00	8.00	6.00	NA	7.00	6.00	6.00	**7.00**
1997	8.00	NA	NA	8.00	7.33	NA	5.00	6.00	6.33	8.67	5.00	**6.79**
1998	8.00	NA	NA	8.00	7.50	NA	NA	7.50	NA	7.50	4.00	**7.08**
1999	NA	NA	NA	8.00	9.00	NA	NA	8.00	NA	9.00	NA	**8.50**
2000	NA	NA	NA	NA	NA	NA	NA	6.50	7.00	8.00	4.50	**6.50**
2001	NA	NA	NA	NA	NA	NA	NA	7.00	NA	9.00	NA	**8.00**
2002	NA	NA	NA	NA	NA	NA	NA	4.50	NA	5.00	NA	**4.75**
2003	8.00	NA	NA	7.00	7.00	6.50	4.00	4.50	6.50	7.00	7.00	**6.39**
2004	8.00	NA	NA	NA	NA	NA	NA	6.50	NA	8.00	NA	**7.50**
2005	NA	7.00	7.00	NA	NA	NA	NA	5.50	NA	7.00	5.00	**6.30**
2006	8.00	NA	7.00	NA	NA	NA	NA	4.00	NA	7.00	6.00	**6.40**
2007	7.00	NA	5.50	7.00	7.00	6.00	5.50	6.00	5.00	6.00	NA	**6.11**
2008	NA	NA	6.00	6.00	5.50	4.00	4.50	6.00	2.50	5.50	NA	**5.00**
2009	6.00	NA	7.00	5.50	7.00	6.00	4.50	6.50	6.00	4.50	NA	**5.89**
2010	7.00	NA	5.00	6.00	7.00	5.00	4.50	5.50	6.00	6.50	5.00	**5.75**
2011	6.00	3.00	6.00	6.50	7.50	4.50	5.00	6.50	6.00	7.00	7.50	**5.95**
2012	6.00	3.00	6.00	5.00	6.50	5.00	4.50	4.50	5.50	4.50	7.00	**5.23**
Average	**7.27**	**4.33**	**6.19**	**6.85**	**7.45**	**5.67**	**4.98**	**5.94**	**5.71**	**7.01**	**5.53**	**6.47**
R-square	***0.67***	***0.98***	*0.23*	***0.54***	***0.46***	***0.53***	***0.43***	*0.16*	*0.06*	***0.41***	***0.38***	***0.34***
Slope	*-0.13*	*-0.60*	*-0.15*	*-0.13*	*-0.10*	*-0.14*	*-0.07*	*-0.10*	*-0.05*	*-0.17*	*0.11*	*-0.10*
N	*11.00*	*3.00*	*8.00*	*13.00*	*13.00*	*9.00*	*10.00*	*16.00*	*12.00*	*19.00*	*12.00*	*19.00*

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

Appendix D

DEP Habitat Scores for Individual Metrics

Left bank riparian buffer

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994	NA	NA	NA	10.00	9.00	NA	NA	NA	10.00	10.00	9.00	**9.60**
1995	NA	NA	NA	10.00	9.50	10.00	1.00	NA	9.67	10.00	9.33	**8.50**
1996	7.00	NA	NA	10.00	9.00	10.00	1.00	NA	10.00	10.00	10.00	**8.38**
1997	9.50	NA	NA	9.67	9.67	NA	1.00	10.00	9.67	10.00	8.67	**8.52**
1998	10.00	NA	NA	10.00	10.00	NA	NA	9.50	NA	9.50	10.00	**9.83**
1999	NA	NA	NA	10.00	10.00	NA	NA	10.00	NA	10.00	NA	**10.00**
2000	NA	NA	NA	NA	NA	NA	NA	10.00	9.50	9.50	7.50	**9.13**
2001	NA	NA	NA	NA	NA	NA	NA	10.00	NA	7.00	NA	**8.50**
2002	NA	NA	NA	NA	NA	NA	NA	9.50	NA	9.00	NA	**9.25**
2003	10.00	NA	NA	10.00	10.00	9.00	2.00	8.50	9.50	9.00	8.00	**8.44**
2004	9.00	NA	NA	NA	NA	NA	NA	10.00	NA	10.00	NA	**9.67**
2005	NA	10.00	6.00	NA	NA	NA	NA	9.50	NA	9.50	6.00	**8.20**
2006	9.00	NA	6.00	NA	NA	NA	NA	9.00	NA	10.00	8.00	**8.40**
2007	9.00	NA	8.00	9.00	9.00	7.00	3.00	6.00	9.00	8.00	NA	**7.56**
2008	NA	NA	7.00	9.00	7.00	8.00	2.00	7.50	9.50	8.00	NA	**7.25**
2009	8.00	NA	8.00	8.50	6.50	8.00	3.00	8.50	8.00	9.00	NA	**7.50**
2010	6.00	NA	8.00	9.00	8.50	8.50	1.50	8.50	8.50	9.00	8.50	**7.60**
2011	9.00	9.00	8.00	9.00	8.50	9.00	1.50	9.00	9.00	8.50	8.50	**8.09**
2012	7.00	9.00	9.00	9.00	7.50	9.00	1.50	9.00	9.00	9.00	8.00	**7.91**
Average	**8.50**	**9.33**	**7.50**	**9.47**	**8.78**	**8.72**	**1.75**	**9.03**	**9.28**	**9.21**	**8.46**	**8.54**
R-square	*0.15*	***0.98***	***0.76***	***0.78***	***0.46***	***0.39***	*0.28*	***0.30***	***0.63***	*0.24*	*0.24*	***0.43***
Slope	*-0.09*	*-0.15*	*0.38*	*-0.07*	*-0.12*	*-0.10*	*0.06*	*-0.13*	*-0.07*	*-0.07*	*-0.08*	*-0.10*
N	*11.00*	*3.00*	*8.00*	*13.00*	*13.00*	*9.00*	*10.00*	*16.00*	*12.00*	*19.00*	*12.00*	*19.00*

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Appendix D

DEP Habitat Scores for Individual Metrics

Right bank riparian buffer

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994	NA	NA	NA	10.00	10.00	NA	NA	NA	10.00	9.00	9.00	**9.60**
1995	NA	NA	NA	10.00	10.00	10.00	1.00	NA	10.00	9.00	9.33	**8.48**
1996	9.00	NA	NA	10.00	10.00	10.00	1.00	NA	10.00	7.00	10.00	**8.38**
1997	10.00	NA	NA	10.00	10.00	NA	1.00	10.00	9.67	8.67	9.33	**8.58**
1998	10.00	NA	NA	10.00	10.00	NA	NA	9.50	NA	7.50	9.00	**9.33**
1999	NA	NA	NA	10.00	10.00	NA	NA	9.00	NA	9.00	NA	**9.50**
2000	NA	NA	NA	NA	NA	NA	NA	9.50	10.00	8.50	9.50	**9.38**
2001	NA	NA	NA	NA	NA	NA	NA	10.00	NA	9.00	NA	**9.50**
2002	NA	NA	NA	NA	NA	NA	NA	9.50	NA	7.00	NA	**8.25**
2003	10.00	NA	NA	10.00	10.00	9.00	2.00	8.50	9.50	7.50	9.00	**8.39**
2004	9.00	NA	NA	NA	NA	NA	NA	9.50	NA	8.50	NA	**9.00**
2005	NA	10.00	6.00	NA	NA	NA	NA	9.50	NA	9.00	9.00	**8.70**
2006	9.00	NA	6.00	NA	NA	NA	NA	9.00	NA	8.00	10.00	**8.40**
2007	9.00	NA	9.00	9.00	9.00	8.00	2.00	7.00	8.00	6.50	NA	**7.50**
2008	NA	NA	9.00	9.00	8.00	6.50	2.00	7.50	9.00	6.50	NA	**7.19**
2009	9.00	NA	9.00	9.50	8.50	8.50	2.00	7.00	9.00	7.50	NA	**7.78**
2010	10.00	NA	9.00	9.50	9.00	8.50	1.50	7.00	9.00	8.00	8.00	**7.95**
2011	9.00	9.00	9.00	9.50	9.00	9.00	1.50	8.00	9.00	8.50	8.50	**8.18**
2012	9.00	9.00	9.00	9.00	9.00	9.00	1.00	7.50	9.00	8.00	9.00	**8.05**
Average	**9.36**	**9.33**	**8.25**	**9.65**	**9.42**	**8.72**	**1.50**	**8.63**	**9.35**	**8.04**	**9.14**	**8.53**
R-square	*0.15*	***0.98***	***0.57***	***0.68***	***0.69***	***0.34***	*0.24*	***0.66***	***0.64***	*0.10*	*0.24*	***0.43***
Slope	*-0.03*	*-0.15*	*0.43*	*-0.05*	*-0.09*	*-0.10*	*0.03*	*-0.19*	*-0.07*	*-0.05*	*-0.04*	*-0.08*
N	*11.00*	*3.00*	*8.00*	*13.00*	*13.00*	*9.00*	*10.00*	*16.00*	*12.00*	*19.00*	*12.00*	*19.00*

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

Appendix D

DEP Habitat Scores for Individual Metrics

Composite

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994	NA	NA	NA	168.00	139.00	NA	NA	NA	142.00	161.00	143.00	**150.60**
1995	NA	NA	NA	154.00	146.00	142.50	120.00	NA	148.33	146.00	137.00	**141.98**
1996	158.00	NA	NA	162.00	161.00	157.00	131.00	NA	147.00	148.00	142.00	**150.75**
1997	167.50	NA	NA	163.33	163.33	NA	136.00	156.00	158.67	163.33	154.00	**157.77**
1998	165.00	NA	NA	164.00	142.50	NA	NA	149.00	NA	147.50	138.00	**151.00**
1999	NA	NA	NA	161.00	157.00	NA	NA	157.00	NA	159.00	NA	**158.50**
2000	NA	NA	NA	NA	NA	NA	NA	154.50	147.00	146.50	140.50	**147.13**
2001	NA	NA	NA	NA	NA	NA	NA	152.00	NA	135.00	NA	**143.50**
2002	NA	NA	NA	NA	NA	NA	NA	142.00	NA	137.00	NA	**139.50**
2003	163.00	NA	NA	144.00	164.00	138.00	125.00	136.50	150.00	148.00	156.00	**147.17**
2004	157.00	NA	NA	NA	NA	NA	NA	155.50	NA	162.00	NA	**158.17**
2005	NA	165.00	105.00	NA	NA	NA	NA	143.00	NA	154.00	146.00	**142.60**
2006	150.00	NA	129.00	NA	NA	NA	NA	141.00	NA	160.00	144.00	**144.80**
2007	132.00	NA	138.00	152.00	132.00	135.00	123.50	133.00	133.50	137.00	NA	**135.11**
2008	NA	NA	143.00	144.00	123.00	125.00	115.50	134.00	120.50	124.00	NA	**128.63**
2009	135.00	NA	147.00	126.50	114.00	134.00	112.50	130.50	119.50	131.00	NA	**127.78**
2010	125.00	NA	142.00	140.50	138.00	128.50	116.50	129.00	131.00	130.50	129.00	**131.00**
2011	136.00	120.00	136.00	143.00	132.50	126.00	113.50	142.50	145.00	136.50	119.50	**131.86**
2012	121.00	98.00	120.00	129.00	116.00	119.50	105.00	121.00	109.50	122.00	119.00	**116.36**
Average	**146.32**	**127.67**	**132.50**	**150.10**	**140.64**	**133.94**	**119.85**	**142.28**	**137.67**	**144.65**	**139.00**	**142.33**
R-square	***0.79***	***0.96***	*0.11*	***0.76***	***0.49***	***0.78***	***0.63***	***0.68***	***0.51***	***0.41***	***0.37***	***0.60***
Slope	*-2.63*	*-8.85*	*1.86*	*-1.75*	*-1.79*	*-1.57*	*-1.12*	*-1.92*	*-1.57*	*-1.48*	*-1.09*	*-1.58*
N	*11.00*	*3.00*	*8.00*	*13.00*	*13.00*	*9.00*	*10.00*	*16.00*	*12.00*	*19.00*	*12.00*	*19.00*

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

2.0 Fish

Fish communities were assessed by DEP staff during summer index periods with the respective sampling years in accordance with the Maryland Biological Stream Survey (MBSS) methods (Kayzak, 2001). The DEP Fish IBI evaluates 9 metrics, which include the following:

- Total number of species
- Total number of riffle benthic insectivore individuals
- Total number of minnow species (*cyprinidae*)
- Total number of intolerant species
- Proportion of tolerant individuals
- Proportion of individuals as omnivores/generalists
- Proportion of individuals as pioneering species
- Total number of individuals (excluding tolerant species)
- Proportion of individuals with disease/anomalies

Each of these metrics is assigned a metric score of 1, 3, or 5 depending on the calculated value, stream order, and presence/absence of Channery Silt Loam and the average of the metric scores is reported according to the following criteria in Table D-3:

Table D-3. Fish IBI scoring criteria

Condition category	Score
Excellent	>4.5
Good	3.4-4.5
Fair	2.3-3.3
Poor	≤2.2

Source: Keith Van Ness, personal communication, January 10, 2013.

The MBSS has also developed and tested a Fish IBI which could be used to corroborate the DEP Fish IBI and provide a comparison to the statewide data sets; however, one or more of the metrics for this comparison was not readily available in the data provided.

Overall the fish community within the Ten Mile Creek drainage, as indicated by its Fish IBI scores, is in good condition. The DEP Fish IBI accounts for some of this natural variability by adjusting the scoring criteria based on stream order. These adjustments do tend to influence the overall Fish IBI scores for the third-order streams, but not the narrative rating, in this data set. Specifically the calculated values for the number of minnow species and number of intolerant species were similar among third-order sites and second-order sites immediately upstream, but the assigned metric dropped to the lower category in the assigned score.

In interpreting the Fish IBI data, one factor that is unlikely to improve naturally is the number of intolerant species. Only Blue Ridge sculpin (*Cottus caeruleomentum*) and an occasional brown trout (*Salmo trutta*) are present within the watershed. Due to the presence of the Little Seneca Lake, it is unlikely that recruitment of new intolerant species will occur. This results in consistent marginal scores of 3 and 1 for the second- and third-order streams respectively.

Similarly, the number of minnow species is stable and shows no recruitment, which is likely related to the presence of physical barrier to fish migration posed by the Little Seneca Lake Dam and impoundment. The consequence of this is a consistently marginal ranking of 3 for third-order stations and an excellent rating for the second-order stations.

Analysis of trends in the Fish IBI metrics over time indicated the following:

- The total number of individuals showed significant declines between the mid-1990s and when sampling resumed in 2007. This appears to have stabilized, but these stations presently declined from an excellent to a good rating.
- The frequency of riffle benthic insectivores in the second-order tributaries show moderate declines in the raw data, but the respective metric values are stable. These declines could be related to an increase in sediment supply and embeddedness documented in habitat assessment.
- Proportion of omnivores/generalist in the samples strong to slight increasing trends (~1%/year) in raw metrics, which are dampened in the scaled metric. These species are likely competing with the riffle benthic insectivores, which have shown some decline.
- Proportion of pioneer species show slight increasing trends (~1%/year), at most stations, which are also likely competing with the riffle benthic insectivores.
- The raw numbers of tolerant individuals are showing slight signs of increasing (≤1%/year), however this is not reflected in the assigned value. Some stations, particularly the second-order stations are showing an increase in the proportion that are negatively influencing the IBI score.
- The proportion of individuals with disease/anomalies has remained low and no trends were observed.

Other observations of note include:

- LSTM206 consistently scored lower than other second-order stations on all metrics except for the proportion of individuals with disease/anomalies, which improves its overall score.
- LSTM204 scored the lowest on the habitat ratings, but was the only station to consistently score excellent in the Fish IBI.

While the trend analysis indicates some shifts in the overall community structure, the total fish diversity appears to be stable. The second-order tributaries, particularly LSTM201, show the strongest declining trends. The strength of the trend appears to be correlated to the watershed position, with the smaller drainages expressing stronger trends, and independent of habitat condition. Since the abundance and diversity of fishes in a drainage is correlated to the stream size, the fish community in the smaller channels is more sensitive to watershed stressors, which may explain the declining trends.

The following tables the present the available habitat assessment data at each station for the respective sampling year.

Appendix D

Fish Individual Raw Metrics

Number of intolerant species

Sample Year	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994		1	1				1	1	1	**1.00**
1995		1	1	1	1		1	1	1	**1.00**
1997		1	1			1	1	1	1	**1.00**
1998			1			1		1	1	**1.00**
2000						1	1	1	1	**1.00**
2001						1		1		**1.00**
2002						1				**1.00**
2003						1	1	1	1	**1.00**
2004						1		1		**1.00**
2005						1		1	1	**1.00**
2006						1		1	1	**1.00**
2007	0	1	1	1	1	1	1	2		**1.00**
2008		1	1	1	1	1	1	1		**1.00**
2009		1	1	1	1	1	1	2		**1.14**
2010		1	1	1	1	1	1	1	1	**1.00**
2011		1	1	1	1	1		1	1	**1.00**
2012		1	1	1	1	1	1	1	1	**1.00**
Average	**0.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.13**	**1.00**	**1.01**
R-square	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*0.08*	*NA*	***0.06***
Slope	*NA*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.02*	*0.00*	***0.00***
N	*1*	*9*	*10*	*7*	*7*	*15*	*10*	*16*	*11*	***17***

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

Appendix D

Fish Individual Raw Metrics

Number of minnow species (Cyprinidae)

Sample Year	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994		5	4				6	4	6	**5.00**
1995		5	4	4	4		5	4	6	**4.57**
1997		3	3			4	4	5	4	**3.83**
1998			3			5		5	5	**4.50**
2000						3	6	5	3	**4.25**
2001						3		3		**3.00**
2002						3				**3.00**
2003						3	6	6	3	**4.50**
2004						3		4		**3.50**
2005						3		5	4	**4.00**
2006						3		4	3	**3.33**
2007	3	4	4	5	4	5	6	4		**4.38**
2008		3	4	5	4	3	4	6		**4.14**
2009		4	4	5	5	4	5	5		**4.57**
2010		5	4	5	4	4	7	4	5	**4.75**
2011		5	4	4	5	5		4	4	**4.43**
2012		5	5	5	4	4	6	5	5	**4.88**
Average	**3.00**	**4.33**	**3.90**	**4.71**	**4.29**	**3.67**	**5.50**	**4.56**	**4.36**	**4.15**
R-square	*NA*	*0.00*	*0.33*	*0.28*	*0.09*	*0.04*	*0.05*	*0.01*	*0.09*	***0.01***
Slope	*NA*	*0.01*	*0.05*	*0.04*	*0.03*	*0.04*	*0.03*	*0.02*	*-0.05*	***0.01***
N	*1*	*9*	*10*	*7*	*7*	*15*	*10*	*16*	*11*	***17***

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

Appendix D

Fish Individual Raw Metrics

Number of riffle benthic insectivorous individuals

Sample Year	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994		37	34				105	48	39	**52.60**
1995		86	124	175	151		273	109	91	**144.14**
1997		105	69			95	114	132	173	**114.67**
1998			120			115		187	190	**153.00**
2000						38	79	11	27	**38.75**
2001						95		82		**88.50**
2002						10				**10.00**
2003						17	55	12	27	**27.75**
2004						42		129		**85.50**
2005						7		104	77	**62.67**
2006						17		64	23	**34.67**
2007	2	22	16	155	174	6	170	191		**92.00**
2008		31	38	145	184	32	53	63		**78.00**
2009		41	18	64	123	47	64	113		**67.14**
2010		39	35	146	261	69	154	51	108	**107.88**
2011		35	20	74	78	37		20	57	**45.86**
2012		23	38	67	501	47	154	164	158	**144.00**
Average	**2.00**	**46.56**	**51.20**	**118.00**	**210.29**	**44.93**	**122.10**	**92.50**	**88.18**	**79.24**
R-square	*NA*	*0.46*	*0.46*	*0.46*	*0.11*	*0.17*	*0.05*	*0.00*	*0.00*	***0.01***
Slope	*NA*	*-2.71*	*-3.80*	*-5.62*	*8.03*	*-3.06*	*-2.20*	*-0.12*	*-0.27*	***-0.72***
N	*1*	*9*	*10*	*7*	*7*	*15*	*10*	*16*	*11*	***17***

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

Appendix D

Fish Individual Raw Metrics

Proportion of individuals as omnivores/generalists

Sample Year	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994		57	70				50	36	46	**51.80**
1995		61	46	47	60		40	46	44	**49.14**
1997		61	53			27	40	41	39	**43.50**
1998			49			57		46	56	**52.00**
2000						69	68	81	63	**70.25**
2001						58		52		**55.00**
2002						82				**82.00**
2003						72	64	83	58	**69.25**
2004						59		51		**55.00**
2005						85		40	50	**58.33**
2006						68		60	68	**65.33**
2007	99	75	66	58	56	84	57	45		**67.50**
2008		69	59	64	43	82	61	53		**61.57**
2009		72	74	71	51	80	67	68		**69.00**
2010		75	72	64	54	76	67	74	45	**65.88**
2011		78	71	57	54	74		84	66	**69.14**
2012		80	78	64	59	62	63	59	49	**64.25**
Average	**99.00**	**69.78**	**63.80**	**60.71**	**53.86**	**69.00**	**57.70**	**57.44**	**53.09**	**61.70**
R-square	*NA*	*0.92*	*0.50*	*0.58*	*0.10*	*0.31*	*0.53*	*0.24*	*0.13*	***0.32***
Slope	*NA*	*1.09*	*1.11*	*1.01*	*-0.32*	*1.81*	*1.19*	*1.38*	*0.53*	***0.98***
N	*1*	*9*	*10*	*7*	*7*	*15*	*10*	*16*	*11*	***17***

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

Appendix D

Fish Individual Raw Metrics

Proportion of individuals as pioneering species

Sample Year	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994		33	65				41	15	5	**31.80**
1995		43	43	35	36		26	24	8	**30.71**
1997		47	51			24	28	22	10	**30.33**
1998			48			55		27	40	**42.50**
2000						65	58	63	15	**50.25**
2001						57		30		**43.50**
2002						81				**81.00**
2003						70	55	70	39	**58.50**
2004						59		32		**45.50**
2005						85		27	25	**45.67**
2006						66		28	32	**42.00**
2007	99	67	58	55	31	80	46	25		**57.63**
2008		64	54	57	33	82	52	29		**53.00**
2009		69	69	67	36	80	65	53		**62.71**
2010		68	67	64	28	76	48	53	30	**54.25**
2011		72	65	48	41	73		52	38	**55.57**
2012		70	61	50	55	55	54	48	32	**53.13**
Average	**99.00**	**59.22**	**58.10**	**53.71**	**37.14**	**67.20**	**47.30**	**37.38**	**24.91**	**49.30**
R-square	*NA*	*0.96*	*0.36*	*0.43*	*0.08*	*0.29*	*0.45*	*0.22*	*0.47*	***0.33***
Slope	*NA*	*1.92*	*0.73*	*1.23*	*0.43*	*1.81*	*1.27*	*1.33*	*1.38*	***1.30***
N	*1*	*9*	*10*	*7*	*7*	*15*	*10*	*16*	*11*	***17***

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

Appendix D

Fish Individual Raw Metrics

Proportion of tolerant individuals

Sample Year	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994		61	68				48	45	52	**54.80**
1995		50	44	36	37		31	33	24	**36.43**
1997		56	53			24	34	27	19	**35.50**
1998			49			56		39	47	**47.75**
2000						65	60	66	50	**60.25**
2001						57		31		**44.00**
2002						82				**82.00**
2003						72	64	75	49	**65.00**
2004						59		39		**49.00**
2005						85		28	28	**47.00**
2006						68		44	57	**56.33**
2007	99	67	60	57	55	83	55	31		**63.38**
2008		65	54	62	35	82	58	43		**57.00**
2009		69	69	69	38	80	68	59		**64.57**
2010		68	67	64	46	76	59	64	39	**60.38**
2011		72	68	57	44	73		71	57	**63.14**
2012		70	62	59	56	61	57	51	38	**56.75**
Average	**99.00**	**64.22**	**59.40**	**57.71**	**44.43**	**68.20**	**53.40**	**46.63**	**41.82**	**55.49**
R-square	*NA*	*0.80*	*0.30*	*0.74*	*0.19*	*0.33*	*0.50*	*0.16*	*0.07*	***0.22***
Slope	*NA*	*0.89*	*0.68*	*1.57*	*0.65*	*1.93*	*1.30*	*1.11*	*0.53*	***0.96***
N	*1*	*9*	*10*	*7*	*7*	*15*	*10*	*16*	*11*	***17***

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

Appendix D

Fish Individual Raw Metrics

Proportion with disease/anomalies

Sample Year	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994		0.5	0				1.2	9.1	13.1	**4.78**
1995		0	0	0	0		0.4	0	0.5	**0.13**
1997		0.4	0			0.7	0	0.4	0.4	**0.32**
1998			1.5			0		0.2	2.7	**1.10**
2000						0	1.6	4.2	4.6	**2.60**
2001						0		0		**0.00**
2002						0				**0.00**
2003						0	1.8	1.7	0	**0.88**
2004						0		0		**0.00**
2005						0		0	0	**0.00**
2006						0		0	1.3	**0.43**
2007	1.8	3.6	2.4	2.8	0.1	2.1	1.7	0		**1.81**
2008		0	0.3	1.7	0	0.3	0.6	0.3		**0.46**
2009		0.4	4.3	1.9	3	0.3	9.3	3.6		**3.26**
2010		3	1	0.2	0	2.1	1.9	0.9	0.5	**1.20**
2011		0	0	0	0	0		0	4.3	**0.61**
2012		0	2.7	0.8	0.1	0	0.2	1.1	0.9	**0.73**
Average	**1.80**	**0.88**	**1.22**	**1.06**	**0.46**	**0.37**	**1.87**	**1.34**	**2.57**	**1.08**
R-square	*NA*	*0.04*	*0.24*	*0.03*	*0.02*	*0.06*	*0.11*	*0.13*	*0.15*	***0.03***
Slope	*NA*	*0.04*	*0.10*	*0.04*	*0.03*	*0.04*	*0.13*	*-0.15*	*-0.23*	***-0.04***
N	*1*	*9*	*10*	*7*	*7*	*15*	*10*	*16*	*11*	***17***

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

Appendix D

Fish Individual Raw Metrics

Total number of fish species

Sample Year	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994		14	9				12	12	15	**12.40**
1995		13	11	11	10		12	13	12	**11.71**
1997		11	8			9	11	12	10	**10.17**
1998			7			9		12	15	**10.75**
2000						8	12	11	12	**10.75**
2001						7		8		**7.50**
2002						7				**7.00**
2003						11	14	12	11	**12.00**
2004						7		12		**9.50**
2005						7		12	10	**9.67**
2006						7		9	7	**7.67**
2007	4	8	11	12	9	10	13	13		**10.00**
2008		8	11	13	10	6	10	14		**10.29**
2009		9	10	11	11	8	13	13		**10.71**
2010		10	9	12	12	8	16	10	12	**11.13**
2011		11	11	12	14	9		12	13	**11.71**
2012		9	10	10	12	12	13	13	12	**11.38**
Average	**4.00**	**10.33**	**9.70**	**11.57**	**11.14**	**8.33**	**12.60**	**11.75**	**11.73**	**10.25**
R-square	*NA*	*0.61*	*0.20*	*0.00*	*0.28*	*0.03*	*0.17*	*0.01*	*0.08*	***0.00***
Slope	*NA*	*-0.23*	*0.09*	*0.01*	*0.15*	*0.06*	*0.10*	*0.02*	*-0.10*	***-0.01***
N	*1*	*9*	*10*	*7*	*7*	*15*	*10*	*16*	*11*	***17***

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

Appendix D

Fish Individual Raw Metrics

Total number of individuals (ex tolerant sp.)

Sample Year	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994		163	118				169	61	96	**121.40**
1995		296	344	265	207		370	181	156	**259.86**
1997		238	79			108	136	171	217	**158.17**
1998			137			144		252	239	**193.00**
2000						49	130	40	55	**68.50**
2001						123		110		**116.50**
2002						41				**41.00**
2003						42	103	30	53	**57.00**
2004						56		146		**101.00**
2005						13		137	110	**86.67**
2006						52		103	33	**62.67**
2007	3	63	99	217	420	55	320	227		**175.50**
2008		62	131	269	348	53	137	178		**168.29**
2009		72	85	100	244	69	116	196		**126.00**
2010		74	69	165	353	90	210	114	133	**151.00**
2011		72	59	100	131	63		58	88	**81.57**
2012		53	100	98	750	104	211	229	211	**219.50**
Average	**3.00**	**121.44**	**122.10**	**173.43**	**350.43**	**70.80**	**190.20**	**139.56**	**126.45**	**128.68**
R-square	*NA*	*0.79*	*0.30*	*0.48*	*0.14*	*0.06*	*0.01*	*0.01*	*0.02*	***0.01***
Slope	*NA*	*-10.96*	*-6.24*	*-9.34*	*13.32*	*-1.88*	*-1.54*	*1.47*	*-1.58*	***-1.07***
N	*1*	*9*	*10*	*7*	*7*	*15*	*10*	*16*	*11*	***17***

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

Appendix D

Fish Individual Scaled Metrics

Number of intolerant species

Sample Year	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994		3	3				1	1	1	**1.80**
1995		3	3	3	3		1	1	1	**2.14**
1997		3	3			3	1	1	1	**2.00**
1998			3			3		1	1	**2.00**
2000						3	1	1	1	**1.50**
2001						3		1		**2.00**
2002						3				**3.00**
2003						3	1	1	1	**1.50**
2004						3		1		**2.00**
2005						3		1	1	**1.67**
2006						3		1	1	**1.67**
2007	1	3	3	3	3	3	1	3		**2.50**
2008		3	3	3	3	3	1	1		**2.43**
2009		3	3	3	3	3	1	3		**2.71**
2010		3	3	3	3	3	1	1	1	**2.25**
2011		3	3	3	3	3		1	1	**2.43**
2012		3	3	3	3	3	1	1	1	**2.25**
Average	**1.00**	**3.00**	**3.00**	**3.00**	**3.00**	**3.00**	**1.00**	**1.25**	**1.00**	**2.11**
R-square	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*0.08*	*NA*	***0.14***
Slope	*NA*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.03*	*0.00*	***0.03***
N	*1*	*9*	*10*	*7*	*7*	*15*	*10*	*16*	*11*	***17***

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

Appendix D

Fish Individual Scaled Metrics

Number of minnow species (Cyprinidae)

Sample Year	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994		5	5				3	3	3	**3.80**
1995		5	5	5	5		3	3	3	**4.14**
1997		5	5			5	3	3	3	**4.00**
1998			5			5		3	3	**4.00**
2000						5	3	3	1	**3.00**
2001						5		1		**3.00**
2002						5				**5.00**
2003						5	3	3	1	**3.00**
2004						5		3		**4.00**
2005						5		3	3	**3.67**
2006						5		3	1	**3.00**
2007	5	5	5	5	5	5	3	3		**4.50**
2008		5	5	5	5	5	3	3		**4.43**
2009		5	5	5	5	5	3	3		**4.43**
2010		5	5	5	5	5	5	3	3	**4.50**
2011		5	5	5	5	5		3	3	**4.43**
2012		5	5	5	5	5	3	3	3	**4.25**
Average	**5.00**	**5.00**	**5.00**	**5.00**	**5.00**	**5.00**	**3.20**	**2.88**	**2.45**	**3.95**
R-square	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*0.12*	*0.02*	*0.00*	***0.10***
Slope	*NA*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.03*	*0.01*	*0.00*	***0.04***
N	*1*	*9*	*10*	*7*	*7*	*15*	*10*	*16*	*11*	***17***

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

Appendix D

Fish Individual Scaled Metrics

Number of riffle benthic insectivorous individuals

Sample Year	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994		5	5				5	3	1	**3.80**
1995		5	5	5	5		5	5	5	**5.00**
1997		5	5			5	5	5	5	**5.00**
1998			5			5		5	5	**5.00**
2000						5	3	1	1	**2.50**
2001						5		5		**5.00**
2002						1				**1.00**
2003						3	3	1	1	**2.00**
2004						5		5		**5.00**
2005						1		5	3	**3.00**
2006						3		3	1	**2.33**
2007	1	3	3	5	5	1	5	5		**3.50**
2008		5	5	5	5	5	3	3		**4.43**
2009		5	3	5	5	5	3	5		**4.43**
2010		5	5	5	5	5	5	3	5	**4.75**
2011		5	3	5	5	5		1	3	**3.86**
2012		3	5	5	5	5	5	5	5	**4.75**
Average	**1.00**	**4.56**	**4.40**	**5.00**	**5.00**	**3.93**	**4.20**	**3.75**	**3.18**	**3.84**
R-square	*NA*	*0.14*	*0.22*	*NA*	*NA*	*0.00*	*0.04*	*0.01*	*0.01*	***0.00***
Slope	*NA*	*-0.04*	*-0.06*	*0.00*	*0.00*	*0.01*	*-0.03*	*-0.03*	*0.03*	***0.00***
N	*1*	*9*	*10*	*7*	*7*	*15*	*10*	*16*	*11*	***17***

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

Appendix D

Fish Individual Scaled Metrics

Proportion of individuals as omnivores/generalists

Sample Year	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994		5	3				5	5	5	**4.60**
1995		5	5	5	5		5	5	5	**5.00**
1997		5	5			5	5	5	5	**5.00**
1998			5			5		5	3	**4.50**
2000						3	3	1	3	**2.50**
2001						5		3		**4.00**
2002						1				**1.00**
2003						3	3	1	3	**2.50**
2004						5		3		**4.00**
2005						1		5	5	**3.67**
2006						3		3	3	**3.00**
2007	1	3	3	5	5	1	3	5		**3.25**
2008		3	5	3	5	1	3	3		**3.29**
2009		3	3	3	5	3	3	3		**3.29**
2010		3	3	3	5	3	3	3	5	**3.50**
2011		3	3	5	5	3		1	3	**3.29**
2012		3	3	3	5	3	3	3	5	**3.50**
Average	**1.00**	**3.67**	**3.80**	**3.86**	**5.00**	**3.00**	**3.60**	**3.38**	**4.09**	**3.52**
R-square	*NA*	*0.95*	*0.30*	*0.25*	*NA*	*0.20*	*0.72*	*0.20*	*0.01*	***0.18***
Slope	*NA*	*-0.13*	*-0.08*	*-0.09*	*0.00*	*-0.14*	*-0.12*	*-0.12*	*-0.02*	***-0.08***
N	*1*	*9*	*10*	*7*	*7*	*15*	*10*	*16*	*11*	***17***

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

Appendix D

Fish Individual Scaled Metrics

Proportion of individuals as pioneering species

Sample Year	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994		5	3				3	5	5	**4.20**
1995		5	5	5	5		5	5	5	**5.00**
1997		5	5			5	3	5	5	**4.67**
1998			5			3		5	3	**4.00**
2000						3	3	3	5	**3.50**
2001						3		3		**3.00**
2002						1				**1.00**
2003						3	3	1	3	**2.50**
2004						3		3		**3.00**
2005						1		5	5	**3.67**
2006						3		3	3	**3.00**
2007	1	3	3	3	5	1	3	5		**3.00**
2008		3	3	3	5	1	3	3		**3.00**
2009		3	3	3	5	1	1	3		**2.71**
2010		3	3	3	5	3	3	3	3	**3.25**
2011		3	3	5	5	3		3	3	**3.57**
2012		3	3	5	3	3	3	3	3	**3.25**
Average	**1.00**	**3.67**	**3.60**	**3.86**	**4.71**	**2.47**	**3.00**	**3.63**	**3.91**	**3.31**
R-square	*NA*	*0.95*	*0.51*	*0.05*	*0.12*	*0.14*	*0.25*	*0.25*	*0.46*	***0.21***
Slope	*NA*	*-0.13*	*-0.10*	*-0.04*	*-0.05*	*-0.09*	*-0.07*	*-0.10*	*-0.11*	***-0.07***
N	*1*	*9*	*10*	*7*	*7*	*15*	*10*	*16*	*11*	***17***

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

Appendix D

Fish Individual Scaled Metrics

Proportion of tolerant individuals

Sample Year	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994		3	3				3	3	3	**3.00**
1995		5	5	5	5		5	5	5	**5.00**
1997		5	5			5	3	5	5	**4.67**
1998			5			5		3	3	**4.00**
2000						3	3	3	3	**3.00**
2001						5		5		**5.00**
2002						1				**1.00**
2003						3	3	1	3	**2.50**
2004						3		3		**3.00**
2005						1		5	5	**3.67**
2006						3		3	3	**3.00**
2007	1	3	3	5	5	1	3	5		**3.25**
2008		3	5	3	5	1	3	3		**3.29**
2009		3	3	3	5	1	1	3		**2.71**
2010		3	3	3	5	3	3	3	3	**3.25**
2011		3	3	5	5	3		1	3	**3.29**
2012		3	3	3	5	3	3	3	3	**3.25**
Average	**1.00**	**3.44**	**3.80**	**3.86**	**5.00**	**2.73**	**3.00**	**3.38**	**3.55**	**3.35**
R-square	*NA*	*0.47*	*0.30*	*0.25*	*NA*	*0.27*	*0.25*	*0.13*	*0.14*	***0.11***
Slope	*NA*	*-0.08*	*-0.08*	*-0.09*	*0.00*	*-0.16*	*-0.07*	*-0.08*	*-0.05*	***-0.06***
N	*1*	*9*	*10*	*7*	*7*	*15*	*10*	*16*	*11*	***17***

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

Appendix D

Fish Individual Scaled Metrics

Proportion with disease/anomalies

Sample Year	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994		5	5				5	1	1	**3.40**
1995		5	5	5	5		5	5	5	**5.00**
1997		5	5			5	5	5	5	**5.00**
1998			5			5		5	5	**5.00**
2000						5	5	5	5	**5.00**
2001						5		5		**5.00**
2002						5				**5.00**
2003						5	5	5	5	**5.00**
2004						5		5		**5.00**
2005						5		5	5	**5.00**
2006						5		5	5	**5.00**
2007	5	3	5	3	5	5	5	5		**4.50**
2008		5	5	5	5	5	5	5		**5.00**
2009		5	3	5	3	5	1	5		**3.86**
2010		3	5	5	5	5	5	5	5	**4.75**
2011		5	5	5	5	5		5	5	**5.00**
2012		5	3	5	5	5	5	5	5	**4.75**
Average	**5.00**	**4.56**	**4.60**	**4.71**	**4.71**	**5.00**	**4.60**	**4.75**	**4.64**	**4.78**
R-square	*NA*	*0.08*	*0.22*	*0.00*	*0.01*	*NA*	*0.09*	*0.20*	*0.20*	***0.01***
Slope	*NA*	*-0.04*	*-0.06*	*0.00*	*-0.02*	*0.00*	*-0.06*	*0.08*	*0.08*	***0.01***
N	*1*	*9*	*10*	*7*	*7*	*15*	*10*	*16*	*11*	***17***

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

Appendix D

Fish Individual Scaled Metrics

Total number of fish species

Sample Year	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994		5	5				5	5	5	**5.00**
1995		5	5	5	5		5	5	5	**5.00**
1997		5	5			5	3	5	3	**4.33**
1998			3			5		5	5	**4.50**
2000						5	5	3	5	**4.50**
2001						3		3		**3.00**
2002						3				**3.00**
2003						5	5	5	3	**4.50**
2004						3		5		**4.00**
2005						3		5	3	**3.67**
2006						3		3	3	**3.00**
2007	3	5	5	5	5	5	5	5		**4.75**
2008		5	5	5	5	3	3	5		**4.43**
2009		5	5	5	5	5	5	5		**5.00**
2010		5	5	5	5	5	5	3	5	**4.75**
2011		5	5	5	5	5		5	5	**5.00**
2012		5	5	5	5	5	5	5	5	**5.00**
Average	**3.00**	**5.00**	**4.80**	**5.00**	**5.00**	**4.20**	**4.60**	**4.50**	**4.27**	**4.32**
R-square	*NA*	*NA*	*0.09*	*NA*	*NA*	*0.01*	*0.01*	*0.00*	*0.00*	***0.01***
Slope	*NA*	*0.00*	*0.03*	*0.00*	*0.00*	*0.02*	*0.01*	*-0.01*	*0.00*	***0.01***
N	*1*	*9*	*10*	*7*	*7*	*15*	*10*	*16*	*11*	***17***

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

Appendix D

Fish Individual Scaled Metrics

Total number of individuals (ex tolerant sp.)

Sample Year	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994		5	5				3	1	1	**3.00**
1995		5	5	5	5		5	3	3	**4.43**
1997		5	3			5	3	3	5	**4.00**
1998			5			5		5	5	**5.00**
2000						3	3	1	1	**2.00**
2001						5		3		**4.00**
2002						1				**1.00**
2003						1	1	1	1	**1.00**
2004						3		3		**3.00**
2005						1		3	3	**2.33**
2006						3		1	1	**1.67**
2007	1	3	5	5	5	3	5	5		**4.00**
2008		3	5	5	5	3	3	3		**3.86**
2009		3	3	5	5	3	3	3		**3.57**
2010		3	3	5	5	3	5	3	3	**3.75**
2011		3	3	5	5	3		1	1	**3.00**
2012		3	5	5	5	5	5	5	5	**4.75**
Average	**1.00**	**3.67**	**4.20**	**5.00**	**5.00**	**3.13**	**3.60**	**2.75**	**2.64**	**3.20**
R-square	*NA*	*0.95*	*0.10*	*NA*	*NA*	*0.02*	*0.07*	*0.03*	*0.00*	***0.00***
Slope	*NA*	*-0.13*	*-0.05*	*0.00*	*0.00*	*-0.04*	*0.05*	*0.04*	*-0.01*	***0.00***
N	*1*	*9*	*10*	*7*	*7*	*15*	*10*	*16*	*11*	***17***

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

Appendix D

Fish Individual Scaled Metrics

Composite

Sample Year	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994		4.56	4.11				3.67	3.00	2.78	**3.00**
1995		4.78	4.78	4.78	4.78		4.33	4.11	4.11	**4.43**
1997		4.78	4.56			4.78	3.44	4.11	4.11	**4.00**
1998			4.56			4.56		4.11	3.67	**5.00**
2000						3.89	3.22	2.33	2.78	**2.00**
2001						4.33		3.22		**4.00**
2002						2.33				**1.00**
2003						3.44		2.11	2.33	**1.00**
2004						3.89		3.44		**3.00**
2005						2.33		4.11	3.67	**2.33**
2006						3.44		2.78	2.33	**1.67**
2007	2.11	3.44	3.89	4.33	4.78	2.78	3.67	4.56		**4.00**
2008		3.89	4.56	4.11	4.78	3.00	3.00	3.22		**3.86**
2009		3.89	3.44	4.11	4.56	3.44	2.33	3.67		**3.57**
2010		3.67	3.89	4.11	4.78	3.89	3.89	3.00	3.67	**3.75**
2011		3.89	3.67	4.78	4.78	3.89		2.33	3.00	**3.00**
2012		3.67	3.89	4.33	4.56	4.11	3.67	3.67	3.89	**4.75**
Average	2.11	4.06	4.13	4.37	4.71	3.61	3.47	3.36	3.30	**3.20**
R-square	NA	**0.81**	**0.48**	0.23	0.13	0.08	0.13	0.02	0.01	**0.00**
Slope	NA	-0.06	-0.04	-0.03	-0.01	-0.05	-0.03	-0.02	-0.01	**0.00**

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

3.0 Benthic Macroinvertebrates

The benthic macroinvertebrate communities were assessed by DEP staff during spring index periods with the respective sampling years in accordance with the Maryland Biological Stream Survey (MBSS) methods (Kayzak, 2001). The DEP Benthic IBI evaluates 8 metrics, which include the following:

- Taxa Richness
- Biotic Index
- Proportion of Dominant Taxa
- Proportion of Ephemeropera, Plecoptera, and Tricoptera (EPT) Individuals
- Proportion of Hydropsyche & Cheumatopsyche
- Proportion of Shredders
- Ratio of Scrapers
- Total Number of EPT Taxa

Each of these metrics is assigned a metric score of 1, 3, or 5 depending on the calculated value, stream order, and presence/absence of Channery Silt Loam and the sum of the metric scores is reported according to the following criteria in Table D-4:

Table D-4. Benthic IBI scoring criteria

Condition category	Score
Excellent	≥36
Good	26-35
Fair	17-25
Poor	<17

Source: Keith Van Ness, personal communication, January 10, 2013.

The overall Benthic IBI scores indicate that the benthic macroinvertebrate community within the Ten Mile Creek drainage is in generally good condition. A similar condition is gained using the MBSS scoring criteria (Southerland et al. 2006), which references a statewide dataset stratified by ecoregion.

Observations in the benthic macroinvertebrate community data over time include:

- Data from the 2003 sample year includes consistently low scores.
- The percent scrapers scored relatively low with declining trends at some stations.
- Overall the first-order streams scored poor in metrics where third-order streams scored fair.
- Overall the number of taxa appears to be increasing.
- The number of Ephemeroptera show some declining trends most pronounced at stations LSTM201 and LSTM206. Trends persist in both the number of individuals and diversity of taxa.
- The first-order streams score fair to good on percent intolerant while second-order score poor to fair, and data from third-order stations were inconsistent. There is some indication that the scores are declining over time.
- The number of taxa is increasing in first-order channels and somewhat consistent to slightly declining in higher order channels.
- The number of EPT weakly declined at stations LSTM110, 201, and 202

Appendix D

DEP Benthic Macroinvertebrate Raw Metric Scores

- Station LSTM201 shows an overall declining trend in most metrics

Other than minor shifts in the benthic macroinvertebrate community structure, the community appears to be stable. The rates of change associated with any observed trends are generally slow and only likely to influence the overall Benthic IBI score over period of decades if natural recovery does not occur. These trends indicate the tendency toward degradation if stressor levels are increased.

Appendix D

DEP Benthic Macroinvertebrate Raw Metric Scores

Biotic Index

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994	NA	NA	NA	4.18	4.29	NA	NA	NA	3.01	3.55	4.09	**3.82**
1995	NA	NA	NA	3.56	3.78	5.76	3.98	NA	3.74	3.38	3.72	**3.99**
1996	3.22	NA	NA	3.46	3.89	4.41	4.22	NA	2.84	3.00	3.83	**3.61**
1997	3.58	NA	NA	3.70	3.78	NA	5.04	5.21	4.19	3.84	3.89	**4.15**
1998	3.70	NA	NA	3.20	3.12	NA	NA	3.31	NA	3.81	NA	**3.43**
1999	NA	NA	NA	4.72	3.67	NA	NA	5.64	NA	4.17	NA	**4.55**
2000	NA	NA	NA	NA	NA	NA	NA	6.27	3.54	4.29	4.72	**4.71**
2001	NA	NA	NA	NA	NA	NA	NA	6.10	NA	3.41	NA	**4.76**
2002	NA	NA	NA	NA	NA	NA	NA	6.42	NA	4.82	NA	**5.62**
2003	3.01	3.74	3.16	3.48	5.00	4.00	5.87	5.98	3.82	3.91	NA	**4.20**
2004	3.10	NA	NA	NA	NA	NA	NA	6.10	NA	3.04	NA	**4.08**
2005	NA	3.13	3.19	NA	NA	NA	NA	6.60	NA	3.77	NA	**4.17**
2006	4.97	NA	4.55	NA	NA	NA	NA	6.70	NA	3.77	NA	**5.00**
2007	3.41	NA	4.90	5.63	5.92	4.57	4.47	6.48	4.75	5.32	NA	**5.05**
2008	NA	NA	3.56	5.34	6.55	3.42	4.19	7.12	3.80	4.50	NA	**4.81**
2009	3.64	NA	5.01	5.16	4.82	4.01	3.96	5.40	5.80	4.23	NA	**4.67**
2010	3.08	NA	4.18	5.45	4.26	3.59	4.02	5.60	4.45	3.75	4.93	**4.33**
2011	2.94	3.50	4.04	5.16	5.10	3.97	4.85	6.18	4.04	4.10	4.96	**4.44**
2012	4.82	5.43	6.65	4.60	5.46	5.94	3.53	5.46	5.44	5.50	5.46	**5.30**
Average	**3.59**	**3.95**	**4.36**	**4.43**	**4.59**	**4.41**	**4.41**	**5.91**	**4.12**	**4.01**	**4.45**	**4.46**
R-square	*0.04*	***0.36***	***0.44***	***0.58***	***0.49***	*0.08*	*0.06*	*0.12*	***0.52***	*0.28*	***0.85***	***0.31***
Slope	*0.02*	*0.14*	*0.25*	*0.10*	*0.10*	*-0.04*	*-0.03*	*0.06*	*0.09*	*0.06*	*0.08*	*0.06*
N	*11.00*	*4.00*	*9.00*	*13.00*	*13.00*	*9.00*	*10.00*	*16.00*	*12.00*	*19.00*	*8.00*	*19.00*

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

Appendix D

DEP Benthic Macroinvertebrate Raw Metric Scores

Proportion of Dominant Taxa

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994	NA	NA	NA	20.00	18.00	NA	NA	NA	12.00	13.00	15.00	**15.60**
1995	NA	NA	NA	20.50	43.00	29.00	32.00	NA	31.00	25.50	29.50	**30.07**
1996	21.00	NA	NA	27.00	12.00	23.00	22.00	NA	22.00	37.00	20.00	**23.00**
1997	22.00	NA	NA	32.00	33.00	NA	41.00	44.00	32.00	33.00	44.00	**35.13**
1998	52.00	NA	NA	49.00	45.00	NA	NA	80.00	NA	55.00	NA	**56.20**
1999	NA	NA	NA	40.00	52.00	NA	NA	60.00	NA	44.00	NA	**49.00**
2000	NA	NA	NA	NA	NA	NA	NA	67.00	28.00	35.00	46.00	**44.00**
2001	NA	NA	NA	NA	NA	NA	NA	78.00	NA	36.00	NA	**57.00**
2002	NA	NA	NA	NA	NA	NA	NA	81.00	NA	35.00	NA	**58.00**
2003	71.00	69.00	78.00	38.00	45.00	43.00	60.00	69.00	64.00	67.00	NA	**60.40**
2004	38.00	NA	NA	NA	NA	NA	NA	58.00	NA	37.00	NA	**44.33**
2005	NA	37.00	45.00	NA	NA	NA	NA	83.00	NA	30.00	NA	**48.75**
2006	31.00	NA	46.00	NA	NA	NA	NA	88.00	NA	33.00	NA	**49.50**
2007	44.00	NA	47.00	57.00	56.00	43.00	26.00	79.00	36.00	50.00	NA	**48.67**
2008	NA	NA	65.00	44.00	84.00	37.00	30.00	93.00	56.00	36.00	NA	**55.63**
2009	55.00	NA	37.00	43.00	23.00	43.00	49.00	37.00	68.00	46.00	NA	**44.56**
2010	31.00	NA	39.00	49.00	50.00	29.00	45.00	56.00	37.00	70.00	33.00	**43.90**
2011	36.00	73.00	59.00	48.00	40.00	25.00	39.00	57.00	48.00	53.00	36.00	**46.73**
2012	43.00	44.00	87.00	38.00	44.00	62.00	23.00	52.00	49.00	43.00	51.00	**48.73**
Average	**40.36**	**55.75**	**55.89**	**38.88**	**41.92**	**37.11**	**36.70**	**67.63**	**40.25**	**40.97**	**34.31**	**45.22**
R-square	*0.05*	*0.00*	*0.01*	***0.50***	*0.18*	*0.22*	*0.01*	*0.02*	***0.49***	*0.26*	*0.30*	*0.26*
Slope	*0.55*	*-0.09*	*0.46*	*1.19*	*1.16*	*0.91*	*0.17*	*-0.46*	*1.75*	*1.25*	*0.88*	*1.08*
N	*11.00*	*4.00*	*9.00*	*13.00*	*13.00*	*9.00*	*10.00*	*16.00*	*12.00*	*19.00*	*8.00*	*19.00*

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Appendix D

DEP Benthic Macroinvertebrate Raw Metric Scores

Proportion of EPT Individuals

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994	NA	NA	NA	59.00	32.00	NA	NA	NA	51.00	58.00	43.00	**48.60**
1995	NA	NA	NA	63.00	57.00	41.00	84.00	NA	35.00	49.50	62.50	**56.00**
1996	62.00	NA	NA	53.00	26.00	42.00	52.00	NA	44.00	37.00	44.00	**45.00**
1997	79.00	NA	NA	71.00	68.00	NA	34.00	38.00	55.00	72.00	75.00	**61.50**
1998	69.00	NA	NA	80.00	83.00	NA	NA	90.00	NA	65.00	NA	**77.40**
1999	NA	NA	NA	46.00	71.00	NA	NA	27.00	NA	66.00	NA	**52.50**
2000	NA	NA	NA	NA	NA	NA	NA	13.00	45.00	58.00	49.00	**41.25**
2001	NA	NA	NA	NA	NA	NA	NA	18.00	NA	70.00	NA	**44.00**
2002	NA	NA	NA	NA	NA	NA	NA	11.00	NA	44.00	NA	**27.50**
2003	88.00	76.00	90.00	59.00	39.00	72.00	34.00	19.00	73.00	74.00	NA	**62.40**
2004	76.00	NA	NA	NA	NA	NA	NA	15.00	NA	69.00	NA	**53.33**
2005	NA	70.00	89.00	NA	NA	NA	NA	6.00	NA	65.00	NA	**57.50**
2006	49.00	NA	40.00	NA	NA	NA	NA	4.00	NA	52.00	NA	**36.25**
2007	78.00	NA	44.00	20.00	24.00	47.00	64.00	10.00	46.00	31.00	NA	**40.44**
2008	NA	NA	83.00	30.00	10.00	75.00	76.00	0.00	75.00	61.00	NA	**51.25**
2009	77.00	NA	39.00	41.00	60.00	63.00	76.00	39.00	29.00	65.00	NA	**54.33**
2010	80.00	NA	67.00	20.00	67.00	64.00	77.00	30.00	62.00	80.00	57.00	**60.40**
2011	81.00	84.00	66.00	25.00	24.00	45.00	45.00	10.00	65.00	60.00	37.00	**49.27**
2012	46.00	37.00	6.00	41.00	36.00	21.00	68.00	30.00	28.00	36.00	35.00	**34.91**
Average	**71.36**	**66.75**	**58.22**	**46.77**	**45.92**	**52.22**	**61.00**	**22.50**	**50.67**	**58.55**	**50.31**	**50.20**
R-square	*0.01*	*0.20*	***0.34***	***0.61***	*0.09*	*0.01*	*0.06*	*0.12*	*0.01*	*0.00*	*0.20*	*0.05*
Slope	*-0.19*	*-2.10*	*-5.63*	*-2.27*	*-1.00*	*0.20*	*0.68*	*-1.59*	*0.24*	*-0.03*	*-0.78*	*-0.44*
N	*11.00*	*4.00*	*9.00*	*13.00*	*13.00*	*9.00*	*10.00*	*16.00*	*12.00*	*19.00*	*8.00*	*19.00*

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Appendix D

DEP Benthic Macroinvertebrate Raw Metric Scores

Proportion of Hydropsyche & Cheumatopsyche

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994	NA	NA	NA	9.00	21.00	NA	NA	NA	32.00	17.00	41.00	**24.00**
1995	NA	NA	NA	5.50	2.50	4.00	37.50	NA	4.00	9.00	7.00	**9.93**
1996	0.00	NA	NA	2.00	2.00	2.00	18.00	NA	5.00	0.00	28.00	**7.13**
1997	1.00	NA	NA	5.00	4.00	NA	1.00	5.00	3.00	8.00	13.00	**5.00**
1998	0.00	NA	NA	0.00	0.00	NA	NA	0.00	NA	0.00	NA	**0.00**
1999	NA	NA	NA	1.00	0.00	NA	NA	8.00	NA	0.00	NA	**2.25**
2000	NA	NA	NA	NA	NA	NA	NA	0.00	0.00	1.00	0.00	**0.25**
2001	NA	NA	NA	NA	NA	NA	NA	8.00	NA	2.00	NA	**5.00**
2002	NA	NA	NA	NA	NA	NA	NA	18.00	NA	0.00	NA	**9.00**
2003	0.00	0.00	0.00	0.00	0.00	1.00	15.00	10.00	0.00	0.00	NA	**2.60**
2004	1.00	NA	NA	NA	NA	NA	NA	10.00	NA	0.00	NA	**3.67**
2005	NA	1.00	0.00	NA	NA	NA	NA	17.00	NA	1.00	NA	**4.75**
2006	0.00	NA	0.00	NA	NA	NA	NA	20.00	NA	0.00	NA	**5.00**
2007	0.00	NA	1.00	3.00	3.00	1.00	16.00	32.00	0.00	3.00	NA	**6.56**
2008	NA	NA	0.00	24.00	0.00	0.00	33.00	60.00	0.00	0.00	NA	**14.63**
2009	0.00	NA	0.00	10.00	5.00	0.00	11.00	19.00	4.00	6.00	NA	**6.11**
2010	0.00	NA	0.00	6.00	2.00	2.00	18.00	19.00	9.00	1.00	13.00	**7.00**
2011	0.00	0.00	0.00	3.00	11.00	0.00	3.00	43.00	3.00	0.00	9.00	**6.55**
2012	3.00	2.00	0.00	3.00	2.00	2.00	2.00	6.00	0.00	2.00	17.00	**3.55**
Average	**0.45**	**0.75**	**0.11**	**5.50**	**4.04**	**1.33**	**15.45**	**17.19**	**5.00**	**2.63**	**16.00**	**6.47**
R-square	*0.06*	*0.20*	*0.01*	*0.05*	*0.03*	***0.39***	*0.11*	***0.34***	*0.19*	*0.21*	*0.12*	*0.04*
Slope	*0.04*	*0.10*	*-0.01*	*0.21*	*-0.16*	*-0.13*	*-0.64*	*1.97*	*-0.58*	*-0.36*	*-0.57*	*-0.19*
N	*11.00*	*4.00*	*9.00*	*13.00*	*13.00*	*9.00*	*10.00*	*16.00*	*12.00*	*19.00*	*8.00*	*19.00*

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Appendix D

DEP Benthic Macroinvertebrate Raw Metric Scores

Proportion of Shredders

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994	NA	NA	NA	7.66	12.15	NA	NA	NA	9.66	19.69	16.82	**13.20**
1995	NA	NA	NA	12.66	27.43	16.15	6.25	NA	16.53	16.74	42.59	**19.76**
1996	30.62	NA	NA	31.00	9.24	21.90	12.68	NA	13.43	12.50	10.98	**17.79**
1997	23.90	NA	NA	35.50	35.41	NA	19.63	27.67	28.38	33.95	44.44	**31.11**
1998	57.14	NA	NA	54.63	47.06	NA	NA	80.17	NA	57.67	NA	**59.33**
1999	NA	NA	NA	23.46	56.14	NA	NA	15.10	NA	52.52	NA	**36.81**
2000	NA	NA	NA	NA	NA	NA	NA	8.08	17.41	35.63	33.65	**23.69**
2001	NA	NA	NA	NA	NA	NA	NA	7.75	NA	37.96	NA	**22.86**
2002	NA	NA	NA	NA	NA	NA	NA	6.00	NA	18.90	NA	**12.45**
2003	75.34	73.98	79.10	57.14	36.27	45.24	13.45	9.82	63.50	67.27	NA	**52.11**
2004	21.37	NA	NA	NA	NA	NA	NA	7.80	NA	18.03	NA	**15.73**
2005	NA	21.74	48.12	NA	NA	NA	NA	3.92	NA	32.28	NA	**26.52**
2006	30.10	NA	27.52	NA	NA	NA	NA	0.84	NA	19.27	NA	**19.43**
2007	56.15	NA	32.58	10.07	17.65	27.14	24.20	3.66	32.82	11.76	NA	**24.00**
2008	NA	NA	66.00	10.00	4.76	46.72	29.52	1.18	58.65	35.51	NA	**31.54**
2009	62.91	NA	26.98	10.95	19.08	44.78	50.79	2.99	17.77	46.43	NA	**31.41**
2010	45.88	NA	44.41	11.84	53.67	32.79	46.06	21.13	43.08	71.36	34.34	**40.46**
2011	43.62	74.75	61.35	5.56	16.52	28.93	27.85	2.86	48.77	53.06	27.33	**35.51**
2012	27.33	22.48	4.62	30.54	25.56	10.84	22.42	24.07	13.91	21.82	13.97	**19.78**
Average	**43.12**	**48.24**	**43.41**	**23.15**	**27.76**	**30.50**	**25.29**	**13.94**	**30.33**	**34.86**	**28.02**	**28.08**
R-square	*0.01*	*0.03*	*0.24*	*0.08*	*0.01*	*0.05*	***0.49***	*0.16*	*0.20*	*0.06*	*0.02*	*0.01*
Slope	*0.38*	*-1.24*	*-3.86*	*-0.75*	*-0.22*	*0.48*	*1.51*	*-1.66*	*1.24*	*0.81*	*-0.24*	*0.27*
N	*11.00*	*4.00*	*9.00*	*13.00*	*13.00*	*9.00*	*10.00*	*16.00*	*12.00*	*19.00*	*8.00*	*19.00*

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Appendix D

DEP Benthic Macroinvertebrate Raw Metric Scores

Ratio of Scrapers

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994	NA	NA	NA	48.00	76.00	NA	NA	NA	54.00	53.00	42.00	**54.60**
1995	NA	NA	NA	64.50	61.50	53.00	27.00	NA	16.00	73.50	65.00	**51.50**
1996	69.00	NA	NA	54.00	83.00	55.00	48.00	NA	25.00	12.00	32.00	**47.25**
1997	80.00	NA	NA	57.00	53.00	NA	6.00	6.00	15.00	23.00	10.00	**31.25**
1998	98.00	NA	NA	77.00	84.00	NA	NA	84.00	NA	89.00	NA	**86.40**
1999	NA	NA	NA	68.00	91.00	NA	NA	57.00	NA	58.00	NA	**68.50**
2000	NA	NA	NA	NA	NA	NA	NA	71.00	68.00	60.00	3.00	**50.50**
2001	NA	NA	NA	NA	NA	NA	NA	20.00	NA	81.00	NA	**50.50**
2002	NA	NA	NA	NA	NA	NA	NA	0.00	NA	73.00	NA	**36.50**
2003	0.00	20.00	0.00	0.00	43.00	57.00	47.00	12.00	14.00	20.00	NA	**21.30**
2004	69.00	NA	NA	NA	NA	NA	NA	12.00	NA	12.00	NA	**31.00**
2005	NA	4.00	32.00	NA	NA	NA	NA	0.00	NA	55.00	NA	**22.75**
2006	75.00	NA	91.00	NA	NA	NA	NA	0.00	NA	32.00	NA	**49.50**
2007	60.00	NA	25.00	13.00	29.00	59.00	29.00	10.00	68.00	53.00	NA	**38.44**
2008	NA	NA	0.00	12.00	20.00	86.00	28.00	0.00	100.00	43.00	NA	**36.13**
2009	54.00	NA	33.00	18.00	14.00	85.00	45.00	17.00	67.00	37.00	NA	**41.11**
2010	75.00	NA	20.00	9.00	5.00	34.00	24.00	4.00	18.00	6.00	17.00	**21.20**
2011	86.00	67.00	17.00	18.00	16.00	16.00	48.00	11.00	45.00	5.00	29.00	**32.55**
2012	55.00	11.00	0.00	5.00	16.00	16.00	26.00	3.00	3.00	4.00	23.00	**14.73**
Average	**65.55**	**25.50**	**24.22**	**34.12**	**45.50**	**51.22**	**32.80**	**19.19**	**41.08**	**41.55**	**27.63**	**41.35**
R-square	*0.02*	*0.18*	*0.05*	***0.69***	***0.81***	*0.07*	*0.03*	***0.33***	*0.03*	*0.25*	*0.13*	***0.36***
Slope	*-0.60*	*2.70*	*-2.25*	*-3.42*	*-4.15*	*-1.10*	*0.34*	*-3.24*	*0.71*	*-2.45*	*-0.91*	*-1.88*
N	*11.00*	*4.00*	*9.00*	*13.00*	*13.00*	*9.00*	*10.00*	*16.00*	*12.00*	*19.00*	*8.00*	*19.00*

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DEP Benthic Macroinvertebrate Raw Metric Scores

Taxa Richness

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994	NA	NA	NA	36.00	26.00	NA	NA	NA	27.00	30.00	24.00	**28.60**
1995	NA	NA	NA	27.50	20.50	27.00	21.00	NA	26.00	29.00	19.50	**24.36**
1996	26.00	NA	NA	31.00	28.00	28.00	29.00	NA	30.00	27.00	27.00	**28.25**
1997	30.00	NA	NA	37.00	22.00	NA	22.00	26.00	26.00	21.00	21.00	**25.63**
1998	30.00	NA	NA	21.00	21.00	NA	NA	13.00	NA	19.00	NA	**20.80**
1999	NA	NA	NA	34.00	22.00	NA	NA	25.00	NA	21.00	NA	**25.50**
2000	NA	NA	NA	NA	NA	NA	NA	19.00	20.00	23.00	14.00	**19.00**
2001	NA	NA	NA	NA	NA	NA	NA	14.00	NA	24.00	NA	**19.00**
2002	NA	NA	NA	NA	NA	NA	NA	12.00	NA	24.00	NA	**18.00**
2003	14.00	9.00	12.00	7.00	12.00	18.00	17.00	16.00	13.00	12.00	NA	**13.00**
2004	21.00	NA	NA	NA	NA	NA	NA	19.00	NA	22.00	NA	**20.67**
2005	NA	13.00	17.00	NA	NA	NA	NA	10.00	NA	21.00	NA	**15.25**
2006	21.00	NA	14.00	NA	NA	NA	NA	10.00	NA	16.00	NA	**15.25**
2007	20.00	NA	16.00	17.00	23.00	22.00	35.00	21.00	23.00	25.00	NA	**22.44**
2008	NA	NA	16.00	18.00	15.00	18.00	33.00	5.00	18.00	16.00	NA	**17.38**
2009	23.00	NA	29.00	25.00	17.00	19.00	27.00	21.00	18.00	18.00	NA	**21.89**
2010	32.00	NA	23.00	20.00	19.00	35.00	35.00	21.00	22.00	16.00	21.00	**24.40**
2011	21.00	23.00	27.00	18.00	16.00	19.00	22.00	20.00	28.00	16.00	31.00	**21.91**
2012	28.00	23.00	17.00	23.00	24.00	18.00	26.00	16.00	19.00	23.00	26.00	**22.09**
Average	**24.18**	**17.00**	**19.00**	**24.19**	**20.42**	**22.67**	**26.70**	**16.75**	**22.50**	**21.21**	**22.94**	**21.23**
R-square	*0.02*	***0.99***	***0.40***	***0.37***	*0.22*	*0.12*	*0.14*	*0.02*	*0.21*	***0.35***	*0.14*	*0.15*
Slope	*-0.15*	*1.60*	*1.28*	*-0.78*	*-0.32*	*-0.33*	*0.36*	*-0.19*	*-0.34*	*-0.51*	*0.25*	*-0.30*
N	*11.00*	*4.00*	*9.00*	*13.00*	*13.00*	*9.00*	*10.00*	*16.00*	*12.00*	*19.00*	*8.00*	*19.00*

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Appendix D

DEP Benthic Macroinvertebrate Raw Metric Scores

Total Number of EPT Taxa

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994	NA	0.00	0.00	208.84	203.44	0.00	0.00	0.00	202.67	210.24	198.91	**102.41**
1995	0.00	0.00	0.00	213.21	226.20	190.91	223.23	0.00	147.27	222.11	240.31	**133.02**
1996	225.84	0.00	0.00	218.46	178.13	193.31	201.90	0.00	160.27	142.50	178.81	**136.29**
1997	259.48	0.00	0.00	261.20	230.19	0.00	141.67	163.88	177.57	206.79	223.33	**151.28**
1998	324.84	0.00	0.00	293.83	294.18	0.00	0.00	356.48	0.00	297.48	0.00	**142.44**
1999	0.00	0.00	0.00	239.18	303.81	0.00	0.00	208.74	0.00	260.69	0.00	**92.04**
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	192.35	196.95	226.92	157.37	**70.33**
2001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	161.85	0.00	267.37	0.00	**39.02**
2002	0.00	0.00	0.00	0.00	0.00	0.00	0.00	140.42	0.00	213.72	0.00	**32.19**
2003	259.35	255.72	271.26	168.62	185.27	250.24	203.32	148.80	238.32	252.18	0.00	**203.01**
2004	242.47	0.00	0.00	0.00	0.00	0.00	0.00	134.90	0.00	174.07	0.00	**50.13**
2005	0.00	157.87	245.31	0.00	0.00	0.00	0.00	131.52	0.00	223.05	0.00	**68.89**
2006	222.07	0.00	230.07	0.00	0.00	0.00	0.00	132.54	0.00	166.04	0.00	**68.25**
2007	273.56	0.00	181.48	133.70	168.57	217.71	220.67	169.14	222.57	194.08	0.00	**161.95**
2008	0.00	0.00	244.56	149.34	147.31	277.14	251.71	166.30	324.45	207.01	0.00	**160.71**
2009	286.55	0.00	182.99	167.11	151.90	270.79	276.75	151.39	222.57	231.66	0.00	**176.52**
2010	287.96	0.00	211.59	132.29	211.93	221.38	270.08	164.73	209.53	259.11	193.27	**196.53**
2011	281.56	334.25	247.39	132.72	136.62	146.90	202.70	158.04	254.81	201.16	189.29	**207.77**
2012	227.15	159.91	129.27	160.14	165.02	143.78	185.95	144.53	131.35	149.32	187.43	**162.17**
Average	**160.60**	**47.78**	**102.31**	**130.45**	**136.98**	**100.64**	**114.63**	**143.45**	**130.96**	**216.08**	**82.56**	**123.94**
R-square	*0.10*	*0.19*	***0.58***	*0.11*	*0.06*	*0.19*	*0.18*	*0.08*	*0.06*	*0.04*	*0.05*	*0.14*
Slope	*7.90*	*7.77*	*15.53*	*-5.95*	*-4.51*	*8.81*	*8.66*	*4.01*	*4.83*	*-1.37*	*-3.90*	*3.77*
N	*18.00*	*19.00*	*19.00*	*19.00*	*19.00*	*19.00*	*19.00*	*19.00*	*19.00*	*19.00*	*19.00*	*19.00*

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Appendix D

DEP Benthic Macroinvertebrate Scaled Metric Scores

Biotic Index

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994	NA	NA	NA	3.00	3.00	NA	NA	NA	5.00	5.00	3.00	**3.80**
1995	NA	NA	NA	4.00	4.00	3.00	3.00	NA	5.00	4.00	4.00	**3.86**
1996	5.00	NA	NA	3.00	3.00	3.00	3.00	NA	5.00	5.00	5.00	**4.00**
1997	3.00	NA	NA	3.00	3.00	NA	3.00	3.00	3.00	3.00	3.00	**3.00**
1998	3.00	NA	NA	5.00	5.00	NA	NA	5.00	NA	5.00	NA	**4.60**
1999	NA	NA	NA	3.00	3.00	NA	NA	3.00	NA	3.00	NA	**3.00**
2000	NA	NA	NA	NA	NA	NA	NA	3.00	5.00	3.00	3.00	**3.50**
2001	NA	NA	NA	NA	NA	NA	NA	3.00	NA	5.00	NA	**4.00**
2002	NA	NA	NA	NA	NA	NA	NA	3.00	NA	3.00	NA	**3.00**
2003	5.00	3.00	5.00	3.00	3.00	3.00	3.00	3.00	5.00	3.00	NA	**3.60**
2004	5.00	NA	NA	NA	NA	NA	NA	3.00	NA	5.00	NA	**4.33**
2005	NA	5.00	5.00	NA	NA	NA	NA	3.00	NA	5.00	NA	**4.50**
2006	3.00	NA	3.00	NA	NA	NA	NA	1.00	NA	5.00	NA	**3.00**
2007	3.00	NA	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	NA	**3.00**
2008	NA	NA	3.00	3.00	3.00	3.00	3.00	1.00	5.00	3.00	NA	**3.00**
2009	3.00	NA	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	NA	**3.00**
2010	5.00	NA	3.00	3.00	3.00	3.00	3.00	3.00	3.00	5.00	3.00	**3.40**
2011	5.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	**3.18**
2012	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	**3.00**
Average	**3.91**	**3.50**	**3.44**	**3.23**	**3.23**	**3.00**	**3.00**	**2.88**	**4.00**	**3.89**	**3.38**	**3.51**
R-square	*0.00*	*0.17*	***0.56***	*0.14*	*0.14*	*NA*	*NA*	*0.13*	***0.41***	*0.08*	*0.21*	*0.18*
Slope	*0.00*	*-0.09*	*-0.23*	*-0.03*	*-0.03*	*0.00*	*0.00*	*-0.07*	*-0.10*	*-0.05*	*-0.04*	*-0.04*
N	*11.00*	*4.00*	*9.00*	*13.00*	*13.00*	*9.00*	*10.00*	*16.00*	*12.00*	*19.00*	*8.00*	*19.00*

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Appendix D

DEP Benthic Macroinvertebrate Scaled Metric Scores

Proportion of Dominant Taxa

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994	NA	NA	NA	5.00	5.00	NA	NA	NA	5.00	5.00	5.00	**5.00**
1995	NA	NA	NA	5.00	4.00	5.00	4.00	NA	5.00	5.00	5.00	**4.71**
1996	5.00	NA	NA	5.00	5.00	5.00	5.00	NA	5.00	5.00	5.00	**5.00**
1997	5.00	NA	NA	5.00	5.00	NA	3.00	3.00	5.00	5.00	5.00	**4.50**
1998	3.00	NA	NA	3.00	3.00	NA	NA	1.00	NA	3.00	NA	**2.60**
1999	NA	NA	NA	5.00	3.00	NA	NA	3.00	NA	5.00	NA	**4.00**
2000	NA	NA	NA	NA	NA	NA	NA	3.00	5.00	5.00	5.00	**4.50**
2001	NA	NA	NA	NA	NA	NA	NA	1.00	NA	5.00	NA	**3.00**
2002	NA	NA	NA	NA	NA	NA	NA	1.00	NA	5.00	NA	**3.00**
2003	3.00	3.00	1.00	5.00	3.00	3.00	3.00	3.00	3.00	3.00	NA	**3.00**
2004	5.00	NA	NA	NA	NA	NA	NA	3.00	NA	5.00	NA	**4.33**
2005	NA	5.00	3.00	NA	NA	NA	NA	1.00	NA	5.00	NA	**3.50**
2006	5.00	NA	3.00	NA	NA	NA	NA	1.00	NA	5.00	NA	**3.50**
2007	3.00	NA	3.00	3.00	3.00	3.00	5.00	1.00	5.00	3.00	NA	**3.22**
2008	NA	NA	3.00	3.00	1.00	5.00	5.00	1.00	3.00	5.00	NA	**3.25**
2009	3.00	NA	5.00	3.00	5.00	3.00	3.00	5.00	3.00	5.00	NA	**3.89**
2010	5.00	NA	5.00	3.00	3.00	5.00	3.00	3.00	5.00	3.00	5.00	**4.00**
2011	5.00	1.00	3.00	3.00	5.00	5.00	5.00	3.00	3.00	3.00	5.00	**3.73**
2012	3.00	3.00	1.00	5.00	3.00	3.00	5.00	3.00	3.00	5.00	3.00	**3.36**
Average	**4.09**	**3.00**	**3.00**	**4.08**	**3.69**	**4.11**	**4.10**	**2.25**	**4.17**	**4.47**	**4.75**	**3.79**
R-square	*0.03*	***0.31***	*0.06*	***0.36***	*0.11*	*0.10*	*0.03*	*0.04*	***0.44***	*0.09*	*0.28*	*0.21*
Slope	*-0.03*	*-0.20*	*0.12*	*-0.09*	*-0.06*	*-0.05*	*0.03*	*0.05*	*-0.10*	*-0.05*	*-0.05*	*-0.06*
N	*11.00*	*4.00*	*9.00*	*13.00*	*13.00*	*9.00*	*10.00*	*16.00*	*12.00*	*19.00*	*8.00*	*19.00*

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

Appendix D

DEP Benthic Macroinvertebrate Scaled Metric Scores

Proportion of EPT Individuals

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994	NA	NA	NA	5.00	3.00	NA	NA	NA	5.00	5.00	3.00	**4.20**
1995	NA	NA	NA	5.00	4.00	3.00	5.00	NA	3.00	4.00	5.00	**4.14**
1996	5.00	NA	NA	3.00	1.00	3.00	3.00	NA	3.00	3.00	3.00	**3.00**
1997	5.00	NA	NA	5.00	5.00	NA	3.00	3.00	5.00	5.00	5.00	**4.50**
1998	5.00	NA	NA	5.00	5.00	NA	NA	5.00	NA	5.00	NA	**5.00**
1999	NA	NA	NA	3.00	5.00	NA	NA	1.00	NA	5.00	NA	**3.50**
2000	NA	NA	NA	NA	NA	NA	NA	1.00	3.00	5.00	3.00	**3.00**
2001	NA	NA	NA	NA	NA	NA	NA	1.00	NA	5.00	NA	**3.00**
2002	NA	NA	NA	NA	NA	NA	NA	1.00	NA	3.00	NA	**2.00**
2003	5.00	5.00	5.00	5.00	3.00	5.00	3.00	1.00	5.00	5.00	NA	**4.20**
2004	5.00	NA	NA	NA	NA	NA	NA	1.00	NA	5.00	NA	**3.67**
2005	NA	5.00	5.00	NA	NA	NA	NA	1.00	NA	5.00	NA	**4.00**
2006	3.00	NA	3.00	NA	NA	NA	NA	1.00	NA	5.00	NA	**3.00**
2007	5.00	NA	3.00	1.00	1.00	3.00	5.00	1.00	3.00	3.00	NA	**2.78**
2008	NA	NA	5.00	3.00	1.00	5.00	5.00	1.00	5.00	5.00	NA	**3.75**
2009	5.00	NA	3.00	3.00	5.00	5.00	5.00	3.00	3.00	5.00	NA	**4.11**
2010	5.00	NA	5.00	1.00	5.00	5.00	5.00	3.00	5.00	5.00	5.00	**4.40**
2011	5.00	5.00	5.00	1.00	1.00	3.00	3.00	1.00	5.00	5.00	3.00	**3.36**
2012	3.00	3.00	1.00	3.00	3.00	1.00	5.00	3.00	3.00	3.00	3.00	**2.82**
Average	**4.64**	**4.50**	**3.89**	**3.31**	**3.23**	**3.67**	**4.20**	**1.75**	**4.00**	**4.53**	**3.75**	**3.60**
R-square	*0.13*	***0.41***	*0.15*	***0.53***	*0.05*	*0.00*	*0.16*	*0.00*	*0.00*	*0.00*	*0.02*	*0.05*
Slope	*-0.05*	*-0.14*	*-0.19*	*-0.17*	*-0.06*	*0.01*	*0.06*	*-0.02*	*0.01*	*0.00*	*-0.02*	*-0.03*
N	*11.00*	*4.00*	*9.00*	*13.00*	*13.00*	*9.00*	*10.00*	*16.00*	*12.00*	*19.00*	*8.00*	*19.00*

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Appendix D

DEP Benthic Macroinvertebrate Scaled Metric Scores

Proportion of Hydropsyche & Cheumatopsyche

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994	NA	NA	NA	3.00	3.00	NA	NA	NA	3.00	5.00	3.00	**3.40**
1995	NA	NA	NA	5.00	5.00	5.00	3.00	NA	5.00	5.00	5.00	**4.71**
1996	5.00	NA	NA	5.00	5.00	5.00	3.00	NA	5.00	5.00	3.00	**4.50**
1997	5.00	NA	NA	5.00	5.00	NA	5.00	5.00	5.00	5.00	5.00	**5.00**
1998	5.00	NA	NA	5.00	5.00	NA	NA	5.00	NA	5.00	NA	**5.00**
1999	NA	NA	NA	5.00	5.00	NA	NA	5.00	NA	5.00	NA	**5.00**
2000	NA	NA	NA	NA	NA	NA	NA	5.00	5.00	5.00	5.00	**5.00**
2001	NA	NA	NA	NA	NA	NA	NA	5.00	NA	5.00	NA	**5.00**
2002	NA	NA	NA	NA	NA	NA	NA	3.00	NA	5.00	NA	**4.00**
2003	5.00	5.00	5.00	5.00	5.00	5.00	3.00	3.00	5.00	5.00	NA	**4.60**
2004	5.00	NA	NA	NA	NA	NA	NA	3.00	NA	5.00	NA	**4.33**
2005	NA	5.00	5.00	NA	NA	NA	NA	3.00	NA	5.00	NA	**4.50**
2006	5.00	NA	5.00	NA	NA	NA	NA	3.00	NA	5.00	NA	**4.50**
2007	5.00	NA	5.00	5.00	5.00	5.00	3.00	3.00	5.00	5.00	NA	**4.56**
2008	NA	NA	5.00	3.00	5.00	5.00	3.00	1.00	5.00	5.00	NA	**4.00**
2009	5.00	NA	5.00	3.00	5.00	5.00	3.00	3.00	5.00	5.00	NA	**4.33**
2010	5.00	NA	5.00	5.00	5.00	5.00	3.00	3.00	5.00	5.00	5.00	**4.60**
2011	5.00	5.00	5.00	5.00	3.00	5.00	5.00	3.00	5.00	5.00	5.00	**4.64**
2012	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	**5.00**
Average	**5.00**	**5.00**	**5.00**	**4.54**	**4.69**	**5.00**	**3.60**	**3.63**	**4.83**	**5.00**	**4.50**	**4.56**
R-square	*NA*	*NA*	*NA*	*0.00*	*0.00*	*NA*	*0.04*	*0.30*	*0.19*	*NA*	*0.30*	*0.00*
Slope	*0.00*	*0.00*	*0.00*	*-0.01*	*0.00*	*0.00*	*0.03*	*-0.14*	*0.04*	*0.00*	*0.07*	*0.00*
N	*11.00*	*4.00*	*9.00*	*13.00*	*13.00*	*9.00*	*10.00*	*16.00*	*12.00*	*19.00*	*8.00*	*19.00*

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Appendix D

DEP Benthic Macroinvertebrate Scaled Metric Scores

Proportion of Shredders

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994	NA	NA	NA	5.00	5.00	NA	NA	NA	3.00	5.00	5.00	**4.60**
1995	NA	NA	NA	5.00	5.00	5.00	4.00	NA	5.00	4.00	5.00	**4.71**
1996	5.00	NA	NA	5.00	5.00	5.00	5.00	NA	3.00	3.00	3.00	**4.25**
1997	5.00	NA	NA	5.00	5.00	NA	5.00	5.00	5.00	5.00	5.00	**5.00**
1998	5.00	NA	NA	5.00	5.00	NA	NA	5.00	NA	5.00	NA	**5.00**
1999	NA	NA	NA	5.00	5.00	NA	NA	5.00	NA	5.00	NA	**5.00**
2000	NA	NA	NA	NA	NA	NA	NA	5.00	5.00	5.00	5.00	**5.00**
2001	NA	NA	NA	NA	NA	NA	NA	5.00	NA	5.00	NA	**5.00**
2002	NA	NA	NA	NA	NA	NA	NA	3.00	NA	5.00	NA	**4.00**
2003	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	NA	**5.00**
2004	5.00	NA	NA	NA	NA	NA	NA	5.00	NA	5.00	NA	**5.00**
2005	NA	5.00	5.00	NA	NA	NA	NA	3.00	NA	5.00	NA	**4.50**
2006	5.00	NA	5.00	NA	NA	NA	NA	1.00	NA	5.00	NA	**4.00**
2007	5.00	NA	5.00	5.00	5.00	5.00	5.00	3.00	5.00	3.00	NA	**4.56**
2008	NA	NA	5.00	5.00	3.00	5.00	5.00	1.00	5.00	5.00	NA	**4.25**
2009	5.00	NA	5.00	5.00	5.00	5.00	5.00	1.00	5.00	5.00	NA	**4.56**
2010	5.00	NA	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	**5.00**
2011	5.00	5.00	5.00	3.00	5.00	5.00	5.00	1.00	5.00	5.00	5.00	**4.45**
2012	5.00	5.00	3.00	5.00	5.00	5.00	5.00	5.00	3.00	5.00	3.00	**4.45**
Average	**5.00**	**5.00**	**4.78**	**4.85**	**4.85**	**5.00**	**4.90**	**3.63**	**4.50**	**4.74**	**4.50**	**4.65**
R-square	*NA*	*NA*	*0.28*	*0.13*	*0.05*	*NA*	*0.28*	*0.27*	*0.06*	*0.04*	*0.03*	*0.07*
Slope	*0.00*	*0.00*	*-0.12*	*-0.03*	*-0.02*	*0.00*	*0.03*	*-0.19*	*0.03*	*0.02*	*-0.02*	*-0.02*
N	*11.00*	*4.00*	*9.00*	*13.00*	*13.00*	*9.00*	*10.00*	*16.00*	*12.00*	*19.00*	*8.00*	*19.00*

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

Appendix D

DEP Benthic Macroinvertebrate Scaled Metric Scores

Ratio of Scrapers

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994	NA	NA	NA	5.00	5.00	NA	NA	NA	5.00	5.00	5.00	**5.00**
1995	NA	NA	NA	4.00	4.00	5.00	3.00	NA	5.00	5.00	5.00	**4.43**
1996	5.00	NA	NA	5.00	5.00	5.00	5.00	NA	5.00	5.00	5.00	**5.00**
1997	5.00	NA	NA	5.00	5.00	NA	1.00	1.00	5.00	5.00	5.00	**4.00**
1998	5.00	NA	NA	5.00	5.00	NA	NA	5.00	NA	5.00	NA	**5.00**
1999	NA	NA	NA	5.00	5.00	NA	NA	5.00	NA	5.00	NA	**5.00**
2000	NA	NA	NA	NA	NA	NA	NA	5.00	5.00	5.00	1.00	**4.00**
2001	NA	NA	NA	NA	NA	NA	NA	1.00	NA	5.00	NA	**3.00**
2002	NA	NA	NA	NA	NA	NA	NA	1.00	NA	5.00	NA	**3.00**
2003	1.00	1.00	1.00	1.00	5.00	5.00	5.00	1.00	5.00	5.00	NA	**3.00**
2004	5.00	NA	NA	NA	NA	NA	NA	1.00	NA	5.00	NA	**3.67**
2005	NA	1.00	3.00	NA	NA	NA	NA	1.00	NA	5.00	NA	**2.50**
2006	5.00	NA	5.00	NA	NA	NA	NA	1.00	NA	5.00	NA	**4.00**
2007	5.00	NA	3.00	1.00	3.00	5.00	3.00	1.00	5.00	5.00	NA	**3.44**
2008	NA	NA	1.00	1.00	1.00	5.00	3.00	1.00	5.00	5.00	NA	**2.75**
2009	5.00	NA	3.00	1.00	1.00	5.00	5.00	1.00	5.00	5.00	NA	**3.44**
2010	5.00	NA	1.00	1.00	1.00	3.00	3.00	1.00	5.00	3.00	5.00	**2.80**
2011	5.00	5.00	1.00	1.00	1.00	1.00	5.00	1.00	5.00	3.00	5.00	**3.00**
2012	5.00	1.00	1.00	1.00	1.00	1.00	3.00	1.00	1.00	3.00	5.00	**2.09**
Average	**4.64**	**2.00**	**2.11**	**2.77**	**3.23**	**3.89**	**3.60**	**1.75**	**4.67**	**4.68**	**4.50**	**3.64**
R-square	*0.01*	*0.24*	*0.14*	***0.84***	***0.82***	***0.38***	*0.04*	***0.33***	*0.16*	***0.40***	*0.01*	***0.63***
Slope	*0.02*	*0.22*	*-0.19*	*-0.27*	*-0.26*	*-0.17*	*0.04*	*-0.19*	*-0.07*	*-0.08*	*0.02*	*-0.13*
N	*11.00*	*4.00*	*9.00*	*13.00*	*13.00*	*9.00*	*10.00*	*16.00*	*12.00*	*19.00*	*8.00*	*19.00*

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Appendix D

DEP Benthic Macroinvertebrate Scaled Metric Scores

Taxa Richness

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994	NA	NA	NA	5.00	5.00	NA	NA	NA	5.00	5.00	5.00	**5.00**
1995	NA	NA	NA	5.00	4.00	5.00	4.00	NA	5.00	5.00	4.00	**4.57**
1996	5.00	NA	NA	5.00	5.00	5.00	5.00	NA	5.00	5.00	5.00	**5.00**
1997	5.00	NA	NA	5.00	3.00	NA	3.00	5.00	5.00	5.00	5.00	**4.50**
1998	5.00	NA	NA	3.00	3.00	NA	NA	3.00	NA	3.00	NA	**3.40**
1999	NA	NA	NA	5.00	3.00	NA	NA	5.00	NA	5.00	NA	**4.50**
2000	NA	NA	NA	NA	NA	NA	NA	3.00	3.00	5.00	3.00	**3.50**
2001	NA	NA	NA	NA	NA	NA	NA	3.00	NA	5.00	NA	**4.00**
2002	NA	NA	NA	NA	NA	NA	NA	3.00	NA	5.00	NA	**4.00**
2003	3.00	1.00	3.00	1.00	3.00	3.00	3.00	3.00	3.00	3.00	NA	**2.60**
2004	3.00	NA	NA	NA	NA	NA	NA	3.00	NA	5.00	NA	**3.67**
2005	NA	3.00	3.00	NA	NA	NA	NA	1.00	NA	5.00	NA	**3.00**
2006	3.00	NA	3.00	NA	NA	NA	NA	1.00	NA	3.00	NA	**2.50**
2007	3.00	NA	3.00	3.00	5.00	3.00	5.00	3.00	5.00	5.00	NA	**3.89**
2008	NA	NA	3.00	3.00	3.00	3.00	5.00	1.00	3.00	3.00	NA	**3.00**
2009	5.00	NA	5.00	5.00	3.00	3.00	5.00	3.00	3.00	3.00	NA	**3.89**
2010	5.00	NA	5.00	3.00	3.00	5.00	5.00	3.00	5.00	3.00	5.00	**4.20**
2011	3.00	5.00	5.00	3.00	3.00	3.00	3.00	3.00	5.00	3.00	5.00	**3.73**
2012	5.00	5.00	3.00	5.00	5.00	3.00	5.00	3.00	3.00	5.00	5.00	**4.27**
Average	**4.09**	**3.50**	**3.67**	**3.92**	**3.69**	**3.67**	**4.30**	**2.88**	**4.17**	**4.26**	**4.63**	**3.85**
R-square	*0.05*	***0.93***	*0.29*	*0.13*	*0.03*	***0.40***	*0.09*	*0.20*	*0.14*	*0.23*	*0.07*	*0.19*
Slope	*-0.04*	*0.42*	*0.18*	*-0.07*	*-0.03*	*-0.10*	*0.04*	*-0.11*	*-0.06*	*-0.08*	*0.03*	*-0.06*
N	*11.00*	*4.00*	*9.00*	*13.00*	*13.00*	*9.00*	*10.00*	*16.00*	*12.00*	*19.00*	*8.00*	*19.00*

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

Appendix D

DEP Benthic Macroinvertebrate Scaled Metric Scores

Total Number of EPT Taxa

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994	NA	NA	NA	36.00	34.00	NA	NA	NA	36.00	40.00	34.00	**36.00**
1995	NA	NA	NA	38.00	34.00	36.00	30.00	NA	38.00	36.00	36.00	**35.43**
1996	40.00	NA	NA	36.00	34.00	36.00	34.00	NA	36.00	36.00	34.00	**35.75**
1997	38.00	NA	NA	38.00	34.00	NA	28.00	28.00	38.00	36.00	36.00	**34.50**
1998	36.00	NA	NA	34.00	34.00	NA	NA	32.00	NA	34.00	NA	**34.00**
1999	NA	NA	NA	36.00	32.00	NA	NA	30.00	NA	38.00	NA	**34.00**
2000	NA	NA	NA	NA	NA	NA	NA	28.00	36.00	36.00	28.00	**32.00**
2001	NA	NA	NA	NA	NA	NA	NA	22.00	NA	40.00	NA	**31.00**
2002	NA	NA	NA	NA	NA	NA	NA	18.00	NA	36.00	NA	**27.00**
2003	30.00	24.00	28.00	26.00	28.00	32.00	28.00	22.00	34.00	32.00	NA	**28.40**
2004	38.00	NA	NA	NA	NA	NA	NA	22.00	NA	40.00	NA	**33.33**
2005	NA	32.00	32.00	NA	NA	NA	NA	14.00	NA	40.00	NA	**29.50**
2006	32.00	NA	30.00	NA	NA	NA	NA	10.00	NA	36.00	NA	**27.00**
2007	32.00	NA	28.00	24.00	28.00	32.00	34.00	18.00	34.00	32.00	NA	**29.11**
2008	NA	NA	28.00	24.00	20.00	34.00	34.00	8.00	36.00	34.00	NA	**27.25**
2009	34.00	NA	34.00	28.00	30.00	32.00	34.00	22.00	32.00	34.00	NA	**31.11**
2010	40.00	NA	34.00	24.00	28.00	36.00	32.00	24.00	38.00	32.00	38.00	**32.60**
2011	36.00	32.00	32.00	22.00	24.00	28.00	34.00	18.00	36.00	30.00	36.00	**29.82**
2012	34.00	30.00	20.00	32.00	28.00	24.00	36.00	26.00	26.00	34.00	32.00	**29.27**
Average	**35.45**	**29.50**	**29.56**	**30.62**	**29.85**	**32.22**	**32.40**	**21.38**	**35.00**	**35.58**	**34.25**	**31.43**
R-square	*0.09*	***0.34***	*0.03*	***0.69***	***0.64***	***0.41***	***0.37***	*0.24*	*0.27*	*0.28*	*0.01*	***0.48***
Slope	*-0.17*	*0.50*	*-0.24*	*-0.75*	*-0.53*	*-0.41*	*0.26*	*-0.70*	*-0.26*	*-0.28*	*0.04*	*-0.37*
N	*11.00*	*4.00*	*9.00*	*13.00*	*13.00*	*9.00*	*10.00*	*16.00*	*12.00*	*19.00*	*8.00*	*19.00*

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

Appendix D

DEP Benthic Macroinvertebrate Scaled Metric Scores

Composite

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994	NA	NA	NA	36.00	34.00	NA	NA	NA	36.00	40.00	34.00	**36.00**
1995	NA	NA	NA	38.00	34.00	36.00	30.00	NA	38.00	36.00	36.00	**35.43**
1996	40.00	NA	NA	36.00	34.00	36.00	34.00	NA	36.00	36.00	34.00	**35.75**
1997	38.00	NA	NA	38.00	34.00	NA	28.00	28.00	38.00	36.00	36.00	**34.50**
1998	36.00	NA	NA	34.00	34.00	NA	NA	32.00	NA	34.00	NA	**34.00**
1999	NA	NA	NA	36.00	32.00	NA	NA	30.00	NA	38.00	NA	**34.00**
2000	NA	NA	NA	NA	NA	NA	NA	28.00	36.00	36.00	28.00	**32.00**
2001	NA	NA	NA	NA	NA	NA	NA	22.00	NA	40.00	NA	**31.00**
2002	NA	NA	NA	NA	NA	NA	NA	18.00	NA	36.00	NA	**27.00**
2003	30.00	24.00	28.00	26.00	28.00	32.00	28.00	22.00	34.00	32.00	NA	**28.40**
2004	38.00	NA	NA	NA	NA	NA	NA	22.00	NA	40.00	NA	**33.33**
2005	NA	32.00	32.00	NA	NA	NA	NA	14.00	NA	40.00	NA	**29.50**
2006	32.00	NA	30.00	NA	NA	NA	NA	10.00	NA	36.00	NA	**27.00**
2007	32.00	NA	28.00	24.00	28.00	32.00	34.00	18.00	34.00	32.00	NA	**29.11**
2008	NA	NA	28.00	24.00	20.00	34.00	34.00	8.00	36.00	34.00	NA	**27.25**
2009	34.00	NA	34.00	28.00	30.00	32.00	34.00	22.00	32.00	34.00	NA	**31.11**
2010	40.00	NA	34.00	24.00	28.00	36.00	32.00	24.00	38.00	32.00	38.00	**32.60**
2011	36.00	32.00	32.00	22.00	24.00	28.00	34.00	18.00	36.00	30.00	36.00	**29.82**
2012	34.00	30.00	20.00	32.00	28.00	24.00	36.00	26.00	26.00	34.00	32.00	**29.27**
Average	**35.45**	**29.50**	**29.56**	**30.62**	**29.85**	**32.22**	**32.40**	**21.38**	**35.00**	**35.58**	**34.25**	**31.43**
R-square	*0.09*	***0.34***	*0.03*	***0.69***	***0.64***	***0.41***	***0.37***	*0.24*	*0.27*	*0.28*	*0.01*	***0.48***
Slope	*-0.17*	*0.50*	*-0.24*	*-0.75*	*-0.53*	*-0.41*	*0.26*	*-0.70*	*-0.26*	*-0.28*	*0.04*	*-0.37*
N	*11.00*	*4.00*	*9.00*	*13.00*	*13.00*	*9.00*	*10.00*	*16.00*	*12.00*	*19.00*	*8.00*	*19.00*

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Appendix D
MBSS Benthic Macroinvertebrate Raw Metric Scores

Number Taxa

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1995	NA	NA	NA	36.00	26.00	NA	NA	NA	27.00	30.00	24.00	**28.60**
1996	NA	NA	NA	55.00	41.00	27.00	42.00	NA	26.00	58.00	39.00	**41.14**
1997	27.00	NA	NA	31.00	29.00	29.00	30.00	NA	30.00	27.00	28.00	**28.88**
1998	31.00	NA	NA	38.00	22.00	NA	22.00	26.00	26.00	21.00	21.00	**25.88**
1999	30.00	NA	NA	21.00	21.00	NA	NA	13.00	NA	19.00	NA	**20.80**
2000	NA	NA	NA	34.00	22.00	NA	NA	25.00	NA	21.00	NA	**25.50**
2001	NA	NA	NA	NA	NA	NA	NA	19.00	20.00	23.00	14.00	**19.00**
2002	NA	NA	NA	NA	NA	NA	NA	14.00	NA	24.00	NA	**19.00**
2003	NA	NA	NA	NA	NA	NA	NA	15.00	NA	27.00	NA	**21.00**
2004	15.00	10.00	16.00	10.00	16.00	22.00	21.00	20.00	16.00	16.00	NA	**16.20**
2005	23.00	NA	NA	NA	NA	NA	NA	22.00	NA	27.00	NA	**24.00**
2006	NA	16.00	19.00	NA	NA	NA	NA	13.00	NA	25.00	NA	**18.25**
2007	24.00	NA	17.00	NA	NA	NA	NA	12.00	NA	19.00	NA	**18.00**
2008	24.00	NA	19.00	21.00	27.00	26.00	39.00	24.00	27.00	29.00	NA	**26.22**
2009	NA	NA	19.00	21.00	18.00	21.00	37.00	9.00	21.00	19.00	NA	**20.63**
2010	26.00	NA	31.00	29.00	21.00	22.00	31.00	24.00	22.00	21.00	NA	**25.22**
2011	35.00	NA	26.00	23.00	22.00	39.00	39.00	25.00	26.00	20.00	24.00	**27.90**
2012	24.00	26.00	30.00	22.00	19.00	24.00	26.00	24.00	34.00	20.00	35.00	**25.82**
Average	**25.90**	**17.33**	**22.13**	**28.42**	**23.67**	**26.25**	**31.89**	**19.00**	**25.00**	**24.78**	**26.43**	**24.00**
R-square	*0.01*	***0.98***	***0.71***	***0.37***	*0.28*	*0.00*	*0.01*	*0.01*	*0.00*	*0.21*	*0.01*	*0.11*
Slope	*-0.09*	*1.92*	*1.88*	*-1.09*	*-0.54*	*-0.02*	*0.13*	*0.11*	*-0.01*	*-0.78*	*0.10*	*-0.36*
N	*10.00*	*3.00*	*8.00*	*12.00*	*12.00*	*8.00*	*9.00*	*15.00*	*11.00*	*18.00*	*7.00*	*18.00*

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Appendix D

MBSS Benthic Macroinvertebrate Raw Metric Scores

 # EPT

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1995	NA	NA	NA	25.00	14.00	NA	NA	NA	14.00	16.00	13.00	**16.40**
1996	NA	NA	NA	32.00	21.00	15.00	23.00	NA	15.00	31.00	21.00	**22.57**
1997	14.00	NA	NA	17.00	14.00	17.00	16.00	NA	18.00	14.00	13.00	**15.38**
1998	20.00	NA	NA	21.00	11.00	NA	13.00	12.00	14.00	12.00	12.00	**14.38**
1999	15.00	NA	NA	9.00	11.00	NA	NA	6.00	NA	8.00	NA	**9.80**
2000	NA	NA	NA	22.00	8.00	NA	NA	11.00	NA	15.00	NA	**14.00**
2001	NA	NA	NA	NA	NA	NA	NA	8.00	15.00	10.00	6.00	**9.75**
2002	NA	NA	NA	NA	NA	NA	NA	10.00	NA	13.00	NA	**11.50**
2003	NA	NA	NA	NA	NA	NA	NA	6.00	NA	14.00	NA	**10.00**
2004	8.00	4.00	9.00	4.00	5.00	10.00	11.00	7.00	7.00	8.00	NA	**7.30**
2005	13.00	NA	NA	NA	NA	NA	NA	7.00	NA	13.00	NA	**11.00**
2006	NA	8.00	11.00	NA	NA	NA	NA	5.00	NA	15.00	NA	**9.75**
2007	11.00	NA	7.00	NA	NA	NA	NA	3.00	NA	10.00	NA	**7.75**
2008	12.00	NA	11.00	8.00	10.00	14.00	22.00	7.00	12.00	15.00	NA	**12.33**
2009	NA	NA	11.00	6.00	7.00	11.00	18.00	NA	13.00	11.00	NA	**11.00**
2010	11.00	NA	13.00	15.00	10.00	12.00	15.00	10.00	14.00	9.00	NA	**12.11**
2011	21.00	NA	14.00	11.00	11.00	21.00	21.00	8.00	14.00	11.00	13.00	**14.50**
2012	11.00	9.00	13.00	10.00	8.00	10.00	13.00	8.00	13.00	10.00	15.00	**10.91**
Average	**13.60**	**7.00**	**11.13**	**15.00**	**10.83**	**13.75**	**16.89**	**7.71**	**13.55**	**13.06**	**13.29**	**12.25**
R-square	*0.05*	***0.67***	***0.58***	***0.47***	***0.34***	*0.04*	*0.00*	*0.08*	*0.12*	*0.21*	*0.01*	*0.24*
Slope	*-0.17*	*0.52*	*0.65*	*-0.91*	*-0.38*	*-0.13*	*-0.02*	*-0.15*	*-0.14*	*-0.44*	*-0.05*	*-0.33*
N	*10.00*	*3.00*	*8.00*	*12.00*	*12.00*	*8.00*	*9.00*	*14.00*	*11.00*	*18.00*	*7.00*	*18.00*

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Appendix D

MBSS Benthic Macroinvertebrate Raw Metric Scores

 # Ephemeroptera

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1995	NA	NA	NA	6.00	3.00	NA	NA	NA	2.00	4.00	4.00	**3.80**
1996	NA	NA	NA	7.00	1.00	4.00	9.00	NA	4.00	8.00	5.00	**5.43**
1997	6.00	NA	NA	6.00	2.00	7.00	6.00	NA	8.00	6.00	2.00	**5.38**
1998	8.00	NA	NA	6.00	3.00	NA	6.00	3.00	3.00	5.00	3.00	**4.63**
1999	7.00	NA	NA	3.00	4.00	NA	NA	1.00	NA	3.00	NA	**3.60**
2000	NA	NA	NA	10.00	3.00	NA	NA	3.00	NA	5.00	NA	**5.25**
2001	NA	NA	NA	NA	NA	NA	NA	2.00	4.00	4.00	3.00	**3.25**
2002	NA	NA	NA	NA	NA	NA	NA	NA	NA	6.00	NA	**6.00**
2003	NA	NA	NA	NA	NA	NA	NA	NA	NA	6.00	NA	**6.00**
2004	4.00	2.00	5.00	1.00	2.00	4.00	4.00	NA	4.00	5.00	NA	**3.44**
2005	4.00	NA	NA	NA	NA	NA	NA	1.00	NA	5.00	NA	**3.33**
2006	NA	2.00	4.00	NA	NA	NA	NA	NA	NA	7.00	NA	**4.33**
2007	5.00	NA	3.00	NA	NA	NA	NA	NA	NA	4.00	NA	**4.00**
2008	6.00	NA	5.00	3.00	1.00	6.00	11.00	1.00	5.00	6.00	NA	**4.89**
2009	NA	NA	5.00	2.00	2.00	5.00	8.00	NA	7.00	5.00	NA	**4.86**
2010	4.00	NA	4.00	4.00	NA	8.00	6.00	1.00	6.00	1.00	NA	**4.25**
2011	9.00	NA	4.00	3.00	2.00	7.00	10.00	1.00	8.00	3.00	6.00	**5.30**
2012	3.00	4.00	4.00	1.00	1.00	4.00	5.00	NA	8.00	5.00	5.00	**4.00**
Average	**5.60**	**2.67**	**4.25**	**4.33**	**2.18**	**5.63**	**7.22**	**1.63**	**5.36**	**4.89**	**4.00**	**4.54**
R-square	*0.11*	*0.94*	*0.04*	*0.45*	*0.24*	*0.03*	*0.01*	*0.48*	*0.42*	*0.10*	*0.37*	*0.01*
Slope	*-0.12*	*0.27*	*-0.06*	*-0.28*	*-0.07*	*0.05*	*0.05*	*-0.12*	*0.21*	*-0.09*	*0.12*	*-0.01*
N	*10.00*	*3.00*	*8.00*	*12.00*	*11.00*	*8.00*	*9.00*	*8.00*	*11.00*	*18.00*	*7.00*	*18.00*

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

Appendix D

MBSS Benthic Macroinvertebrate Raw Metric Scores

% Intollerant

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1995	NA	NA	NA	0.51	0.39	NA	NA	NA	0.50	0.37	0.34	**0.42**
1996	NA	NA	NA	0.61	0.45	0.64	0.20	NA	0.65	0.62	0.37	**0.51**
1997	0.64	NA	NA	0.71	0.38	0.64	0.32	NA	0.75	0.75	0.50	**0.59**
1998	0.74	NA	NA	0.69	0.70	NA	0.33	0.40	0.55	0.64	0.65	**0.59**
1999	0.73	NA	NA	0.80	0.86	NA	NA	0.89	NA	0.66	NA	**0.79**
2000	NA	NA	NA	0.46	0.75	NA	NA	0.30	NA	0.56	NA	**0.52**
2001	NA	NA	NA	NA	NA	NA	NA	0.20	0.70	0.55	0.48	**0.48**
2002	NA	NA	NA	NA	NA	NA	NA	0.17	NA	0.78	NA	**0.48**
2003	NA	NA	NA	NA	NA	NA	NA	0.17	NA	0.50	NA	**0.34**
2004	0.90	0.81	0.92	0.60	0.49	0.71	0.33	0.25	0.72	0.76	NA	**0.65**
2005	0.69	NA	NA	NA	NA	NA	NA	0.20	NA	0.67	NA	**0.52**
2006	NA	0.66	0.80	NA	NA	NA	NA	0.13	NA	0.73	NA	**0.58**
2007	0.58	NA	0.55	NA	NA	NA	NA	0.03	NA	0.70	NA	**0.46**
2008	0.82	NA	0.47	0.19	0.38	0.57	0.47	0.15	0.55	0.50	NA	**0.46**
2009	NA	NA	0.81	0.30	0.12	0.77	0.41	0.09	0.75	0.45	NA	**0.46**
2010	0.77	NA	0.47	0.25	0.41	0.80	0.59	0.20	0.32	0.65	NA	**0.50**
2011	0.79	NA	0.65	0.26	0.68	0.69	0.53	0.37	0.52	0.79	0.39	**0.57**
2012	0.85	0.89	0.72	0.33	0.49	0.71	0.35	0.30	0.73	0.65	0.42	**0.59**
Average	**0.75**	**0.79**	**0.67**	**0.48**	**0.51**	**0.69**	**0.39**	**0.26**	**0.61**	**0.63**	**0.45**	**0.53**
R-square	*0.16*	***0.38***	*0.16*	***0.66***	*0.05*	*0.21*	***0.56***	*0.17*	*0.02*	*0.04*	*0.02*	*0.00*
Slope	*0.01*	*0.02*	*-0.03*	*-0.03*	*-0.01*	*0.01*	*0.01*	*-0.02*	*0.00*	*0.00*	*0.00*	*0.00*
N	*10.00*	*3.00*	*8.00*	*12.00*	*12.00*	*8.00*	*9.00*	*15.00*	*11.00*	*18.00*	*7.00*	*18.00*

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MBSS Benthic Macroinvertebrate Raw Metric Scores

% Tanytarsini

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1995	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
1996	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
1997	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
1998	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
1999	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
2000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
2001	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
2002	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
2003	NA	NA	NA	NA	NA	NA	NA	0.09	NA	0.10	NA	**0.10**
2004	0.01	NA	NA	NA	0.01	0.01	0.04	0.01	0.01	0.01	NA	**0.01**
2005	NA	NA	NA	NA	NA	NA	NA	0.02	NA	0.01	NA	**0.01**
2006	NA	NA	NA	NA	NA	NA	NA	0.05	NA	0.03	NA	**0.04**
2007	0.03	NA	0.14	NA	NA	NA	NA	0.11	NA	0.06	NA	**0.08**
2008	0.05	NA	0.16	0.11	0.10	0.06	0.05	0.24	0.07	0.01	NA	**0.10**
2009	NA	NA	0.04	0.06	0.02	0.03	0.02	0.02	0.01	0.09	NA	**0.04**
2010	0.05	NA	0.14	0.08	0.05	0.09	0.03	0.05	0.17	0.04	NA	**0.08**
2011	0.05	NA	0.14	0.06	0.05	0.05	0.02	0.08	0.11	0.01	NA	**0.06**
2012	0.02	NA	0.01	0.08	0.03	0.04	0.03	0.09	0.01	0.05	0.01	**0.04**
Average	**0.03**	**NA**	**0.11**	**0.08**	**0.04**	**0.05**	**0.03**	**0.08**	**0.06**	**0.04**	**0.01**	**0.06**
R-square	*0.16*	*NA*	*0.25*	*0.22*	*0.02*	*0.29*	***0.33***	*0.03*	*0.11*	*0.01*	*NA*	*0.00*
Slope	*0.00*	*NA*	*-0.02*	*-0.01*	*0.00*	*0.01*	*0.00*	*0.00*	*0.01*	*0.00*	*NA*	*0.00*
N	*6.00*	*0.00*	*6.00*	*5.00*	*6.00*	*6.00*	*6.00*	*10.00*	*6.00*	*10.00*	*1.00*	*10.00*

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MBSS Benthic Macroinvertebrate Raw Metric Scores

% Scrapers

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1995	NA	NA	NA	15%	30%	NA	NA	NA	32%	25%	19%	**0.24**
1996	NA	NA	NA	16%	6%	5%	20%	NA	6%	21%	19%	**0.13**
1997	11%	NA	NA	18%	31%	13%	21%	NA	6%	5%	18%	**0.15**
1998	13%	NA	NA	15%	14%	NA	2%	1%	3%	4%	1%	**0.06**
1999	17%	NA	NA	24%	11%	NA	NA	9%	NA	14%	NA	**0.15**
2000	NA	NA	NA	10%	14%	NA	NA	4%	NA	3%	NA	**0.08**
2001	NA	NA	NA	NA	NA	NA	NA	8%	31%	8%	0%	**0.12**
2002	NA	NA	NA	NA	NA	NA	NA	2%	NA	15%	NA	**0.09**
2003	NA	NA	NA	NA	NA	NA	NA	NA	NA	15%	NA	**0.15**
2004	NA	1%	NA	NA	6%	14%	7%	2%	1%	1%	NA	**0.04**
2005	8%	NA	NA	NA	NA	NA	NA	2%	NA	5%	NA	**0.05**
2006	NA	2%	6%	NA	NA	NA	NA	NA	NA	15%	NA	**0.08**
2007	3%	NA	9%	NA	NA	NA	NA	NA	NA	10%	NA	**0.07**
2008	2%	NA	3%	3%	4%	5%	7%	1%	10%	8%	NA	**0.05**
2009	NA	NA	NA	3%	1%	9%	13%	NA	10%	3%	NA	**0.06**
2010	5%	NA	4%	6%	5%	17%	13%	7%	3%	8%	NA	**0.08**
2011	4%	NA	2%	3%	1%	7%	8%	1%	2%	0%	2%	**0.03**
2012	12%	3%	2%	7%	6%	5%	9%	4%	8%	1%	7%	**0.06**
Average	**0.08**	**0.02**	**0.04**	**0.11**	**0.11**	**0.09**	**0.11**	**0.04**	**0.10**	**0.09**	**0.10**	**0.09**
R-square	***0.40***	***0.93***	***0.54***	***0.70***	***0.53***	*0.01*	*0.14*	*0.05*	*0.15*	***0.30***	***0.33***	***0.53***
Slope	*-0.01*	*0.00*	*-0.01*	*-0.01*	*-0.01*	*0.00*	*0.00*	*0.00*	*-0.01*	*-0.01*	*-0.01*	*-0.01*
N	*9.00*	*3.00*	*6.00*	*11.00*	*12.00*	*8.00*	*9.00*	*11.00*	*11.00*	*18.00*	*7.00*	*18.00*

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MBSS Benthic Macroinvertebrate Raw Metric Scores

% Swimmers

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1995	NA	NA	NA	0.21	0.01	NA	NA	NA	0.01	0.03	0.02	**0.06**
1996	NA	NA	NA	0.15	0.00	0.15	0.04	NA	0.02	0.04	0.02	**0.06**
1997	0.11	NA	NA	0.10	0.01	0.12	0.05	NA	0.13	0.07	NA	**0.09**
1998	0.31	NA	NA	0.13	0.09	NA	0.06	0.04	0.13	0.15	0.09	**0.12**
1999	0.06	NA	NA	0.06	0.09	NA	NA	0.01	NA	0.02	NA	**0.05**
2000	NA	NA	NA	0.10	0.11	NA	NA	0.02	NA	0.11	NA	**0.08**
2001	NA	NA	NA	NA	NA	NA	NA	0.02	0.04	0.11	0.05	**0.06**
2002	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.08	NA	**0.08**
2003	NA	NA	NA	NA	NA	NA	NA	0.01	NA	0.08	NA	**0.04**
2004	0.08	0.03	0.08	0.01	0.02	0.13	0.09	NA	0.07	0.05	NA	**0.06**
2005	0.46	NA	NA	NA	NA	NA	NA	0.02	NA	0.09	NA	**0.19**
2006	NA	0.07	0.26	NA	NA	NA	NA	NA	NA	0.16	NA	**0.16**
2007	0.14	NA	0.11	NA	NA	NA	NA	NA	NA	0.07	NA	**0.11**
2008	0.18	NA	0.06	0.01	0.02	0.12	0.08	0.00	0.08	0.07	NA	**0.07**
2009	NA	NA	0.09	0.01	0.02	0.19	0.06	NA	0.08	0.09	NA	**0.08**
2010	0.07	NA	0.05	0.01	0.01	0.08	0.04	NA	0.04	0.01	NA	**0.04**
2011	0.23	NA	0.13	0.01	0.01	0.14	0.05	0.01	0.09	0.03	0.14	**0.08**
2012	0.18	0.06	0.02	0.01	NA	0.07	0.03	NA	0.06	0.02	0.01	**0.05**
Average	**0.18**	**0.05**	**0.10**	**0.07**	**0.03**	**0.12**	**0.06**	**0.02**	**0.07**	**0.07**	**0.05**	**0.08**
R-square	*0.00*	*0.27*	*0.20*	***0.80***	*0.07*	*0.10*	*0.01*	***0.45***	*0.01*	*0.03*	*0.13*	*0.00*
Slope	*0.00*	*0.00*	*-0.01*	*-0.01*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
N	*10.00*	*3.00*	*8.00*	*12.00*	*11.00*	*8.00*	*9.00*	*8.00*	*11.00*	*18.00*	*6.00*	*18.00*

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Appendix D

MBSS Benthic Macroinvertebrate Raw Metric Scores

%Diptera

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1995	NA	NA	NA	0.25	0.35	NA	NA	NA	0.28	0.21	0.23	**0.26**
1996	NA	NA	NA	0.18	0.33	0.25	0.07	NA	0.63	0.14	0.21	**0.26**
1997	0.22	NA	NA	0.24	0.33	0.42	0.32	NA	0.49	0.56	0.43	**0.37**
1998	0.03	NA	NA	0.16	0.25	NA	0.65	0.59	0.41	0.23	0.20	**0.32**
1999	0.15	NA	NA	0.06	0.05	NA	NA	0.08	NA	0.16	NA	**0.10**
2000	NA	NA	NA	0.43	0.14	NA	NA	0.68	NA	0.31	NA	**0.39**
2001	NA	NA	NA	NA	NA	NA	NA	0.74	0.24	0.34	0.49	**0.45**
2002	NA	NA	NA	NA	NA	NA	NA	0.82	NA	0.18	NA	**0.50**
2003	NA	NA	NA	NA	NA	NA	NA	0.88	NA	0.42	NA	**0.65**
2004	0.11	0.23	0.10	0.41	0.55	0.26	0.63	0.79	0.26	0.26	NA	**0.36**
2005	0.16	NA	NA	NA	NA	NA	NA	0.77	NA	0.25	NA	**0.39**
2006	NA	0.29	0.08	NA	NA	NA	NA	0.93	NA	0.27	NA	**0.39**
2007	0.34	NA	0.48	NA	NA	NA	NA	0.94	NA	0.36	NA	**0.53**
2008	0.19	NA	0.56	0.78	0.65	0.47	0.32	0.86	0.44	0.61	NA	**0.54**
2009	NA	NA	0.13	0.59	0.87	0.15	0.14	0.95	0.18	0.36	NA	**0.42**
2010	0.17	NA	0.54	0.54	0.38	0.25	0.16	0.55	0.69	0.27	NA	**0.39**
2011	0.15	NA	0.31	0.78	0.31	0.27	0.16	0.68	0.35	0.19	0.41	**0.36**
2012	0.17	0.11	0.28	0.74	0.71	0.52	0.46	0.84	0.31	0.39	0.52	**0.46**
Average	**0.17**	**0.21**	**0.31**	**0.43**	**0.41**	**0.32**	**0.32**	**0.74**	**0.39**	**0.30**	**0.36**	**0.40**
R-square	*0.08*	***0.75***	*0.12*	***0.80***	***0.37***	*0.00*	*0.03*	*0.19*	*0.02*	*0.05*	***0.46***	*0.21*
Slope	*0.00*	*-0.02*	*0.03*	*0.04*	*0.02*	*0.00*	*-0.01*	*0.02*	*0.00*	*0.01*	*0.01*	*0.01*
N	*10.00*	*3.00*	*8.00*	*12.00*	*12.00*	*8.00*	*9.00*	*15.00*	*11.00*	*18.00*	*7.00*	*18.00*

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

Appendix D

Number Taxa

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994	NA	NA	NA	5.00	5.00	NA	NA	NA	5.00	5.00	5.00	**5.00**
1995	NA	NA	NA	5.00	5.00	5.00	5.00	NA	5.00	5.00	5.00	**5.00**
1996	5.00	NA	NA	5.00	5.00	5.00	5.00	NA	5.00	5.00	5.00	**5.00**
1997	5.00	NA	NA	5.00	3.00	NA	3.00	5.00	5.00	3.00	3.00	**4.00**
1998	5.00	NA	NA	3.00	3.00	NA	NA	1.00	NA	3.00	NA	**3.00**
1999	NA	NA	NA	5.00	3.00	NA	NA	5.00	NA	3.00	NA	**4.00**
2000	NA	NA	NA	NA	NA	NA	NA	3.00	3.00	3.00	1.00	**2.50**
2001	NA	NA	NA	NA	NA	NA	NA	1.00	NA	5.00	NA	**3.00**
2002	NA	NA	NA	NA	NA	NA	NA	3.00	NA	5.00	NA	**4.00**
2003	3.00	1.00	3.00	1.00	3.00	3.00	3.00	3.00	3.00	3.00	NA	**2.60**
2004	3.00	NA	NA	NA	NA	NA	NA	3.00	NA	5.00	NA	**3.67**
2005	NA	3.00	3.00	NA	NA	NA	NA	1.00	NA	5.00	NA	**3.00**
2006	5.00	NA	3.00	NA	NA	NA	NA	1.00	NA	3.00	NA	**3.00**
2007	5.00	NA	3.00	3.00	5.00	5.00	5.00	5.00	5.00	5.00	NA	**4.56**
2008	NA	NA	3.00	3.00	3.00	3.00	5.00	1.00	3.00	3.00	NA	**3.00**
2009	5.00	NA	5.00	5.00	3.00	3.00	5.00	5.00	3.00	3.00	NA	**4.11**
2010	5.00	NA	5.00	3.00	3.00	5.00	5.00	5.00	5.00	3.00	5.00	**4.40**
2011	5.00	5.00	5.00	3.00	3.00	5.00	5.00	5.00	5.00	3.00	5.00	**4.45**
2012	5.00	5.00	3.00	5.00	5.00	5.00	5.00	3.00	5.00	5.00	5.00	**4.64**
Average	**4.64**	**3.50**	**3.67**	**3.92**	**3.77**	**4.33**	**4.60**	**3.13**	**4.33**	**3.95**	**4.25**	**3.84**
R-square	*0.01*	***0.93***	*0.29*	*0.13*	*0.07*	*0.01*	*0.15*	*0.03*	*0.03*	*0.04*	*0.05*	*0.01*
Slope	*0.02*	*0.42*	*0.18*	*-0.07*	*-0.04*	*-0.02*	*0.05*	*0.06*	*-0.02*	*-0.04*	*0.04*	*-0.01*
N	*11.00*	*4.00*	*9.00*	*13.00*	*13.00*	*9.00*	*10.00*	*16.00*	*12.00*	*19.00*	*8.00*	*19.00*

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

Appendix D

 # EPT

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994	NA	NA	NA	5.00	5.00	NA	NA	NA	5.00	5.00	3.00	**4.60**
1995	NA	NA	NA	5.00	5.00	5.00	5.00	NA	5.00	5.00	5.00	**5.00**
1996	5.00	NA	NA	5.00	5.00	5.00	5.00	NA	5.00	5.00	3.00	**4.75**
1997	5.00	NA	NA	5.00	3.00	NA	3.00	3.00	5.00	3.00	3.00	**3.75**
1998	5.00	NA	NA	3.00	3.00	NA	NA	1.00	NA	3.00	NA	**3.00**
1999	NA	NA	NA	5.00	3.00	NA	NA	3.00	NA	5.00	NA	**4.00**
2000	NA	NA	NA	NA	NA	NA	NA	3.00	5.00	3.00	1.00	**3.00**
2001	NA	NA	NA	NA	NA	NA	NA	3.00	NA	3.00	NA	**3.00**
2002	NA	NA	NA	NA	NA	NA	NA	1.00	NA	5.00	NA	**3.00**
2003	3.00	1.00	3.00	1.00	1.00	3.00	3.00	1.00	1.00	3.00	NA	**2.00**
2004	3.00	NA	NA	NA	NA	NA	NA	1.00	NA	3.00	NA	**2.33**
2005	NA	3.00	3.00	NA	NA	NA	NA	1.00	NA	5.00	NA	**3.00**
2006	3.00	NA	1.00	NA	NA	NA	NA	1.00	NA	3.00	NA	**2.00**
2007	3.00	NA	3.00	3.00	3.00	5.00	5.00	1.00	3.00	5.00	NA	**3.44**
2008	NA	NA	3.00	1.00	1.00	3.00	5.00	NA	3.00	3.00	NA	**2.71**
2009	3.00	NA	3.00	5.00	3.00	3.00	5.00	3.00	5.00	3.00	NA	**3.67**
2010	5.00	NA	5.00	3.00	3.00	5.00	5.00	3.00	5.00	3.00	3.00	**4.00**
2011	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	5.00	**3.18**
2012	5.00	5.00	3.00	5.00	3.00	3.00	5.00	3.00	5.00	5.00	5.00	**4.27**
Average	**3.91**	**3.00**	**3.00**	**3.77**	**3.15**	**3.89**	**4.40**	**2.07**	**4.17**	**3.84**	**3.50**	**3.41**
R-square	*0.14*	***0.69***	*0.12*	*0.15*	***0.32***	***0.30***	*0.01*	*0.02*	*0.08*	*0.07*	*0.14*	*0.12*
Slope	*-0.07*	*0.31*	*0.12*	*-0.09*	*-0.11*	*-0.09*	*0.02*	*0.03*	*-0.06*	*-0.05*	*0.07*	*-0.05*
N	*11.00*	*4.00*	*9.00*	*13.00*	*13.00*	*9.00*	*10.00*	*15.00*	*12.00*	*19.00*	*8.00*	*19.00*

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

Appendix D

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Ephemeroptera

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994	NA	NA	NA	5.00	3.00	NA	NA	NA	1.00	3.00	3.00	**3.00**
1995	NA	NA	NA	5.00	1.00	3.00	5.00	NA	3.00	5.00	5.00	**3.86**
1996	5.00	NA	NA	5.00	1.00	5.00	5.00	NA	5.00	5.00	1.00	**4.00**
1997	5.00	NA	NA	5.00	3.00	NA	5.00	3.00	3.00	5.00	3.00	**4.00**
1998	5.00	NA	NA	3.00	3.00	NA	NA	1.00	NA	3.00	NA	**3.00**
1999	NA	NA	NA	5.00	3.00	NA	NA	3.00	NA	5.00	NA	**4.00**
2000	NA	NA	NA	NA	NA	NA	NA	1.00	3.00	3.00	3.00	**2.50**
2001	NA	NA	NA	NA	NA	NA	NA	NA	NA	5.00	NA	**5.00**
2002	NA	NA	NA	NA	NA	NA	NA	NA	NA	5.00	NA	**5.00**
2003	3.00	1.00	5.00	1.00	1.00	3.00	3.00	NA	3.00	5.00	NA	**2.78**
2004	3.00	NA	NA	NA	NA	NA	NA	1.00	NA	5.00	NA	**3.00**
2005	NA	1.00	3.00	NA	NA	NA	NA	NA	NA	5.00	NA	**3.00**
2006	5.00	NA	3.00	NA	NA	NA	NA	NA	NA	3.00	NA	**3.67**
2007	5.00	NA	5.00	3.00	1.00	5.00	5.00	1.00	5.00	5.00	NA	**3.89**
2008	NA	NA	5.00	1.00	1.00	5.00	5.00	NA	5.00	5.00	NA	**3.86**
2009	3.00	NA	3.00	3.00	NA	5.00	5.00	1.00	5.00	1.00	NA	**3.25**
2010	5.00	NA	3.00	3.00	1.00	5.00	5.00	1.00	5.00	3.00	5.00	**3.60**
2011	3.00	3.00	3.00	1.00	1.00	3.00	5.00	NA	5.00	5.00	5.00	**3.40**
2012	5.00	3.00	1.00	5.00	3.00	5.00	5.00	1.00	5.00	3.00	5.00	**3.73**
Average	**4.27**	**2.00**	**3.44**	**3.46**	**1.83**	**4.33**	**4.80**	**1.44**	**4.00**	**4.16**	**3.75**	**3.61**
R-square	*0.07*	***0.96***	***0.39***	***0.32***	*0.11*	*0.10*	*0.01*	***0.36***	***0.57***	*0.05*	***0.42***	*0.00*
Slope	*-0.05*	*0.26*	*-0.28*	*-0.14*	*-0.05*	*0.05*	*0.01*	*-0.09*	*0.15*	*-0.05*	*0.12*	*-0.01*
N	*11.00*	*4.00*	*9.00*	*13.00*	*12.00*	*9.00*	*10.00*	*9.00*	*12.00*	*19.00*	*8.00*	*19.00*

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

Appendix D

% Intollerant

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994	NA	NA	NA	3.00	3.00	NA	NA	NA	3.00	1.00	1.00	**2.20**
1995	NA	NA	NA	3.00	3.00	3.00	1.00	NA	3.00	3.00	1.00	**2.43**
1996	3.00	NA	NA	3.00	1.00	3.00	1.00	NA	3.00	3.00	3.00	**2.50**
1997	3.00	NA	NA	3.00	3.00	NA	1.00	3.00	3.00	3.00	3.00	**2.75**
1998	3.00	NA	NA		5.00	NA	NA	5.00	NA	3.00	NA	**4.00**
1999	NA	NA	NA	3.00	3.00	NA	NA	1.00	NA	3.00	NA	**2.50**
2000	NA	NA	NA	NA	NA	NA	NA	1.00	3.00	3.00	3.00	**2.50**
2001	NA	NA	NA	NA	NA	NA	NA	1.00	NA	3.00	NA	**2.00**
2002	NA	NA	NA	NA	NA	NA	NA	1.00	NA	3.00	NA	**2.00**
2003	5.00	5.00	5.00	3.00	3.00	3.00	1.00	1.00	3.00	3.00	NA	**3.20**
2004	3.00	NA	NA	NA	NA	NA	NA	1.00	NA	3.00	NA	**2.33**
2005	NA	3.00	5.00	NA	NA	NA	NA	1.00	NA	3.00	NA	**3.00**
2006	3.00	NA	3.00	NA	NA	NA	NA	1.00	NA	3.00	NA	**2.50**
2007	5.00	NA	3.00	1.00	3.00	3.00	3.00	1.00	3.00	3.00	NA	**2.78**
2008	NA	NA	5.00	1.00	1.00	3.00	3.00	1.00	3.00	3.00	NA	**2.50**
2009	3.00	NA	3.00	1.00	3.00		3.00	1.00	1.00	3.00	NA	**2.25**
2010		NA	3.00	1.00	3.00	3.00	3.00	1.00	3.00		3.00	**2.50**
2011	5.00	5.00	3.00	1.00	3.00	3.00	1.00	1.00	3.00	3.00	3.00	**2.82**
2012	3.00	3.00	1.00	3.00	3.00	1.00	3.00	1.00	1.00	1.00	1.00	**1.91**
Average	**3.60**	**4.00**	**3.44**	**2.17**	**2.85**	**2.75**	**2.00**	**1.38**	**2.67**	**2.78**	**2.25**	**2.56**
R-square	*0.10*	*0.04*	***0.57***	***0.52***	*0.01*	*0.17*	***0.50***	*0.28*	*0.23*	*0.00*	*0.03*	*0.02*
Slope	*0.05*	*-0.05*	*-0.34*	*-0.11*	*-0.01*	*-0.04*	*0.11*	*-0.12*	*-0.06*	*0.00*	*0.02*	*-0.01*
N	*10.00*	*4.00*	*9.00*	*12.00*	*13.00*	*8.00*	*10.00*	*16.00*	*12.00*	*18.00*	*8.00*	*19.00*

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

Appendix D

% Tanytarsini

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
1995	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
1996	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
1997	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
1998	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
1999	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
2000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
2001	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
2002	NA	NA	NA	NA	NA	NA	NA	5.00	NA	5.00	NA	**5.00**
2003	3.00	NA	NA	NA	3.00	3.00	5.00	3.00	3.00	3.00	NA	**3.29**
2004	NA	NA	NA	NA	NA	NA	NA	3.00	NA	3.00	NA	**3.00**
2005	NA	NA	NA	NA	NA	NA	NA	5.00	NA	3.00	NA	**4.00**
2006	3.00	NA	5.00	NA	NA	NA	NA	5.00	NA	5.00	NA	**4.50**
2007	5.00	NA	5.00	5.00	5.00	5.00	5.00	5.00	5.00	3.00	NA	**4.78**
2008	NA	NA	5.00	5.00	3.00	3.00	3.00	3.00	3.00	5.00	NA	**3.75**
2009	5.00	NA	5.00	5.00	5.00	5.00	3.00	5.00	5.00	5.00	NA	**4.78**
2010	5.00	NA	5.00	5.00	5.00	5.00	3.00	5.00	5.00	3.00	NA	**4.56**
2011	3.00	NA	3.00	5.00	3.00	3.00	3.00	5.00	3.00	5.00	5.00	**3.80**
2012	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	**3.00**
Average	**3.86**	**3.00**	**4.43**	**4.67**	**3.86**	**3.86**	**3.57**	**4.27**	**3.86**	**3.91**	**4.00**	**4.04**
R-square	*0.01*	*NA*	***0.63***	***0.43***	*0.00*	*0.00*	***0.66***	*0.00*	*0.00*	*0.00*	***1.00***	*0.01*
Slope	*0.04*	*NA*	*-0.36*	*-0.29*	*0.01*	*0.01*	*-0.27*	*0.02*	*0.01*	*0.02*	*-2.00*	*-0.02*
N	*7.00*	*1.00*	*7.00*	*6.00*	*7.00*	*7.00*	*7.00*	*11.00*	*7.00*	*11.00*	*2.00*	*11.00*

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

Appendix D

% Scrapers

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994	NA	NA	NA	5.00	5.00	NA	NA	NA	5.00	5.00	5.00	**5.00**
1995	NA	NA	NA	5.00	3.00	3.00	5.00	NA	3.00	5.00	5.00	**4.14**
1996	3.00	NA	NA	5.00	5.00	5.00	5.00	NA	3.00	3.00	5.00	**4.25**
1997		NA	NA	5.00	5.00	NA	1.00	1.00	1.00	3.00	1.00	**2.43**
1998	5.00	NA	NA	5.00	3.00	NA	NA	3.00	NA	5.00	NA	**4.20**
1999	NA	NA	NA	3.00	5.00	NA	NA	3.00	NA	3.00	NA	**3.50**
2000	NA	NA	NA	NA	NA	NA	NA	3.00	5.00	3.00	1.00	**3.00**
2001	NA	NA	NA	NA	NA	NA	NA	1.00	NA	5.00	NA	**3.00**
2002	NA	NA	NA	NA	NA	NA	NA	NA	NA	5.00	NA	**5.00**
2003	NA	1.00	NA	NA	3.00	5.00	3.00	1.00	1.00	1.00	NA	**2.14**
2004	3.00	NA	NA	NA	NA	NA	NA	1.00	NA	3.00	NA	**2.33**
2005	NA	1.00	3.00	NA	NA	NA	NA	NA	NA	5.00	NA	**3.00**
2006	1.00	NA	3.00	NA	NA	NA	NA	NA	NA	3.00	NA	**2.33**
2007	1.00	NA	1.00	3.00	3.00	3.00	3.00	1.00	3.00	3.00	NA	**2.33**
2008	NA	NA	NA	1.00	1.00	3.00	5.00	NA	3.00	1.00	NA	**2.33**
2009	3.00	NA	3.00	3.00	3.00	5.00		3.00	3.00	3.00	NA	**3.25**
2010	3.00	NA	1.00	1.00	1.00	3.00	3.00	1.00	1.00	1.00	1.00	**1.60**
2011		3.00	1.00	3.00	3.00	3.00	3.00	3.00	3.00	1.00	3.00	**2.60**
2012	3.00	1.00	NA	1.00	1.00	1.00	3.00	1.00	1.00	1.00	1.00	**1.40**
Average	**2.75**	**1.50**	**2.00**	**3.33**	**3.15**	**3.44**	**3.44**	**1.83**	**2.67**	**3.11**	**2.75**	**3.04**
R-square	*0.15*	*0.24*	***0.38***	***0.75***	***0.59***	*0.21*	*0.03*	*0.02*	*0.15*	***0.43***	***0.35***	***0.52***
Slope	*-0.09*	*0.11*	*-0.29*	*-0.21*	*-0.17*	*-0.10*	*-0.04*	*-0.03*	*-0.08*	*-0.18*	*-0.15*	*-0.14*
N	*8.00*	*4.00*	*6.00*	*12.00*	*13.00*	*9.00*	*9.00*	*12.00*	*12.00*	*19.00*	*8.00*	*19.00*

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

Appendix D

% Swimmers

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994	NA	NA	NA	5.00	1.00	NA	NA	NA	1.00	3.00	1.00	**2.20**
1995	NA	NA	NA	3.00	1.00	3.00	3.00	NA	1.00	3.00	1.00	**2.14**
1996	3.00	NA	NA	3.00	1.00	3.00	3.00	NA	3.00	3.00	NA	**2.71**
1997	5.00	NA	NA	3.00	3.00	NA	3.00	3.00	3.00	3.00	3.00	**3.25**
1998	3.00	NA	NA	3.00	3.00	NA	NA	1.00	NA	1.00	NA	**2.20**
1999	NA	NA	NA	3.00	3.00	NA	NA	1.00	NA	3.00	NA	**2.50**
2000	NA	NA	NA	NA	NA	NA	NA	1.00	3.00	3.00	3.00	**2.50**
2001	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.00	NA	**3.00**
2002	NA	NA	NA	NA	NA	NA	NA	1.00	NA	3.00	NA	**2.00**
2003	3.00	3.00	3.00	1.00	1.00	3.00	3.00	NA	3.00	3.00	NA	**2.56**
2004	5.00	NA	NA	NA	NA	NA	NA	1.00	NA	3.00	NA	**3.00**
2005	NA	3.00	5.00	NA	NA	NA	NA	NA	NA	3.00	NA	**3.67**
2006	3.00	NA	3.00	NA	NA	NA	NA	NA	NA	3.00	NA	**3.00**
2007		NA	3.00	1.00	1.00	3.00	3.00	1.00	3.00	3.00	NA	**2.25**
2008	NA	NA	3.00	1.00	1.00	5.00	3.00	NA	3.00	3.00	NA	**2.71**
2009	3.00	NA	3.00	1.00	1.00	3.00	3.00	NA	3.00	1.00	NA	**2.25**
2010	5.00	NA	3.00	1.00	1.00	3.00	3.00	1.00	3.00	1.00	3.00	**2.40**
2011	5.00	3.00	1.00	1.00	NA	3.00	3.00	NA	3.00	1.00	1.00	**2.33**
2012	3.00	3.00	1.00	1.00	1.00	3.00	3.00	1.00	3.00	3.00	1.00	**2.09**
Average	**3.80**	**3.00**	**2.78**	**2.08**	**1.50**	**3.22**	**3.00**	**1.22**	**2.67**	**2.58**	**1.86**	**2.57**
R-square	*0.02*	*NA*	***0.51***	***0.81***	*0.16*	*0.02*	*NA*	*0.19*	***0.38***	*0.14*	*0.00*	*0.00*
Slope	*0.02*	*0.00*	*-0.29*	*-0.18*	*-0.06*	*0.01*	*0.00*	*-0.05*	*0.07*	*-0.06*	*-0.01*	*0.00*
N	*10.00*	*4.00*	*9.00*	*13.00*	*12.00*	*9.00*	*10.00*	*9.00*	*12.00*	*19.00*	*7.00*	*19.00*

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

Appendix D

%Diptera

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994	NA	NA	NA	1.00	5.00	NA	NA	NA	5.00	1.00	1.00	**2.60**
1995	NA	NA	NA	1.00	5.00	1.00	1.00	NA	5.00	1.00	1.00	**2.14**
1996	1.00	NA	NA	1.00	5.00	5.00	5.00	NA	5.00	5.00	5.00	**4.00**
1997	1.00	NA	NA	1.00	1.00	NA	5.00	5.00	5.00	1.00	1.00	**2.50**
1998	1.00	NA	NA	1.00	1.00	NA	NA	1.00	NA	1.00	NA	**1.00**
1999	NA	NA	NA	5.00	1.00	NA	NA	5.00	NA	5.00	NA	**4.00**
2000	NA	NA	NA	NA	NA	NA	NA	5.00	1.00	5.00	5.00	**4.00**
2001	NA	NA	NA	NA	NA	NA	NA	5.00	NA	1.00	NA	**3.00**
2002	NA	NA	NA	NA	NA	NA	NA	5.00	NA	5.00	NA	**5.00**
2003	1.00	1.00	1.00	5.00	5.00	1.00	5.00	5.00	5.00	5.00	NA	**3.40**
2004	1.00	NA	NA	NA	NA	NA	NA	5.00	NA	1.00	NA	**2.33**
2005	NA	5.00	1.00	NA	NA	NA	NA	5.00	NA	5.00	NA	**4.00**
2006	5.00	NA	5.00	NA	NA	NA	NA	5.00	NA	5.00	NA	**5.00**
2007	1.00	NA	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	NA	**4.56**
2008	NA	NA	1.00	5.00	5.00	1.00	1.00	5.00	1.00	5.00	NA	**3.00**
2009	1.00	NA	5.00	5.00	5.00	1.00	1.00	5.00	5.00	5.00	NA	**3.67**
2010	1.00	NA	5.00	5.00	5.00	5.00	1.00	5.00	5.00	1.00	5.00	**3.80**
2011	1.00	1.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	**4.27**
2012	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	**5.00**
Average	**1.73**	**3.00**	**3.67**	**3.46**	**4.08**	**3.22**	**3.40**	**4.75**	**4.33**	**3.53**	**3.50**	**3.54**
R-square	*0.13*	*0.04*	***0.43***	***0.73***	*0.18*	*0.08*	*0.01*	*0.13*	*0.00*	*0.19*	***0.49***	*0.28*
Slope	*0.10*	*0.10*	*0.45*	*0.26*	*0.11*	*0.10*	*-0.03*	*0.08*	*-0.01*	*0.15*	*0.19*	*0.10*
N	*11.00*	*4.00*	*9.00*	*13.00*	*13.00*	*9.00*	*10.00*	*16.00*	*12.00*	*19.00*	*8.00*	*19.00*

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

Appendix D

Composite

	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994	NA	NA	NA	4.14	3.86	NA	NA	NA	3.57	3.29	2.71	**3.51**
1995	NA	NA	NA	3.86	3.29	3.29	3.57	NA	3.57	3.86	3.29	**3.53**
1996	3.57	NA	NA	3.86	3.29	4.43	4.14	NA	4.14	4.14	3.67	**3.90**
1997	4.00	NA	NA	3.86	3.00	NA	3.00	3.29	3.57	3.00	2.43	**3.27**
1998	3.86	NA	NA	3.00	3.00	NA	NA	1.86	NA	2.71	NA	**2.89**
1999	NA	NA	NA	4.14	3.00	NA	NA	3.00	NA	3.86	NA	**3.50**
2000	NA	NA	NA	NA	NA	NA	NA	2.43	3.29	3.29	2.43	**2.86**
2001	NA	NA	NA	NA	NA	NA	NA	2.20	NA	3.57	NA	**2.89**
2002	NA	NA	NA	NA	NA	NA	NA	2.67	NA	4.50	NA	**3.58**
2003	3.00	1.86	3.33	2.00	2.50	3.00	3.25	2.33	2.75	3.25	NA	**2.73**
2004	3.00	NA	NA	NA	NA	NA	NA	2.00	NA	3.25	NA	**2.75**
2005	NA	2.71	3.29	NA	NA	NA	NA	2.60	NA	4.25	NA	**3.21**
2006	3.50	NA	3.25	NA	NA	NA	NA	2.60	NA	3.50	NA	**3.21**
2007	3.57	NA	3.50	3.00	3.25	4.25	4.25	2.50	4.00	4.00	NA	**3.59**
2008	NA	NA	3.57	2.25	2.00	3.25	3.75	2.50	3.00	3.50	NA	**2.98**
2009	3.25	NA	3.75	3.50	3.29	3.57	3.57	3.29	3.75	3.00	NA	**3.44**
2010	4.14	NA	3.75	2.75	2.75	4.25	3.50	2.75	4.00	2.14	3.57	**3.36**
2011	3.86	3.57	3.00	3.00	3.00	3.50	3.75	3.67	4.00	3.50	4.00	**3.53**
2012	3.86	3.25	2.43	3.35	3.02	3.36	3.93	2.13	3.40	3.11	3.06	**3.17**
Average	**3.60**	**2.85**	**3.32**	**3.28**	**3.02**	**3.66**	**3.67**	**2.61**	**3.59**	**3.46**	**3.14**	**3.26**
R-square	*0.01*	***0.84***	*0.11*	***0.33***	*0.20*	*0.01*	*0.06*	*0.04*	*0.00*	*0.05*	*0.21*	*0.01*
Slope	*0.00*	*0.16*	*-0.05*	*-0.06*	*-0.03*	*-0.01*	*0.01*	*0.02*	*0.00*	*-0.02*	*0.03*	*-0.01*
N	*11.00*	*4.00*	*9.00*	*13.00*	*13.00*	*9.00*	*10.00*	*16.00*	*12.00*	*19.00*	*8.00*	*19.00*

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

4.0 Herptofauna

Table 4-5. DEP Herptofauna Presence Data

Species	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304
American Bull Frog	●				●				●	●	●
Common Ribbonsnake			●						●		
Eastern American Toad			●			●	●	●	●	●	
Eastern Box Turtle			●						●		
Eastern Gartersnake			●		●						
Eastern Red-backed Salamander	●	●	●	●	●	●	●	●	●	●	●
Eastern Snapping Turtle									●		
Fowler's Toad				●	●					●	
Grey Tree Frog	●								●		
Long-tailed Salamander				●						●	
Northern Dusky Salamander	●		●	●	●	●		●	●	●	
Northern Green Frog	●	●	●	●	●	●	●	●	●	●	
Northern Red Salamander	●				●		●				
Northern Red-bellied Turtle							●				
Northern Ring-necked Snake										●	
Northern Slimy Salamander					●						
Northern Two-lined Salamander	●		●	●	●	●	●	●	●	●	●
Northern Watersnake			●				●		●	●	
Pickerel Frog			●	●	●	●	●	●	●	●	●
Queen Snake							●				
Spotted Salamander	●										
Wood Frog	●				●	●		●	●		●

Key:
Bold-Italics name indicates species most sensitive to urbanization. **Bold name** indicates species moderately sensitive to urbanization. Plain text name indicates species insensitive to urbanization. Source: Boward et al. 1999

5.0 Biological Condition

The overall biological condition is the average of the percent of the maximum value for the fish and benthic macroinvertabrate IBIs (Keith Van Ness, personal communication, February 12, 2013). These data are qualified according to the following criteria presented in TableD-6. The individual biological condition scores are presented in the Table D-7

Table D-6. Fish IBI scoring criteria

Condition category	Score
Excellent	>87
Good	>63-87
Fair	>41-63
Poor	≤41

Source: Keith Van Ness, personal communication, February 11, 2013.

Appendix D

Table D-7. Biological Condition Scores

Sample Year	LSTM110	LSTM111	LSTM112	LSTM201	LSTM202	LSTM203	LSTM204	LSTM206	LSTM302	LSTM303B	LSTM304	Average
1994	NA	NA	NA	0.91	0.84	NA	NA	NA	0.82	0.80	0.70	**0.81**
1995	NA	NA	NA	0.95	0.90	0.93	0.85	NA	0.91	0.86	0.86	**0.90**
1996	1.00	NA	NA	0.90	0.85	0.90	0.85	NA	0.90	0.90	0.85	**0.89**
1997	0.95	NA	NA	0.95	0.88	NA	0.70	0.83	0.82	0.86	0.86	**0.86**
1998	0.90	NA	NA	0.85	0.88	NA	NA	0.86	NA	0.84	0.73	**0.84**
1999	NA	NA	NA	0.90	0.80	NA	NA	0.75	NA	0.95	NA	**0.85**
2000	NA	NA	NA	NA	NA	NA	NA	0.74	0.77	0.68	0.63	**0.71**
2001	NA	NA	NA	NA	NA	NA	NA	0.71	NA	0.82	NA	**0.77**
2002	NA	NA	NA	NA	NA	NA	NA	0.46	NA	0.90	NA	**0.68**
2003	0.75	0.60	0.70	0.65	0.70	0.80	0.70	0.62	0.85	0.61	0.47	**0.68**
2004	0.95	NA	NA	NA	NA	NA	NA	0.66	NA	0.84	NA	**0.82**
2005	NA	0.80	0.80	NA	NA	NA	NA	0.41	NA	0.91	0.73	**0.73**
2006	0.80	NA	0.75	NA	NA	NA	NA	0.47	NA	0.73	0.47	**0.64**
2007	0.80	NA	0.56	0.64	0.74	0.83	0.90	0.50	0.79	0.86	NA	**0.74**
2008	NA	NA	0.70	0.69	0.71	0.84	0.90	0.40	0.75	0.75	NA	**0.72**
2009	0.85	NA	0.85	0.74	0.72	0.81	0.88	0.62	0.63	0.79	NA	**0.77**
2010	1.00	NA	0.85	0.67	0.74	0.86	0.88	0.69	0.86	0.70	0.84	**0.81**
2011	0.90	0.80	0.80	0.66	0.67	0.83	0.90	0.61	0.90	0.61	0.75	**0.77**
2012	0.85	0.75	0.50	0.77	0.74	0.73	0.91	0.74	0.69	0.79	0.79	**0.75**
Average	**0.89**	**0.74**	**0.72**	**0.79**	**0.78**	**0.84**	**0.85**	**0.63**	**0.81**	**0.80**	**0.72**	**0.77**
R-square	*0.09*	*0.34*	*0.01*	*0.71*	*0.76*	*0.57*	*0.32*	*0.19*	*0.19*	*0.20*	*0.02*	*0.27*
Slope	*0.00*	*0.01*	*0.00*	*-0.02*	*-0.01*	*-0.01*	*0.01*	*-0.01*	*-0.01*	*-0.01*	*0.00*	*-0.01*
N	*11*	*4*	*9*	*13*	*13*	*9*	*10*	*16*	*12*	*19*	*12*	*19*

Note: NA within the data table indicates that data was not available for the respective station for that sample year. NA associated with the calculated parameters below the data table indicates that a value could not be computed because either no variation in the data was observed over time or an insufficient number of observations were recorded to compute a value.

APPENDIX E. RARE, THREATENED, AND ENDANGERED SPECIES INFORMATION REQUEST LETTERS

Biohabitats
Incorporated

2081 Clipper Park Road
Baltimore, MD 21211
Tel 410.554.0156
Fax 410.554.0168
www.biohabitats.com

January 23, 2013

Lori A. Byrne
Environmental Review Coordinator
MD DNR - Wildlife and Heritage Service
Tawes State Office Building
580 Taylor Ave.
Annapolis, MD 21401

RE: Montgomery County, Ten Mile Creek Watershed
Species Information Request

Dear Ms. Byrne:

Biohabitats, Inc. is requesting any information you may have regarding state rare, threatened and/or endangered plant or animal species within or near Ten Mile Creek watershed in Montgomery County.

The site encompasses Ten Mile Creek watershed located in northern Montgomery County (ADC Map #12, B-H, 1-9 and Map #4, B-K, 9-13). Brown and Caldwell/Biohabitats, a Joint Venture, are contracted by Maryland - National Capital Park and Planning Commission (M-NCPPC) Montgomery County Planning Department to provide data and environmental analysis of Ten Mile Creek watershed. This analysis is in support of the Planning Department undertaking a Limited Amendment to the Clarksburg Master Plan focusing on the Ten Mile Creek area in response to a request by the County Council in October 2012. Rare, threatened and endangered species is one piece of information being collected to assess the existing conditions of the watershed.

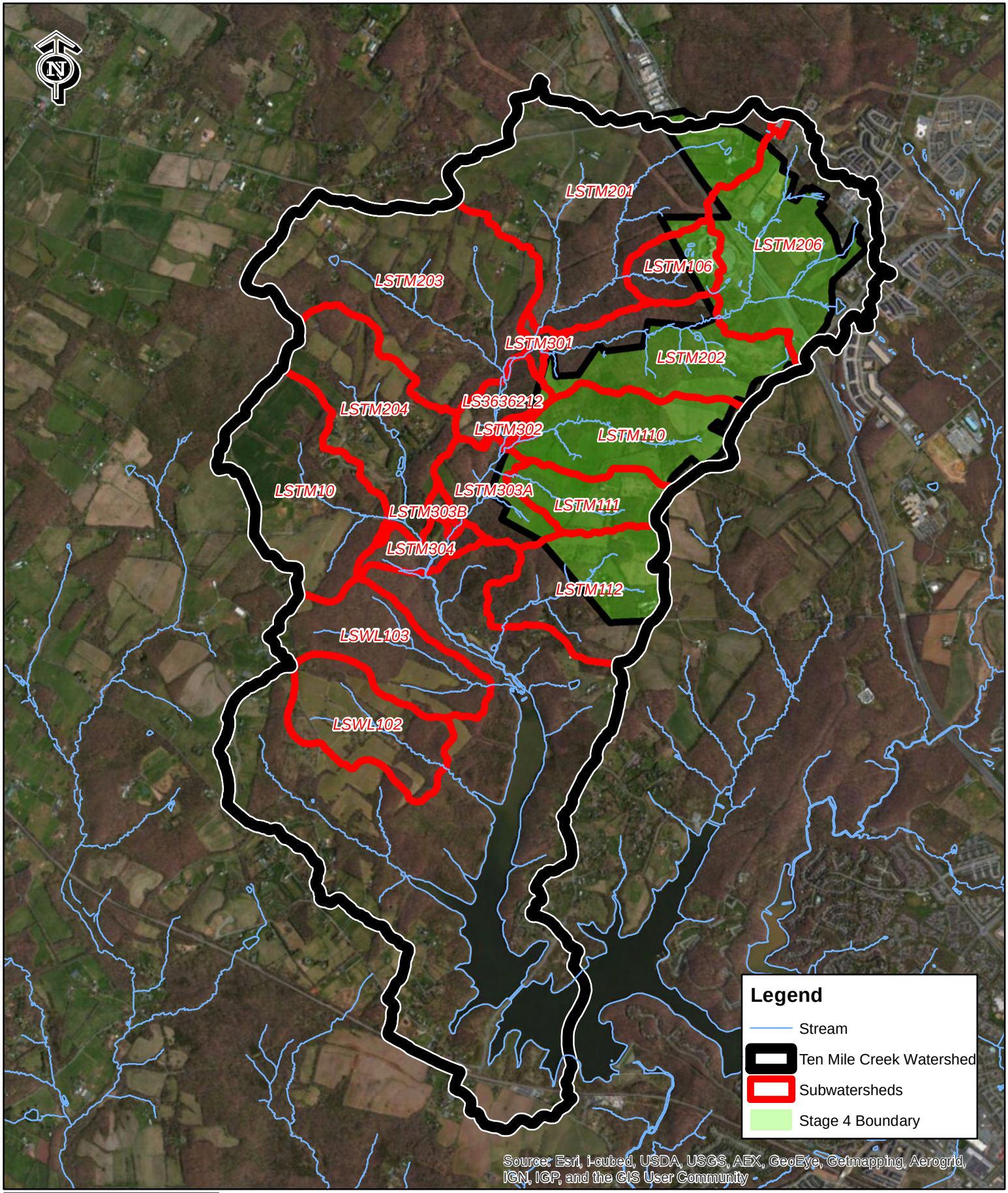
Please find the enclosed vicinity map showing the watershed location. Feel free to call me at 410-554-0156 should you have any questions. Thank you for your time and attention.

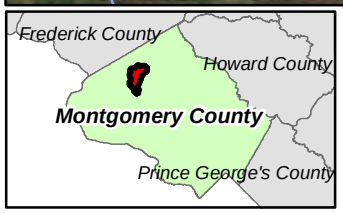
Sincerely,
BIOHABITATS, INC.

_____

Sarah Roberts
Environmental Scientist

Enclosure: Map of the Ten Mile Creek watershed





Ten Mile Creek

Map of Watershed

0 3,000 6,000 Feet

1 inch = 3,000 feet

United States Department of the Interior
U.S. Fish & Wildlife Service
Chesapeake Bay Field Office
177 Admiral Cochrane Drive
Annapolis, MD 21401
410/573 4575

Online Certification Letter

Today's date: January 22, 2013

Project: Clarksburg Master Plan Limited Amendment for the Ten Mile Creek Watershed

Dear Applicant for online certification:

Thank you for choosing to use the U.S. Fish and Wildlife Service Chesapeake Bay Field Office online list request certification resource. This letter confirms that you have reviewed the conditions in which this online service can be used. On our website (http://www.fws.gov/chesapeakebay/EndSppWeb/ELEMENTS/listreq.html) are the USGS topographic map areas where no federally proposed or listed endangered or threatened species are known to occur in Maryland, Washington, D.C. and Delaware.

You have indicated that your project is located on the following USGS topographic map(s)

Germantown, Montgomery County

Based on this information and in accordance with section 7 of the Endangered Species Act (87 Stat. 884, as amended; 16 U.S.C. 1531 et seq.), we certify that except for occasional transient individuals, no federally proposed or listed endangered or threatened species are known to exist within the project area. Therefore, no Biological Assessment or further section 7 consultation with the U.S. Fish and Wildlife Service is required. Should project plans change, or if additional information on the distribution of listed or proposed species becomes available, this determination may be reconsidered.

This response relates only to federally protected threatened or endangered species under our jurisdiction. For additional information on threatened or endangered species in Maryland, you should contact the Maryland Wildlife and Heritage Division at (410) 260-8540. For information in Delaware you should contact the Delaware Natural Heritage and Endangered Species Program, at (302) 653-2880. For information in the District of Columbia, you should contact the National Park Service at (202) 535-1739.

The U.S. Fish and Wildlife Service also works with other Federal agencies and states to minimize loss of wetlands, reduce impacts to fish and migratory birds, including bald eagles,

and restore habitat for wildlife. Information on these conservation issues and how development projects can avoid affecting these resources can be found on our website (www.fws.gov/chesapeakebay)

We appreciate the opportunity to provide information relative to fish and wildlife issues, and thank you for your interest in these resources. If you have any questions or need further assistance, please contact Chesapeake Bay Field Office Threatened and Endangered Species program at (410) 573-4527.

Sincerely,

Genevieve LaRouche
Field Supervisor

MARYLAND
DEPARTMENT OF
NATURAL RESOURCES

Martin O'Malley, Governor
Anthony G. Brown, Lt. Governor
John R. Griffin, Secretary
Joseph P. Gill, Deputy Secretary

April 9, 2013

Ms. Sarah Roberts
Biohabitats, Inc.
2081 Clipper Park Road
Baltimore, MD 21211

RE: Environmental Review for Ten Mile Creek Watershed Existing Conditions, Montgomery County, Maryland.

Dear Ms. Roberts:

The Wildlife and Heritage Service has determined that there are no State or Federal records for rare, threatened or endangered species within the boundaries of the project site as delineated. This statement should not be interpreted however as meaning that rare, threatened or endangered species are not in fact present. If appropriate habitat is available, certain species could be present without documentation because adequate surveys have not been conducted. It is also important to note that the utilization of state funds, or the need to obtain a state authorized permit may warrant additional evaluations that could lead to protection or survey recommendations by the Wildlife and Heritage Service. If this project falls into one of these categories, please contact us for further coordination.

Our analysis of the information provided also suggests that the forested area on the project site contains Forest Interior Dwelling Bird habitat. Populations of many Forest Interior Dwelling Bird species (FIDS) are declining in Maryland and throughout the eastern United States. The conservation of FIDS habitat is strongly encouraged by the Department of Natural Resources. In order to do so, the following guidelines could be incorporated into the site design to help minimize the project's impacts on FIDS and other native forest plants and wildlife:

1. Restrict development to nonforested areas.
2. If forest loss or disturbance is unavoidable, concentrate or restrict development to the following areas:
   a. the perimeter of the forest (i.e., within 300 feet of existing forest edge)
   b. thin strips of upland forest less than 300 feet wide
   c. small, isolated forests less than 50 acres in size
   d. portions of the forest with low quality FIDS habitat, (i.e., areas that are already heavily fragmented, relatively young, exhibit low structural diversity, etc.)
3. Maximize the amount if forest "interior" (forest area >300 feet from the forest edge) within each forest tract (i.e., minimize the forest edge:area ratio). Circular forest tracts are ideal and square tracts are better than rectangular or long, linear forests.
4. Minimize forest isolation. Generally, forests that are adjacent, close to, or connected to other forests provide higher quality FIDS habitat than more isolated forests.

5. Maintain or create wildlife corridors.
6. Do not remove or disturb forest habitat during April-August, the breeding season for most FIDS. This seasonal restriction may be expanded to February-August if certain early nesting FIDS (e.g., Barred Owl) are present.
7. In forested areas reserved from development, promote the development of a diverse forest understory by removing livestock from forested areas and controlling white-tailed deer populations. Do not mow the forest understory or remove woody debris and snags.
8. Afforestation efforts should target a) riparian or streamside areas that lack woody vegetative buffers, b) forested riparian areas less than 300 feet wide, and c) gaps or peninsulas of nonforested habitat within or adjacent to existing FIDS habitat.

Thank you for allowing us the opportunity to review this project. If you should have any further questions regarding this information, please contact me at (410) 260-8573.

Sincerely,

Lori A. Byrne

Lori A. Byrne
Environmental Review Coordinator
Wildlife and Heritage Service
MD Dept. of Natural Resources

ER # 2013.0119.mo

APPENDIX F. HISTORIC AND ARCHEOLOGICAL PROPERTIES INFORMATION REQUEST LETTERS

Biohabitats
Incorporated

2081 Clipper Park Road
Baltimore, MD 21211
Tel 410.554.0156
Fax 410.554.0168
www.biohabitats.com

January 23, 2013

Ms. Elizabeth Cole, Administrator
Project Review and Compliance - Maryland Historical Trust
100 Community Place
Crownsville, MD 21032

RE: Montgomery County, Ten Mile Creek Watershed
Historic Properties Information Request

Dear Ms. Cole:

The purpose of this letter is to obtain information or assistance with any relevant historic and archeological properties information in Ten Mile Creek watershed in Montgomery County, Maryland (see enclosed map for location). Specifically, we would like to know whether or not the Maryland Historical Trust's database includes any of the following for the project vicinity:

- Inventoried historic properties,
- National Register listed properties,
- Prior archeological or architectural research conducted in the project vicinity,
- An informed assessment of the watershed's potential for containing historic properties that have not yet been identified.

The site encompasses Ten Mile Creek watershed located in northern Montgomery County (ADC Map #12, B-H, 1-9 and Map #4, B-K, 9-13). The watershed is located on the Georgetown quadrangle 7.5-minute USGS Topo Map. Brown and Caldwell/Biohabitats, a Joint Venture, are contracted by Maryland - National Capital Park and Planning Commission (M-NCPPC) Montgomery County Planning Department to provide data and environmental analysis of Ten Mile Creek watershed. This analysis is in support of the Planning Department undertaking a Limited Amendment to the Clarksburg Master Plan focusing on the Ten Mile Creek area in response to a request by the County Council in October 2012. Historical and archeological properties are one piece of information being collected to assess the existing conditions of the watershed.

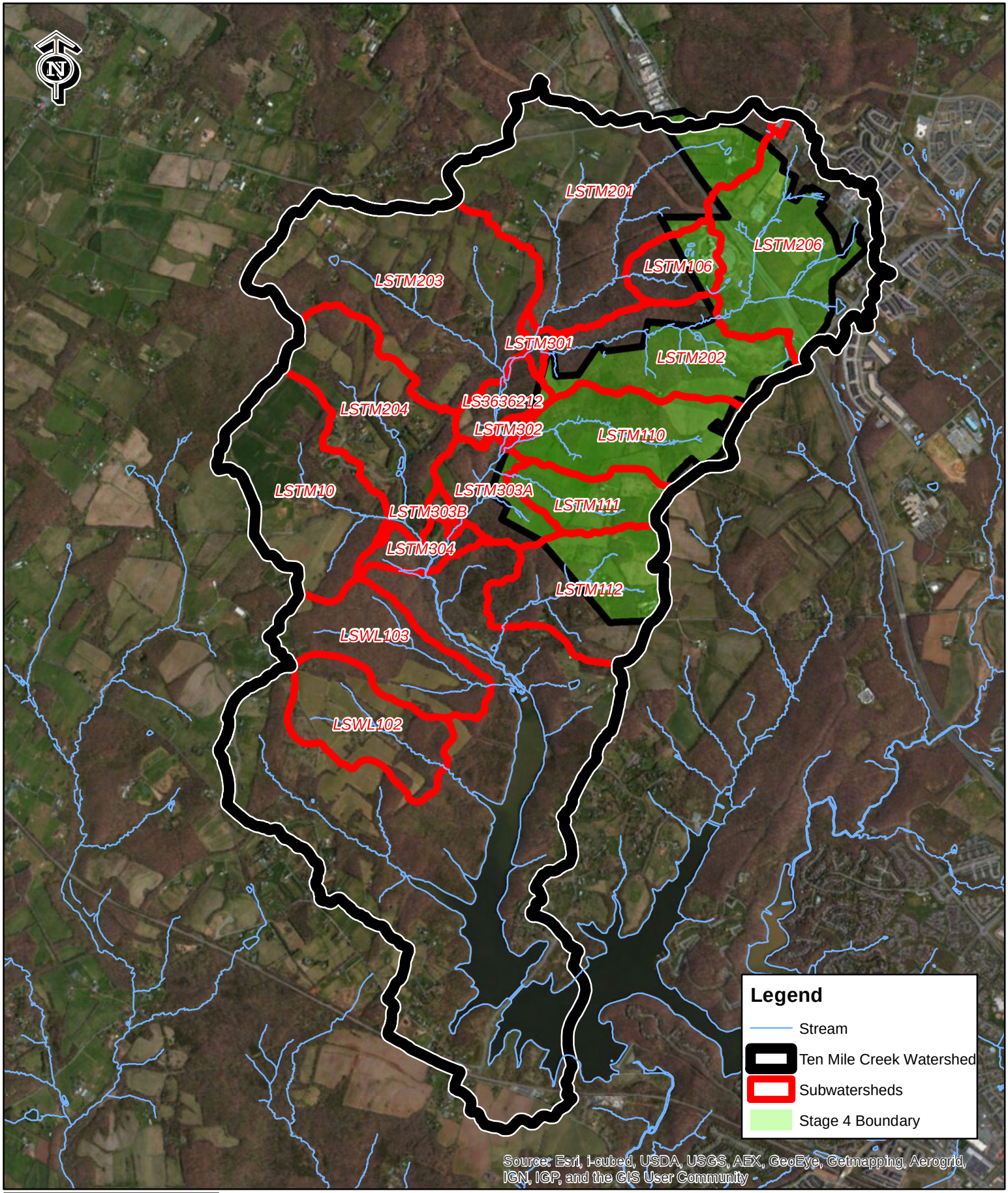
Please find the enclosed vicinity map showing the watershed location. Feel free to call me at 410-554-0156 should you have any questions. Thank you for your time and attention.

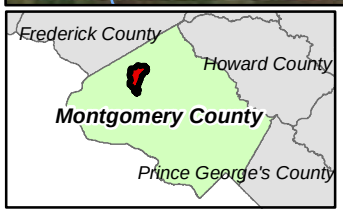
Sincerely,
BIOHABITATS, INC.

_____

Sarah Roberts
Environmental Scientist

Enclosure: Map of the Ten Mile Creek watershed





Ten Mile Creek

Map of Watershed

0 3,000 6,000 Feet

1 inch = 3,000 feet

Maryland Department of Planning
Maryland Historical Trust

Martin O'Malley
Governor

Anthony G. Brown
Lt. Governor

Richard Eberhart Hall
Secretary

Matthew J. Power
Deputy Secretary

February 8, 2013

Ms. Sarah Roberts
Biohabitats, Inc.
2081 Clipper Park Road
Baltimore, MD 21211

Re: MHT Review of Ten Mile Creek Watershed Study Area, Montgomery County

Dear Ms. Roberts:

In response to your January 24, 2013 request for information, the Maryland Historical Trust (MHT) has reviewed the above-referenced study area to assess potential effects on historic properties in accordance with Section 106 of the National Historic Preservation Act and the Maryland Historical Trust Act, §§ 5A-325 and 5A-326 of the State Finance and Procurement Article. Below are our preliminary comments and recommendations regarding the presence of historic properties within the Ten Mile Creek Watershed study area.

MHT files indicate that literally dozens of historic properties (including a number of archeological resources and an MHT easement property) are located within the broad study area boundaries illustrated in the project submittal. These properties include (but certainly are not limited to) the National Register-eligible historic district of Clarksburg, the National Register listed Clarksburg School (a two-room schoolhouse built in 1909), the Tenmile Creek Stream Valley Historic District, and the MHT easement property known as Moneysworth Farm. The study area also contains several known archeological sites (both prehistoric and historic) as well as a number of archeologically sensitive areas that are likely to contain significant sites that have not yet been identified.

Given the extensive nature of the watershed study area, we are unable to provide a complete inventory of the known historic properties or an assessment of areas having a moderate to high potential for containing resources that have not yet been identified. We are therefore recommending that the Maryland-National Capital Park and Planning Commission (M-NCPPC) send their qualified cultural resources staff or a cultural resources consultant to the MHT Library to conduct the necessary research and obtain all available information on the historic properties located within the proposed study area. Our library is open to the public on Tuesdays, Wednesdays, and Thursdays by appointment only. To make an appointment, please contact Mary Louise de Sarran at 410-514-7655.

A list of preservation consultants can be found on our website at www.marylandhistoricaltrust.net. If you have any questions or require additional information, please do not hesitate to contact me (for archeology) at 410-514-7638 or Jonathan Sager (for the historic built environment) at 410-514-7636.

Sincerely,

Dixie Henry

Dr. Dixie L. Henry
Preservation Officer
Maryland Historical Trust

DLH/201300327
cc: Scott Whipple (Montgomery County)

Attachment C. Trend Analysis of Little Seneca Creek Benthic and Habitat Assessment Data

MEMORANDUM

Date: April 3, 2013

To: Mary Dolan and Valdis Lazdins, Montgomery County Planning Department

From: Biohabitats and Brown and Caldwell, a Joint Venture

RE: Ten Mile Creek Watershed Environmental Analysis in Support of the Clarksburg Master Plan Limited Amendment

SUBJ: Trend Analysis of Little Seneca Creek Benthic and Habitat Assessment Data

---

The use of analog or reference sites is a common tool used by biologists to extrapolate stressor response relationships to a test site. In the case of this study, the goal is to extrapolate the likely impacts to the habitats and benthic macroinvertebrate communities of the Ten Mile Creek Watershed (LSTM) using an adjacent Special Protection Area as an analog. The Little Seneca Creek Watershed (LSLS) within the Clarksburg Special Protection area was selected as an analog due to its proximity to the study site and similarities among the hydrology, physiography and historic land use. In addition, pre-development benthic macroinvertebrate index of biotic integrity (BIBI) and habitat scores for the LSLS watershed generally scored in the good range similar to the LSTM watershed. Biological and habitat sampling has been performed consistently in both watersheds since 1994 to document baseline and post-development conditions.

The biological and habitat sampling data within the LSLS watershed represents three distinct time periods (DEP 2010):

- *Pre-development*. This period spanned from 1994 to 2000 when the dominant land use within the watershed was agricultural.
- *Construction*. This period spanned from 2001-2007 when most of the land clearing and grading activities occurred. During this time period only sediment control Best Management Practices (BMPs) were in place and no water quality or quantity BMPs were functional.
- *Stabilization*. This period encompasses 2008 to present when the decline in the housing market significantly slowed construction and the first sites were permanently stabilized and stormwater BMPs were brought online. It should be noted that the during this period, the decline in the housing market prevented build-out in a timely manner and delayed the conversion of sediment BMPs to functional stormwater BMPs.

Existing Biological and Habitat Conditions

The biological and habitat conditions as determined by the County BIBI and habitat assessment metrics are discussed for the full period of record and relative to these three distinct time periods. A graphical summary of the available data is presented in Attachment A and the raw data are presented in tabular format in Attachment B and C. Microsoft Excel was used to develop standard correlation calculations that quantify the strength of relationships between metrics. Results from these correlation analyses are presented in tabular form in Attachment D.

Note: References to data provided in the text correspond to the attachment letter and figure/table number. For example, A1 references Attachment A, Figure 1.

Overall Trends

The biological condition of the Little Seneca Creek Watershed, as represented by the BIBI scores, is highly variable. Overall the BIBI scores fluctuated between good and fair with no strong upward or downward tendency (A1). The variability in BIBI scores among years and sampling stations does, however, increase after construction started. This increase in variability may reflect a stressor response at some specific sample stations, such as LSLS103B and 103C, and may relate to the specific construction activities occurring in a given sample year (A1). The two individual metrics that demonstrate an overall declining trend over time are the biotic index (B1) and proportion of EPT individuals (B3). Declines in both of these metrics reflect an increase in the proportion of tolerant individuals within the watershed.

In contrast to the BIBI scores, the habitat scores do show an overall declining trend over time and 6 of the 14 individual stations also show a decline (A6). The individual metrics showing decline include sediment deposits (C5), channel flow diversity (C7), bank vegetation (C8 and C9), and bank stability (C10 and C11). The declines in bank vegetation and bank stability likely lead to bank erosion, which increases the sediment supply. This increase in sediment supply coupled with an increase of fine sediments associated with construction activities could be influencing the scores for sediment deposits and flow diversity as the excess sediment is stored within the channel boundaries and fills pools.

The correlation analysis shows that the average annual BIBI and habitat metrics are positively correlated. Specifically the bank stability, bank vegetation and buffer condition have relatively greater influences on average annual BIBI score than other metrics (D1).

Pre-development

During the pre-development period both the BIBI and habitat scores experienced relatively low variability and scored in the good and good to excellent/good range respectively (A3 and B9). Indications of a good quality system include slight increasing trends in the raw metrics for the Proportion of Shredders (B5), and Ratio of Scrapers (B6) combined with slight declining trends in the Proportion of Hydropsyche & Cheumatopsyche (B4). In contrast, slight declining trends in the raw Number of EPT Taxa (B8) and increases in the Proportion of Dominant Taxa (B2) over time are indicative of a degrading system. Overall the habitat values did not show much variability (A8), but the scores for instream cover showed slight increases during the pre-development period (C1). The correlation analysis indicates that habitat parameters influencing the BIBI score are bank vegetation, channel alteration, epibenthic substrate and riffle frequency (D2).

Construction

During the construction phase, the average of the BIBI showed no strong overall trend; however, the average BIBI score was 4 points lower than the pre-development period (A4 and B9). Increasing trends in the raw Biotic Index (B1), Proportion of Dominant Taxa (B2), Proportion of Hydropsyche & Cheumatopsyche (B4) combined with declining trends in the Proportion of EPT individuals (B3), and Ratio of Scrapers (B6) contribute to the decline in the average BIBI score (B9). The average of the habitat scores showed no overall trend, but LSLS102 and 413 showed declining trends while LSLS103C and 206 show improving trends (A9 and C14). Correlation analysis indicates that bank stability, buffer condition, instream cover and sediment deposits emerge as the important factors influencing the BIBI score (D3).

Stabilization

During the Stabilization Phase, the overall BIBI showed no strong overall trend (A5 and B9). While the average BIBI score was similar to the construction phase, the stabilization phase shows the widest year to year variability (A5 and B9). The one observed trend of note was a slight decrease in the Taxa Richness (B7), which corresponds to a decrease in diversity and could lead to a more fragile system in the future. The overall habitat scores show declining trends at 5 of the stations (LSTM 102, 103C, 104, 109, and 110) and increasing trends at LSLS202, 203 and 206 (A10 and C14). Both Instream Cover (C1) and Bank Vegetation (C8 and C9) show very slight signs of decline over the periods and Embeddedness (C3) and Riffle Frequency (C6) show very slight improvements over the period. Correlation analysis indicates that the same factors habitat parameters are influencing the average annual BIBI scores; however, the buffer conditions and channel alteration parameters are negatively correlated indicating that as these parameters improve, the BIBI still declines (D4).

Data Extrapolation

While the data sets represent a reasonable account of biological conditions for the pre-construction, construction, and stabilization time periods, several confounding issues prevent these findings from being extrapolated quantitatively to the Ten Mile Creek Watershed. These confounding issues include:

1. The SPA reports do not contain adequate quantitative data to ascertain the extent of development activities occurring in a given subwatershed at a given time. Based on personal communications between DEP staff and Biohabitats, it may be possible to develop a more detailed spatial chronology of development, but the associated effort is beyond the scope of this study.
2. The state of the economy prolonged the period from initial disturbance to final stabilization, but current regulations now will limit the amount of land disturbance that can occur before site stabilization.
3. The Clarksburg development was designed according to the MD 2000 SWM regulations, whereas the new regulations are designed to better match existing hydrology using LID.

Conclusion

While the data do not indicate that the Little Seneca Watershed is showing strong signs of decline in biological condition as evidenced by the BIBI score, the variability from year to year and site to site suggests that some degree of stressor response is occurring within the system. The data do suggest that the overall habitat conditions are declining slightly over time. Some correlation between these habitat parameters and the BIBI score was observed and if the habitat continues to decline, the BIBI scores are expected to ultimately respond accordingly. Based on the rates of change and the continuing construction within the watershed, it may take some time before the system stabilizes and a new baseline is established such that the true impact of the development in the watershed can be determined. Given the changes in land development regulations and changes in economic condition since the development plans in the Little Seneca Watershed were approved, these data do not provide a perfect analog to describe the magnitude of change in biological condition associated with development in the Ten Mile Creek Watershed. These data, however, do generally agree with other studies that suggest that biological condition degrades above a certain threshold of impervious cover (*e.g.*, Paul and Meyer 2001). The results of the Little Seneca Creek data review indicate that development does negatively influence the biological condition in the short term despite the application of the “best available technologies” at the time of plan approval. The long-term influence on biological condition is uncertain at the present time.

References

Montgomery County Department of Environmental Protection (DEP). (2012). Special protection area program annual report 2010. Montgomery County Department of Environmental Protection, Department of Permitting Services, and Maryland-National Capital Park and Planning Commission.

Paul, M.J., and Meyer, J.L., 2001, Streams in the urban landscape: Annual Review of Ecology and Systems, v. 32, p. 333–365.

Attachments

Attachment A: Graphical Data Summaries
Attachment B: Montgomery County Benthic Index of Biotic Integrity (BIBI) Data Summary
Attachment C: Montgomery County Habitat Assessment Data Summary
Attachment D: Montgomery County BIBI and Habitat Assessment Correlation Analysis

Attachment A

Graphical Data Summaries

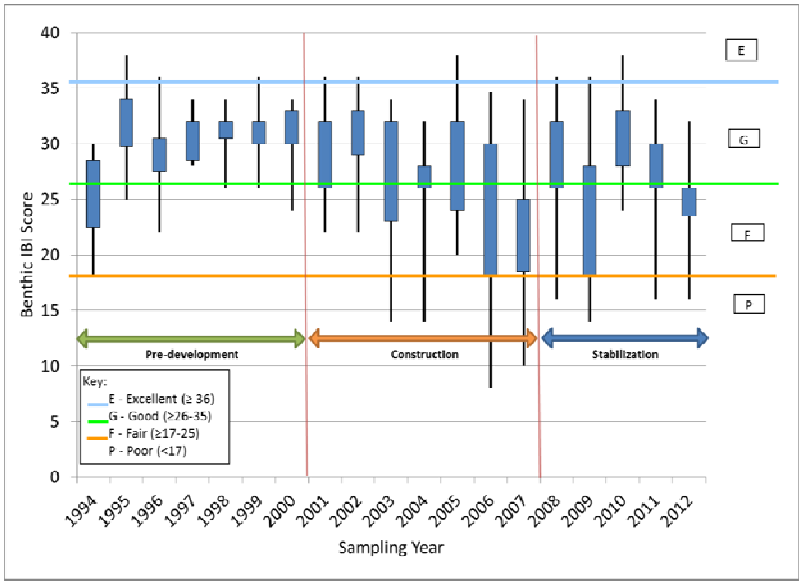


Figure A1. Variability among BIBI scores at all sampling stations over time.

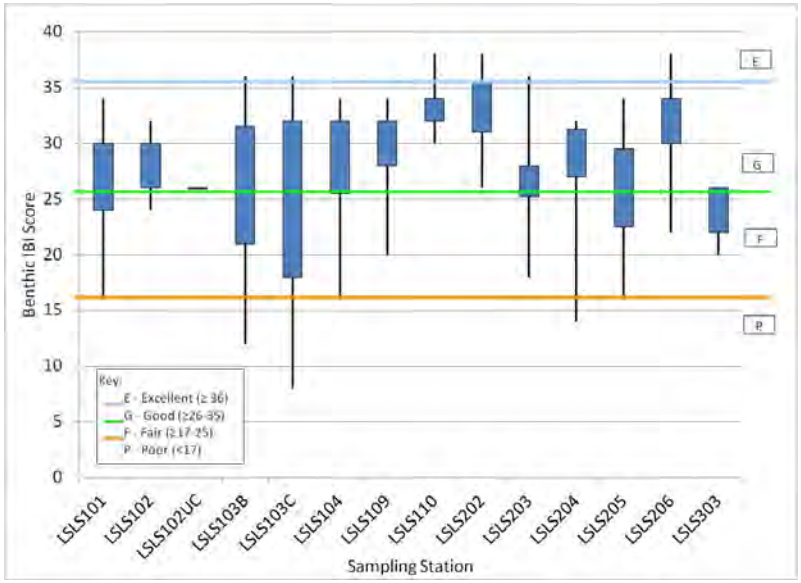


Figure A2. Variability among BIBI scores at all sampling stations over time (1994-2012).

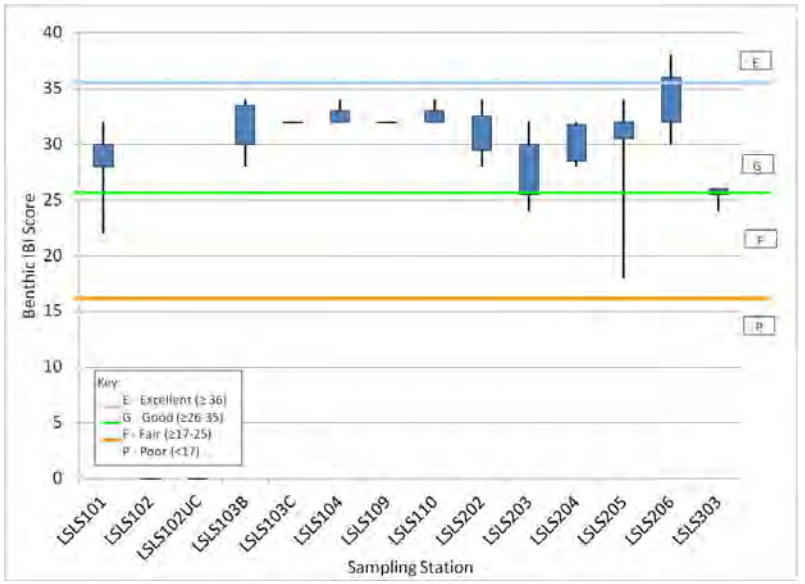


Figure A3. Variability among pre-development period BIBI scores

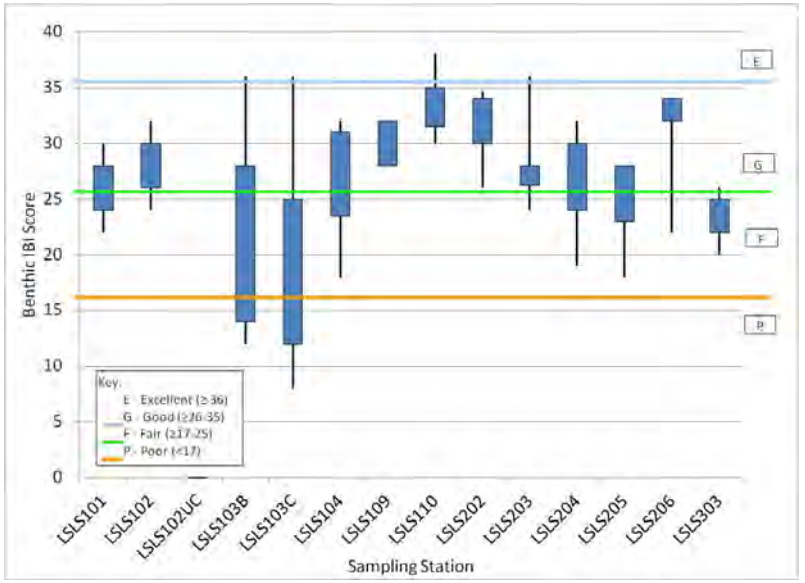


Figure A4. Variability among construction period BIBI scores

Attachment A

Graphical Data Summaries

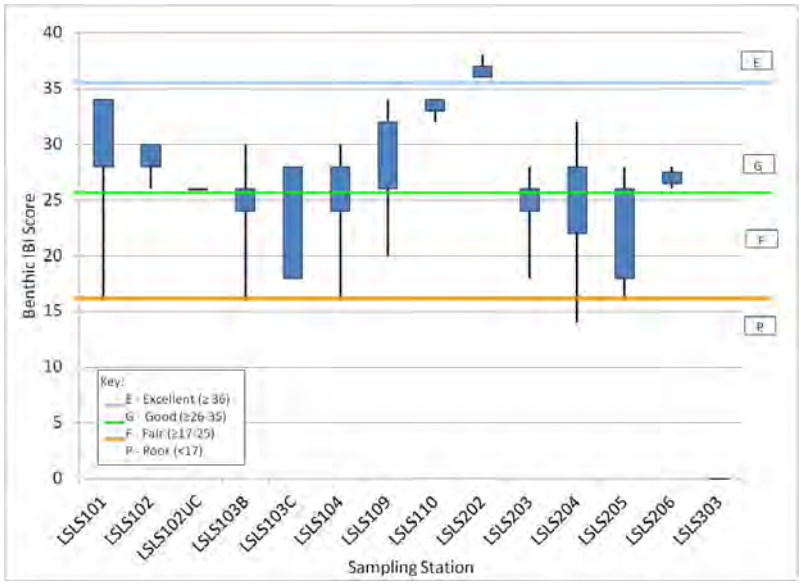


Figure A5. Variability among stabilization period phase BIBI scores

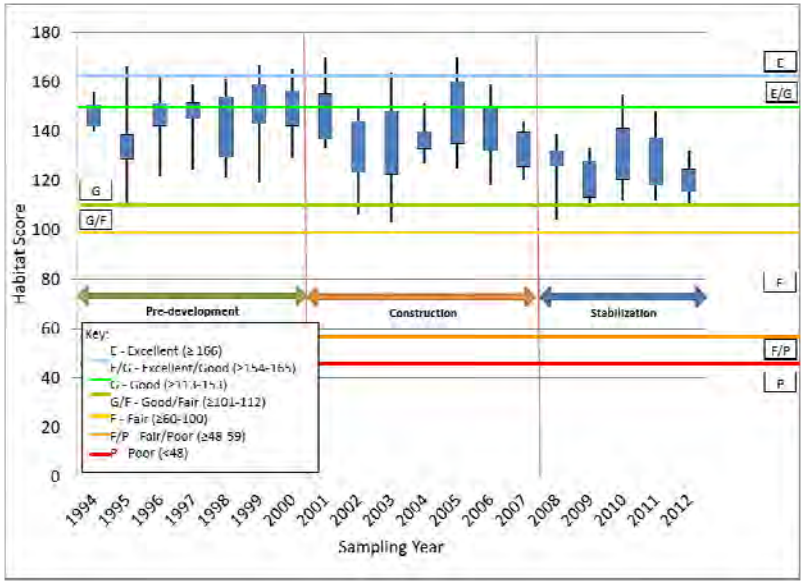


Figure A6. Variability among habitat scores at all sampling stations over time (1994-2012).

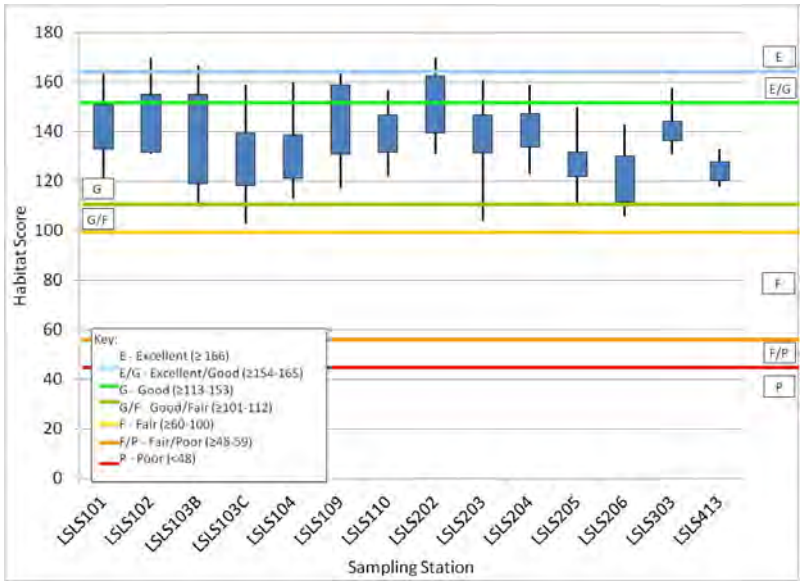


Figure A7. Ranges of composite habitat scores among the permanent sampling stations

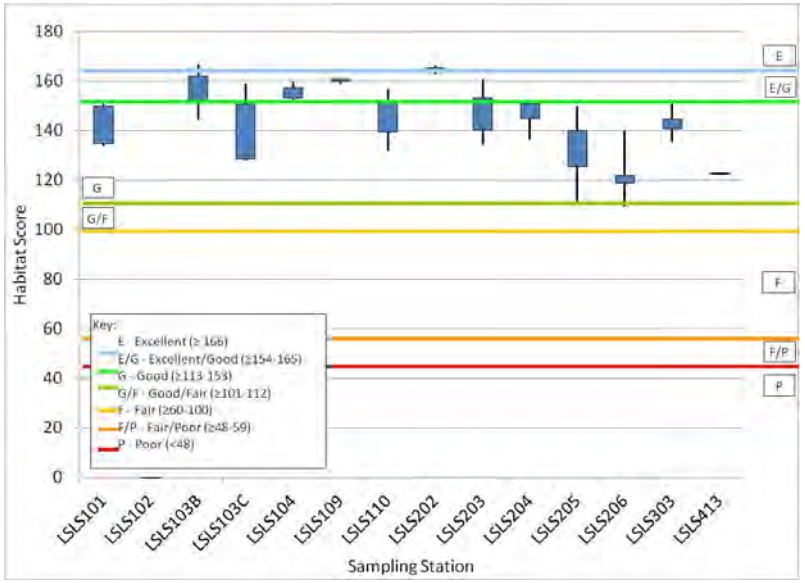


Figure A8. Variability among pre-development period habitat scores

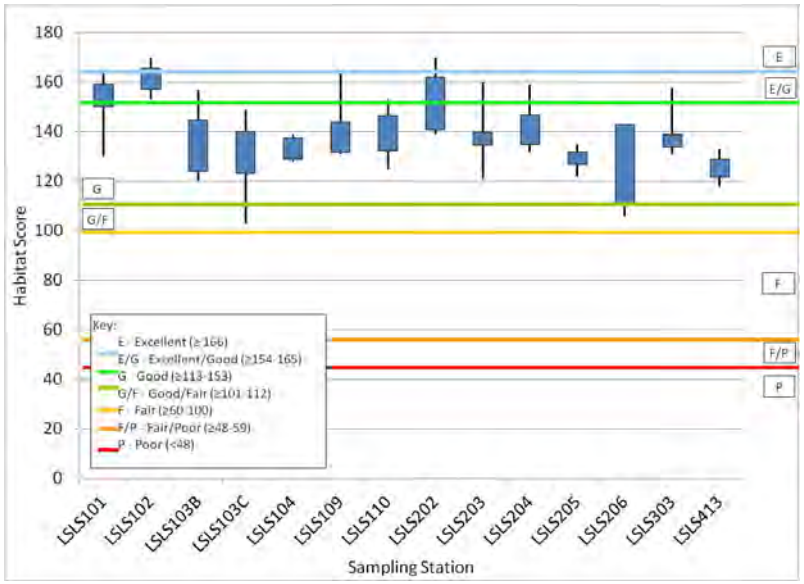


Figure A9. Variability among construction habitat scores

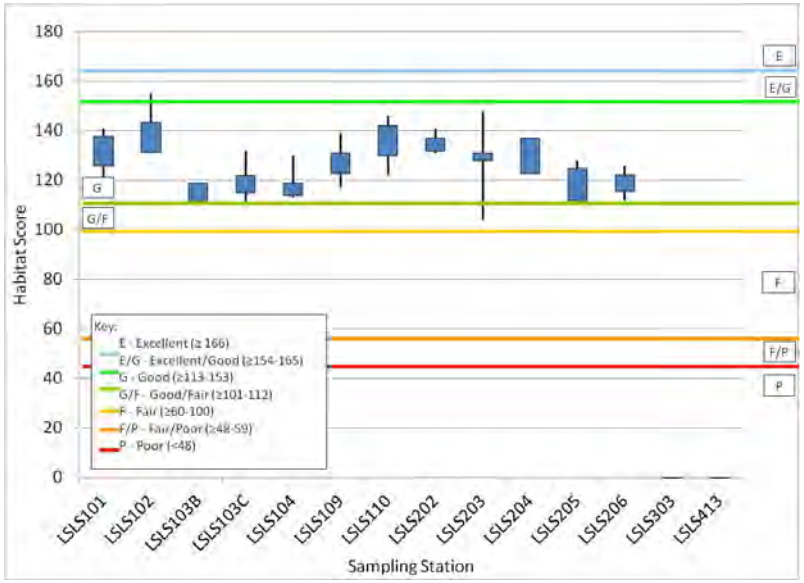


Figure A10. Variability among stabilization period habitat scores

Attachment B

Montgomery County Benthic Index of Biotic Inegrity (BIBI)

Data Summary

Table B1. Biotic Index

Time Period	Sample Year	LSLS101	LSLS102	LSLS102UC	LSLS103B	LSLS103C	LSLS104	LSLS109	LSLS110	LSLS202	LSLS203	LSLS204	LSLS205	LSLS206	LSLS303	Average
Pre-development	1994										4.31	4.34	4.67	3.82		*4.29*
	1995	4.9			3.18					4	4.315	3.36	2.89	3.05	5.48	*3.90*
	1996	6.23			4.29					4.51	4.53	3.88	4.94	3.9	6.05	*4.79*
	1997	4.48			3.77	4.16					4.85	4.56	4.21			*4.34*
	1998				3.14	3.8	3.22	4.04	3.86		3.63	3.21	3.07	4.61	5.71	*3.83*
	1999	4.4			3.16	4.22	3.41		4.58		4.67	3.82	3.9	3.87		*4.00*
	2000	4.46			3.26	4.42	3.27		4.81		4.33				6.39	*4.42*
Construction	2001	5.61			3.08	4.88	3.87	4.05	4.93	5.92	3.79	4.24	4.67	5.67	6.4	*4.76*
	2002	2.88			4.62	4.82	4.22						4.35	3.96	6.05	*4.41*
	2003	6			6.78	6.705	3.61	3.27	4.42		5.15	4.42	5.62	3.9	5.99	*5.08*
	2004	4.13			5.42	6.66	4.785	3.94		3.56	5.37	4.35	5.08	3.68	6.52	*4.86*
	2005	3.45	3.79		5.5	5.72	4.05	4.39	4.12	3.53	4.7	5.68	5.07	4.14	5.44	*4.58*
	2006	5.39	3.68		6.77	6.8	6.81	5.29	3.85	4.36	6.08	6.155	6.56	4.27	6.3	*5.56*
	2007	5.7			6.61	6.85	6.44	5.52		5.08	5.92		5.84			*6.00*
Stabilization	2008	4.08			4.84	6.14	5.94	4.9		4.61	5.39	4.92	5.08			*5.10*
	2009	5.74			5.24	6.18	5.45	4.34		4.47	5.54	6.08	5.92			*5.44*
	2010	2.8	3.57		5.88	4.08	5.31	3.55	4.79	3.66	5.03	4.57	5.12			*4.40*
	2011	4.71	4.95		6.26	5.77	5.35	5.51	4.27		5.15	5.93	6.18	5.67		*5.43*
	2012	6.24	5.9	5.52	5.62	4.31	5.53	6.39	5.22		5.86	5.98	6.34	5.26		*5.68*

Pre-development	Average	4.89	#DIV/0!	#DIV/0!	3.47	4.15	3.30	4.04	4.42	4.26	4.38	3.86	3.95	3.85	5.91	*4.22*
	RSQ	0.32	#DIV/0!	#DIV/0!	0.17	0.36	0.06	#DIV/0!	**0.92**	**1.00**	0.00	0.06	0.07	0.28	**0.55**	*0.01*
	Slope	-0.21	#DIV/0!	#DIV/0!	-0.10	0.12	0.02	#DIV/0!	0.48	0.51	0.00	-0.07	-0.12	0.14	0.13	*-0.01*
Construction	*Average*	*4.74*	*3.74*	*#DIV/0!*	*5.54*	*6.06*	*4.83*	*4.41*	*4.33*	*4.49*	*5.17*	*4.97*	*5.31*	*4.27*	*6.12*	*5.04*
	RSQ	0.03	**1.00**	#DIV/0!	**0.60**	**0.58**	**0.64**	**0.62**	**0.99**	0.16	**0.73**	**0.79**	**0.58**	0.25	0.06	*0.57*
	Slope	0.10	-0.11	#DIV/0!	0.49	0.32	0.48	0.31	-0.21	-0.18	0.33	0.39	0.26	-0.19	-0.05	*0.20*
Stabilization	*Average*	*4.71*	*4.81*	*5.52*	*5.57*	*5.30*	*5.52*	*4.94*	*4.76*	*4.25*	*5.39*	*5.50*	*5.73*	*5.47*	*#DIV/0!*	*5.21*
	RSQ	0.15	**0.99**	#DIV/0!	**0.55**	0.40	0.33	0.36	0.20	**0.86**	0.07	0.20	**0.55**	**1.00**	#DIV/0!	*0.13*
	Slope	0.33	1.17	#DIV/0!	0.26	-0.41	-0.09	0.42	0.22	-0.48	0.06	0.20	0.28	-0.41	#DIV/0!	*0.12*
Composite	Average	4.78	4.38	5.52	4.86	5.34	4.75	4.60	4.49	4.37	4.92	4.72	4.97	4.29	6.03	*4.78*
	RSQ	0.00	**0.55**	#DIV/0!	**0.54**	0.14	**0.60**	0.33	0.06	0.01	**0.51**	**0.60**	**0.56**	0.38	0.10	*0.53*
	Slope	-0.01	0.24	#DIV/0!	0.19	0.09	0.20	0.13	0.02	-0.02	0.09	0.13	0.14	0.09	0.03	*0.08*

Table B2. Proportion of Dominant Taxa

Time Period	Sample Year	LSLS101	LSLS102	LSLS102UC	LSLS103B	LSLS103C	LSLS104	LSLS109	LSLS110	LSLS202	LSLS203	LSLS204	LSLS205	LSLS206	LSLS303	Average
Pre-development	1994										39	31	50	21		*35.25*
	1995	43			15					31	41.5	38.5	36	33	55	*36.63*
	1996	68			48					40	24	48	39	30	64	*45.13*
	1997	36			47	38					38	29	24			*35.33*
	1998				59	68	71	59	53		49	77	73	32	47	*58.80*
	1999	41			84	53	61		25		34	55	42	31		*47.33*
	2000	46			60	55	52		23		34				76	*49.43*
Construction	2001	60			35	47	27	32	37	68	28	35	42	71	69	*45.92*
	2002	41			34	27	36						42	33	58	*38.71*
	2003	68			90	66	64	79	20		45	31	57	27	45	*53.82*
	2004	43			60	89	51	35		30	60	46	59	40	77	*53.64*
	2005	41	54		48	43	22	39	26	53	31	53	38	41	38	*40.54*
	2006	59	70		92	93	93	53	36	51.25	55.5	72.5	80	37	62	*65.71*
	2007	63			86	91	68	61		40	57		59			*65.63*
Stabilization	2008	45			43	79	73	44		37	41	40	26			*47.56*
	2009	65			43	70	58	38		37	41	62	47			*51.22*
	2010	36	33		62	49	59	28	36	19	31	36	33			*38.36*
	2011	35	49		68	60	55	60	29		35	49	64	62		*51.45*
	2012	71	65	56	60	40	71	78	47		59	70	50	58		*60.42*

Pre-development	Average	46.80	#DIV/0!	#DIV/0!	52.17	53.50	61.33	59.00	33.67	35.50	37.07	46.42	44.00	29.40	60.50	*43.99*
	RSQ	0.07	#DIV/0!	#DIV/0!	**0.67**	0.14	**1.00**	#DIV/0!	**0.80**	**1.00**	0.00	**0.41**	0.03	0.34	0.24	*0.48*
	Slope	-1.60	#DIV/0!	#DIV/0!	9.86	3.60	-9.50	#DIV/0!	-15.00	9.00	-0.18	6.19	1.60	1.35	2.75	*2.77*
Construction	*Average*	*53.57*	*62.00*	*#DIV/0!*	*63.57*	*65.14*	*51.57*	*49.83*	*29.75*	*48.45*	*46.08*	*47.50*	*53.86*	*41.50*	*58.17*	*51.99*
	RSQ	0.01	**1.00**	#DIV/0!	**0.47**	**0.48**	0.35	0.07	0.00	0.31	0.38	**0.75**	0.33	0.21	0.05	*0.49*
	Slope	0.64	16.00	#DIV/0!	8.11	8.61	6.96	2.29	-0.22	-3.48	3.94	7.40	3.86	-3.80	-1.80	*3.57*
Stabilization	*Average*	*50.40*	*49.00*	*56.00*	*55.20*	*59.60*	*63.20*	*49.60*	*37.33*	*31.00*	*41.40*	*51.40*	*44.00*	*60.00*	*#DIV/0!*	*49.80*
	RSQ	0.04	**1.00**	#DIV/0!	**0.66**	**0.79**	0.02	**0.52**	0.37	**0.75**	0.20	0.27	**0.47**	**1.00**	#DIV/0!	*0.27*
	Slope	2.20	16.00	#DIV/0!	5.90	-8.80	-0.70	9.00	5.50	-9.00	3.00	4.70	6.50	-4.00	#DIV/0!	*2.60*
Composite	Average	50.65	54.20	56.00	57.44	60.50	57.40	50.50	33.20	40.63	41.28	48.31	47.83	39.69	59.10	*48.47*
	RSQ	0.01	0.06	#DIV/0!	0.10	0.04	0.06	0.01	0.02	0.03	0.10	0.10	0.03	**0.41**	0.00	*0.22*
	Slope	0.29	-1.18	#DIV/0!	1.23	0.88	1.01	0.33	0.26	-0.49	0.59	0.82	0.46	1.67	-0.21	*0.81*

Table B3. Proportion of EPT Individuals

Time Period	Sample Year	LSLS101	LSLS102	LSLS102UC	LSLS103B	LSLS103C	LSLS104	LSLS109	LSLS110	LSLS202	LSLS203	LSLS204	LSLS205	LSLS206	LSLS303	Average
Pre-development	1994										80	77	79	71		*76.75*
	1995	35			40					67.5	80	86	86	84	22	*62.56*
	1996	11			59					58	64	71	43	61	20	*48.38*
	1997	47			61	64					52	54	61			*56.50*
	1998				82	77	86	72	72		88	90	93	39	21	*72.00*
	1999	46			93	79	84		71		58	73	68	52		*69.33*
	2000	53			69	60	78		54		63				6	*54.71*
Construction	2001	29			72	35	58	60	52	22	74	57	46	22	6	*44.42*
	2002	62			50	67	56						53	59	10	*51.00*
	2003	13			2	24.5	81	89	74		42	61	20	62	2	*42.77*
	2004	45			7	2	39	56		64	31	46	23	36	9	*32.55*
	2005	49	74		34	49	46	51	64	83	64	18	33	34	28	*48.23*
	2006	32	77		4	6	1	37	66	67.75	20	16	13	43	19	*30.90*
	2007	32			6	3	7	29		48	32		29			*23.25*
Stabilization	2008	59			40	12	15	39		51	47	49	58			*41.11*
	2009	18			50	23	32	61		58	47	27	45			*40.11*
	2010	68	61		27	65	19	53	56	66	59	53	47			*52.18*
	2011	54	45		20	30	34	31	62		60	33	23	28		*38.18*
	2012	4	26	29	34	58	25	7	44		25	25	24	38		*28.25*

Pre-development	Average	38.40	#DIV/0!	#DIV/0!	67.33	70.00	82.67	72.00	65.67	62.75	69.29	75.17	71.67	61.40	17.25	*62.89*
	RSQ	**0.46**	#DIV/0!	#DIV/0!	**0.59**	0.02	**0.92**	#DIV/0!	**0.79**	**1.00**	0.17	0.01	0.00	**0.64**	**0.71**	*0.05*
	Slope	5.42	#DIV/0!	#DIV/0!	7.66	-1.00	-4.00	#DIV/0!	-9.00	-9.50	-2.54	-0.71	-0.46	-6.67	-2.86	*-1.03*
Construction	*Average*	*37.43*	*75.50*	*#DIV/0!*	*25.00*	*26.64*	*41.14*	*53.67*	*64.00*	*56.95*	*43.83*	*39.60*	*31.00*	*42.67*	*12.33*	*39.02*
	RSQ	0.01	**1.00**	#DIV/0!	**0.52**	0.35	**0.65**	**0.53**	0.25	0.35	**0.45**	**0.75**	**0.41**	0.00	**0.50**	*0.55*
	Slope	-0.54	3.00	#DIV/0!	-9.21	-6.91	-10.64	-7.04	2.03	5.93	-6.50	-9.62	-4.21	0.11	3.60	*-3.51*
Stabilization	*Average*	*40.60*	*44.00*	*29.00*	*34.20*	*37.60*	*25.00*	*38.20*	*54.00*	*58.33*	*47.60*	*37.40*	*39.40*	*33.00*	*#DIV/0!*	*39.97*
	RSQ	0.18	**1.00**	#DIV/0!	0.33	**0.47**	0.18	**0.50**	**0.43**	**1.00**	0.12	0.27	**0.86**	**1.00**	#DIV/0!	*0.26*
	Slope	-7.40	-17.50	#DIV/0!	-4.20	9.90	2.20	-9.40	-6.00	7.50	-3.10	-4.20	-9.00	10.00	#DIV/0!	*-2.77*
Composite	Average	38.65	56.60	29.00	41.67	40.91	44.07	48.75	61.50	58.53	54.78	52.25	46.89	48.38	14.30	*48.06*
	RSQ	0.00	**0.83**	#DIV/0!	0.31	0.19	**0.64**	**0.49**	0.24	0.01	0.39	**0.61**	**0.45**	**0.44**	0.03	*0.56*
	Slope	0.16	-6.22	#DIV/0!	-2.87	-2.47	-5.13	-3.64	-0.93	0.23	-2.11	-3.05	-2.78	-2.11	-0.42	*-1.97*

KEY:

1. **Bold Green** numbers indicate an R-square value in excess of 0.4. This would be considered a moderate to strong trend.

Attachment B
Montgomery County Benthic Index of Biotic Inegrity (BIBI)
Data Summary

Table B4. Proportion of Hydropsyche & Cheumatopsyche

Time Period	Sample Year	LSLS101	LSLS102	LSLS102UC	LSLS103B	LSLS103C	LSLS104	LSLS109	LSLS110	LSLS202	LSLS203	LSLS204	LSLS205	LSLS206	LSLS303	Average
Pre-development	1994										80	70	96	45		*72.75*
	1995	5			19					31.5	69.5	28.5	13	5	20	*23.94*
	1996	50			2					9	44	17	14	6	8	*18.75*
	1997	7			0	2					34	23	22			*14.67*
	1998				0	0	0	0	1		30	1	1	0	66	*9.90*
	1999	4			0	0	0		11		22	2	3	0		*4.67*
	2000	0			1	0	0		0		22				21	*6.29*
Construction	2001	0			0	0	0	2	0	13	21	2	11	3	38	*7.50*
	2002	0			2	1	2						6	0	15	*3.71*
	2003	7			0	1	0	0	0		19	11	18	0	50	*9.64*
	2004	5			0	33	1.5	1		2	13	0	0	0	14	*6.32*
	2005	0	0		59	94	42	2	1	6	59	29	49	6	91	*33.69*
	2006	1	0		43	89	0	0	1	2.75	34.5	29	43	1	30	*21.10*
	2007	9			33	25	17	0		17	43		59			*25.38*
Stabilization	2008	0			4	0	10	0		1	45	20	43			*13.67*
	2009	5			26	30	3	2		5	57	72	82			*31.33*
	2010	2	2		38	9	0	1	5	5	52	13	54			*16.45*
	2011	6	8		61	17	4	6	4		60	37	65	9		*25.18*
	2012	17	0	0	20	7	2	18	7		43	32	48	10		*17.00*

Pre-development	Average	13.20	#DIV/0!	#DIV/0!	3.67	0.50	0.00	0.00	4.00	20.25	43.07	23.58	24.83	11.20	28.75	*21.57*
	RSQ	0.21	#DIV/0!	#DIV/0!	0.46	0.60	#DIV/0!	#DIV/0!	0.01	1.00	0.89	0.77	0.54	0.55	0.09	*0.65*
	Slope	-4.56	#DIV/0!	#DIV/0!	-2.74	-0.60	0.00	#DIV/0!	-0.50	-22.50	-10.11	-11.90	-14.09	-6.83	3.54	*-8.81*
Construction	*Average*	*3.14*	*0.00*	*#DIV/0!*	*19.57*	*34.71*	*8.93*	*0.83*	*0.50*	*8.15*	*31.58*	*14.20*	*26.57*	*1.67*	*39.67*	*15.33*
	RSQ	0.20	#DIV/0!	#DIV/0!	0.55	0.42	0.19	0.28	0.83	0.00	0.36	0.60	0.68	0.03	0.08	*0.58*
	Slope	0.79	0.00	#DIV/0!	8.57	12.29	3.18	-0.24	0.24	-0.04	4.79	5.69	8.89	0.23	4.34	*4.02*
Stabilization	*Average*	*6.00*	*3.33*	*0.00*	*29.80*	*12.60*	*3.80*	*5.40*	*5.33*	*3.67*	*51.40*	*34.80*	*58.40*	*9.50*	*#DIV/0!*	*20.73*
	RSQ	0.70	0.06	#DIV/0!	0.25	0.00	0.40	0.73	0.43	0.75	0.00	0.01	0.01	1.00	#DIV/0!	*0.00*
	Slope	3.50	-1.00	#DIV/0!	6.70	0.10	-1.50	4.00	1.00	2.00	-0.10	-1.10	-0.70	1.00	#DIV/0!	*0.05*
Composite	Average	6.94	2.00	0.00	17.11	19.25	5.43	2.67	3.00	9.23	41.56	24.16	34.83	6.54	35.30	*19.05*
	RSQ	0.06	0.21	#DIV/0!	0.36	0.07	0.02	0.30	0.06	0.42	0.00	0.01	0.16	0.08	0.11	*0.02*
	Slope	-0.57	0.52	#DIV/0!	2.40	1.63	0.38	0.66	0.17	-1.15	0.05	0.40	2.06	-0.60	2.32	*-0.36*

Table B5. Proportion of Shredders

Time Period	Sample Year	LSLS101	LSLS102	LSLS102UC	LSLS103B	LSLS103C	LSLS104	LSLS109	LSLS110	LSLS202	LSLS203	LSLS204	LSLS205	LSLS206	LSLS303	Average
Pre-development	1994										2.02	5.41	0.53	2.31		*2.57*
	1995	21.81			14.92					31.93	11.285	42.32	31.41	32.86	3.45	*23.75*
	1996	8.2			48.54					40.49	27.64	48.84	26.75	30.87	11.15	*30.31*
	1997	38.24			48.45	39.1					21.99	27.74	24.84			*33.39*
	1998				62.71	68.03	72.97	58.66	53.23		50.27	76.71	73.49	22.22	5.96	*54.43*
	1999	16.52			85.4	53.48	61.19		25.21		31.8	55.78	42.68	18.66		*43.41*
	2000	47.62			61.69	56.41	52.57		16.6		36.45				0	*38.76*
Construction	2001	4.85			36.7	7.27	26.67	32.18	22.73	9.17	28.96	27.75	21.05	9.4	1.48	*19.02*
	2002	14.95			26	29.03	18.56						14.41	12.4	0	*16.48*
	2003	6.73			1.77	1.39	64.44	79.47	9.52		18.92	32.43	3.67	10.68	2.04	*21.01*
	2004	20.69			3.17	0	18.86	32.16		26.01	18.03	22.47	7.38	9.49	2.45	*14.61*
	2005	8.11	59.84		4.59	13.76	8.94	25.22	28.03	54.89	11.65	3.48	5.36	12.26	3.45	*18.43*
	2006	27.31	70.97		1.53	0	1.01	17.6	36.87	51.9325	6.15	2.905	2.7	19.81	0	*18.37*
	2007	24.46			1.02	0.71	3.33	21.01		24.6	2.97		4.44			*10.32*
Stabilization	2008	46.15			5.56	5.62	0.99	36.8		39.44	1.47	13.33	3.75			*17.01*
	2009	6.67			5.88	2.62	23.94	38.82		42.71	0.57	1.88	0.88			*13.77*
	2010	64.78	47.59		7.03	53.61	13.45	30.52	28.41	35.66	11.43	19.83	10.78			*29.37*
	2011	36.15	21.62		2.6	6.74	28.97	18.83	14.29		3.01	5.42	0.54	15.66		*13.98*
	2012	1.81	19.26	17.65	16.44	42.16	10	2.65	10.37		7.14	11.11	3.88	5.84		*12.36*

Pre-development	Average	26.48	#DIV/0!	#DIV/0!	53.62	54.26	62.24	58.66	31.68	36.21	25.92	42.80	33.28	21.38	5.14	*32.37*
	RSQ	0.28	#DIV/0!	#DIV/0!	0.68	0.16	0.98	#DIV/0!	0.91	1.00	0.65	0.53	0.55	0.04	0.30	*0.65*
	Slope	4.14	#DIV/0!	#DIV/0!	10.25	3.74	-10.20	#DIV/0!	-18.32	8.56	5.96	9.54	9.57	1.17	-1.17	*6.14*
Construction	*Average*	*15.30*	*65.41*	*#DIV/0!*	*10.68*	*7.45*	*20.26*	*34.61*	*24.29*	*33.32*	*14.45*	*17.81*	*8.43*	*12.34*	*1.57*	*16.89*
	RSQ	0.52	1.00	#DIV/0!	0.66	0.22	0.33	0.25	0.40	0.34	0.98	0.70	0.66	0.48	0.02	*0.30*
	Slope	3.03	11.13	#DIV/0!	-5.47	-2.33	-5.74	-5.22	3.28	4.96	-4.36	-5.99	-2.56	1.44	0.10	*-0.89*
Stabilization	*Average*	*31.11*	*29.49*	*17.65*	*7.50*	*22.15*	*15.47*	*25.52*	*17.69*	*39.27*	*4.72*	*10.31*	*3.97*	*10.75*	*#DIV/0!*	*17.30*
	RSQ	0.12	0.81	#DIV/0!	0.31	0.26	0.11	0.87	0.90	0.29	0.23	0.00	0.00	1.00	#DIV/0!	*0.04*
	Slope	-5.92	-14.17	#DIV/0!	1.85	7.72	2.31	-8.83	-9.02	-1.89	1.38	-0.09	-0.01	-9.82	#DIV/0!	*-0.91*
Composite	Average	23.24	43.86	17.65	24.11	23.75	27.06	32.83	24.53	35.68	16.21	24.84	15.47	15.57	3.00	*22.70*
	RSQ	0.02	0.83	#DIV/0!	0.44	0.15	0.47	0.39	0.17	0.05	0.29	0.34	0.32	0.15	0.36	*0.15*
	Slope	0.50	-6.70	#DIV/0!	-3.31	-2.03	-3.69	-3.00	-1.08	0.59	-1.31	-2.13	-1.87	-0.63	-0.55	*-0.87*

Table B6. Ratio of Scrapers

Time Period	Sample Year	LSLS101	LSLS102	LSLS102UC	LSLS103B	LSLS103C	LSLS104	LSLS109	LSLS110	LSLS202	LSLS203	LSLS204	LSLS205	LSLS206	LSLS303	Average
Pre-development	1994										22	13	12	42		*22.25*
	1995	68			23					37	9.5	15	14	63	79	*38.56*
	1996	36			24					33	11	9	24	73	68	*34.75*
	1997	11			0	8					11	31	31			*15.33*
	1998				46	57	39	73	97		13	55	38	68	52	*53.80*
	1999	22			92	68	63		71		18	42	53	78		*56.33*
	2000	47			12	63	44		93		38				79	*53.71*
Construction	2001	77			58	57	30	30	100	47	49	30	28	12	84	*50.17*
	2002	14			83	87	46						29	100	93	*64.57*
	2003	36			40	87.5	60	20	89		56	43	76	80	96	*62.14*
	2004	21			83	27	28.5	15		4	29	38	78	97	73	*44.86*
	2005	7	55		11	2	20	95	58	44	24	42	49	94	47	*42.15*
	2006	48	0		20	0	80	64	14	61.25	58	33	25	94	73	*43.87*
	2007	17			11	0	42	38		49	18		23			*24.75*
Stabilization	2008	75			36	13	8	22		60	36	33	29			*34.67*
	2009	88			17	10	33	75		71	18	13	16			*37.89*
	2010	22	0		32	7	50	50	42	64	20	30	28			*31.36*
	2011	66	50		12	48	50	54	78		18	21	20	42		*41.73*
	2012	2	38	0	18	3	0	75	83		36	17	27	53		*29.33*

Pre-development	Average	36.80	#DIV/0!	#DIV/0!	32.83	49.00	48.67	73.00	87.00	35.00	17.50	27.50	28.67	64.80	69.50	*39.25*
	RSQ	0.11	#DIV/0!	#DIV/0!	0.10	0.67	0.04	#DIV/0!	0.02	1.00	0.26	0.70	0.96	0.65	0.01	*0.50*
	Slope	-3.52	#DIV/0!	#DIV/0!	5.57	17.60	2.50	#DIV/0!	-2.00	-4.00	2.39	8.20	8.11	5.43	-0.44	*5.32*
Construction	*Average*	*31.43*	*27.50*	*#DIV/0!*	*43.71*	*37.21*	*43.79*	*43.67*	*65.25*	*41.05*	*39.00*	*37.20*	*44.00*	*79.50*	*77.67*	*47.50*
	RSQ	0.20	1.00	#DIV/0!	0.52	0.70	0.06	0.18	0.86	0.06	0.21	0.08	0.03	0.42	0.42	*0.63*
	Slope	-5.04	-55.00	#DIV/0!	-10.57	-15.38	2.29	5.99	-16.12	2.33	-3.73	0.82	-1.79	11.69	-6.17	*-4.92*
Stabilization	*Average*	*50.60*	*29.33*	*0.00*	*23.00*	*16.20*	*28.20*	*55.20*	*67.67*	*65.00*	*25.60*	*22.80*	*24.00*	*47.50*	*#DIV/0!*	*35.00*
	RSQ	0.52	0.53	#DIV/0!	0.39	0.02	0.00	0.38	0.84	0.13	0.00	0.20	0.00	1.00	#DIV/0!	*0.05*
	Slope	-16.80	19.00	#DIV/0!	-4.10	1.80	0.10	8.50	20.50	2.00	0.00	-2.40	0.00	11.00	#DIV/0!	*-0.68*
Composite	Average	38.65	28.60	0.00	34.33	33.59	39.57	50.92	72.50	47.03	26.92	29.06	33.33	68.92	74.40	*41.17*
	RSQ	0.00	0.00	#DIV/0!	0.04	0.26	0.10	0.03	0.16	0.31	0.08	0.00	0.00	0.00	0.00	*0.00*
	Slope	0.11	0.58	#DIV/0!	-1.08	-3.49	-1.46	1.06	-2.15	2.07	0.75	0.01	0.04	0.28	0.06	*-0.15*

KEY:
1. **Bold Green** numbers indicate an R-square value in excess of 0.4. This would be considered a moderate to strong trend.

Attachment B
Montgomery County Benthic Index of Biotic Inegrity (BIBI)
Data Summary

Table B7. Taxa Richness

Time Period	Sample Year	LSLS101	LSLS102	LSLS102UC	LSLS103B	LSLS103C	LSLS104	LSLS109	LSLS110	LSLS202	LSLS203	LSLS204	LSLS205	LSLS206	LSLS303	Average
Pre-development	1994										17	23	14	26		*20.00*
	1995	25			31					25	18	21.5	23	26	23	*24.06*
	1996	15			19					18	29	25	29	27	20	*22.75*
	1997	22			20	26					23	28	27			*24.33*
	1998				22	13	22	17	17		16	14	17	18	18	*17.40*
	1999	18			14	15	12		16		19	18	21	24		*17.44*
	2000	16			22	15	19		33		23				15	*20.43*
Construction	2001	13			15	18	13	20	16	12	23	20	17	11	18	*16.33*
	2002	13			15	18	14						17	13	11	*14.43*
	2003	14			9	9.5	17	11	14		19	18	20	18	10	*14.50*
	2004	17			13	10	12	15		21	18	17	14	19	18	*15.82*
	2005	15	20		21	12	29	13	23	20	20	26	17	23	15	*19.54*
	2006	12	9		12	6	11	24	17	24.75	25	15	14	22	15	*15.90*
	2007	10			12	9	19	16		26	27		20			*17.38*
Stabilization	2008	15			31	13	18	13		23	30	32	16			*21.22*
	2009	19			25	21	18	16		28	22	15	15			*19.89*
	2010	21	20		18	18	19	20	25	23	22	16	18			*20.00*
	2011	23	19		16	19	21	19	21		20	28	19	25		*20.91*
	2012	13	15	21	21	18	13	18	22		24	15	25	14		*18.25*

Pre-development	Average	19.20	#DIV/0!	#DIV/0!	21.33	17.25	17.67	17.00	22.00	21.50	20.71	21.58	21.83	24.20	19.00	*20.92*
	RSQ	0.31	#DIV/0!	#DIV/0!	0.31	0.46	0.09	#DIV/0!	0.70	1.00	0.01	0.23	0.02	0.37	0.97	*0.21*
	Slope	-1.13	#DIV/0!	#DIV/0!	-1.66	-3.10	-1.50	#DIV/0!	8.00	-7.00	0.25	-1.27	0.43	-1.07	-1.49	*-0.62*
Construction	*Average*	*13.43*	*14.50*	*#DIV/0!*	*13.86*	*11.79*	*16.43*	*16.50*	*17.50*	*20.75*	*22.00*	*19.20*	*17.00*	*17.67*	*14.50*	*16.27*
	RSQ	0.12	1.00	#DIV/0!	0.00	0.66	0.09	0.01	0.24	0.96	0.24	0.01	0.00	0.92	0.01	*0.24*
	Slope	-0.36	-11.00	#DIV/0!	-0.11	-1.73	0.86	0.21	0.85	2.32	0.81	-0.19	0.00	2.46	0.14	*0.40*
Stabilization	*Average*	*18.20*	*18.00*	*21.00*	*22.20*	*17.80*	*17.80*	*17.20*	*22.67*	*24.67*	*23.60*	*21.20*	*18.60*	*19.50*	*#DIV/0!*	*20.05*
	RSQ	0.00	0.89	#DIV/0!	0.59	0.18	0.14	0.55	0.52	0.00	0.33	0.17	0.79	1.00	#DIV/0!	*0.45*
	Slope	0.00	-2.50	#DIV/0!	-2.90	0.80	-0.70	1.30	-1.50	0.00	-1.40	-2.10	2.20	-11.00	#DIV/0!	*-0.49*
Composite	Average	16.53	16.60	21.00	18.67	15.03	17.13	16.83	20.40	22.08	21.94	20.72	19.06	20.46	16.30	*18.98*
	RSQ	0.04	0.05	#DIV/0!	0.01	0.00	0.01	0.03	0.04	0.17	0.10	0.02	0.06	0.12	0.43	*0.06*
	Slope	-0.15	0.32	#DIV/0!	-0.12	-0.06	0.09	0.14	0.22	0.37	0.21	-0.13	-0.19	-0.33	-0.69	*-0.13*

Table B8. Number EPT Taxa

Time Period	Sample Year	LSLS101	LSLS102	LSLS102UC	LSLS103B	LSLS103C	LSLS104	LSLS109	LSLS110	LSLS202	LSLS203	LSLS204	LSLS205	LSLS206	LSLS303	Average
Pre-development	1994										12	14	4	16		*11.50*
	1995	12			16					14	8.5	13	12	11	10	*12.06*
	1996	4			9					11	12	12	14	11	7	*10.00*
	1997	12			9	12					15	14	15			*12.83*
	1998				12	9	9	10	9		10	7	12	8	6	*9.20*
	1999	9			10	8	7		9		10	8	11	13		*9.44*
	2000	7			11	7	10		11		9				7	*8.86*
Construction	2001	7			6	9	9	12	8	9	15	11	9	5	6	*8.83*
	2002	9			8	13	9						11	9	4	*9.00*
	2003	5			2	4.5	12	8	9		11	11	6	10	2	*7.32*
	2004	9			4	3	5.5	7		12	10	10	8	10	9	*7.95*
	2005	3	12		9	4	14	10	14	13	10	11	8	14	4	*9.69*
	2006	4	5		5	3	1	10	11	14.5	11	6.5	7	12	5	*7.31*
	2007	6			4	4	5	9		16	15		11			*8.75*
Stabilization	2008	6			16	4	7	5		14	18	17	9			*10.67*
	2009	10			15	9	8	11		13	12	5	7			*10.00*
	2010	11	10		10	8	6	9	13	16	11	11	11			*10.55*
	2011	8	11		8	9	10	10	12		11	14	8	17		*10.73*
	2012	3	6	9	13	10	7	7	14		10	9	11	9		*9.00*

Pre-development	Average	8.80	#DIV/0!	#DIV/0!	11.17	9.00	8.67	10.00	9.67	12.50	10.93	11.33	11.33	11.80	7.50	*10.56*
	RSQ	0.05	#DIV/0!	#DIV/0!	0.15	0.91	0.11	#DIV/0!	0.75	1.00	0.08	0.64	0.25	0.22	0.42	*0.48*
	Slope	-0.38	#DIV/0!	#DIV/0!	-0.54	-1.60	0.50	#DIV/0!	1.00	-3.00	-0.29	-1.31	1.03	-0.67	-0.51	*-0.50*
Construction	*Average*	*6.14*	*8.50*	*#DIV/0!*	*5.43*	*5.79*	*7.93*	*9.33*	*10.50*	*12.90*	*12.00*	*9.90*	*8.57*	*10.00*	*5.00*	*8.41*
	RSQ	0.24	1.00	#DIV/0!	0.03	0.52	0.20	0.09	0.59	0.99	0.01	0.45	0.00	0.78	0.00	*0.01*
	Slope	-0.54	-7.00	#DIV/0!	-0.18	-1.27	-0.93	-0.24	0.92	1.15	-0.13	-0.68	0.00	1.43	0.06	*-0.05*
Stabilization	*Average*	*7.60*	*9.00*	*9.00*	*12.40*	*8.00*	*7.60*	*8.40*	*13.00*	*14.33*	*12.40*	*11.20*	*9.20*	*13.00*	*#DIV/0!*	*10.19*
	RSQ	0.16	0.57	#DIV/0!	0.37	0.65	0.04	0.04	0.25	0.43	0.70	0.06	0.20	1.00	#DIV/0!	*0.32*
	Slope	-0.80	-2.00	#DIV/0!	-1.30	1.20	0.20	0.30	0.50	1.00	-1.70	-0.70	0.50	-8.00	#DIV/0!	*-0.26*
Composite	Average	7.35	8.80	9.00	9.28	7.28	7.97	9.00	11.00	13.25	11.69	10.84	9.67	11.15	6.00	*9.67*
	RSQ	0.08	0.01	#DIV/0!	0.00	0.04	0.05	0.08	0.59	0.27	0.02	0.03	0.06	0.01	0.30	*0.09*
	Slope	-0.15	-0.11	#DIV/0!	-0.02	-0.14	-0.16	-0.13	0.33	0.22	0.06	-0.09	-0.12	0.04	-0.35	*-0.08*

Table B9. BIBI Score

Time Period	Sample Year	LSLS101	LSLS102	LSLS102UC	LSLS103B	LSLS103C	LSLS104	LSLS109	LSLS110	LSLS202	LSLS203	LSLS204	LSLS205	LSLS206	LSLS303	Average
Pre-development	1994										32.04	29.72	32.53	28.39		*30.67*
	1995	26.84			20.26					30.24	30.33	31.02	27.29	32.24	27.24	*28.18*
	1996	24.80			26.73					26.75	27.02	29.34	24.34	30.35	25.53	*26.86*
	1997	22.22			23.65	24.16					24.98	26.41	26.13			*24.59*
	1998				35.86	36.98	37.90	36.71	38.26		32.49	40.49	38.82	23.98	27.71	*34.92*
	1999	20.12			47.70	35.09	36.45		29.10		24.68	32.20	30.57	27.57		*31.50*
	2000	27.64			29.99	32.60	32.36		29.43		28.72				26.30	*29.58*
Construction	2001	24.56			28.22	22.27	20.94	24.03	30.08	23.26	30.34	23.37	22.34	17.38	28.61	*24.62*
	2002	19.60			27.83	30.86	23.22						22.10	28.80	24.63	*25.29*
	2003	19.47			18.94	25.14	37.76	36.22	27.49		27.01	26.48	25.79	26.45	26.63	*27.03*
	2004	20.60			21.95	21.33	20.14	20.64		20.32	23.05	22.98	24.31	26.90	26.12	*22.58*
	2005	15.82	34.83		24.01	27.94	23.25	29.95	27.27	34.68	28.04	23.52	25.55	28.55	28.99	*27.11*
	2006	23.59	29.46		23.04	25.48	24.23	26.36	23.22	34.82	27.03	22.63	23.91	29.14	26.29	*26.09*
	2007	20.90			19.95	17.45	20.97	22.44		28.21	25.11		26.41			*22.68*
Stabilization	2008	31.28			22.55	16.60	17.24	20.59		28.76	27.98	26.16	23.73			*23.88*
	2009	27.18			23.39	21.48	22.67	30.77		32.40	25.39	25.25	27.35			*26.21*
	2010	28.45	22.15		24.99	26.71	21.47	24.38	26.28	29.04	26.43	22.93	25.86			*25.33*
	2011	29.11	26.07		24.23	24.44	26.04	25.54	28.07		26.52	24.17	25.72	25.54		*25.95*
	2012	14.76	21.90	17.27	23.51	22.81	16.69	26.51	29.07		26.25	23.14	24.40	24.14		*22.54*

Pre-development	Average	24.32	#DIV/0!	#DIV/0!	30.70	32.21	35.57	36.71	32.26	28.50	28.61	31.53	29.95	28.50	26.69	*29.47*
	RSQ	0.02	#DIV/0!	#DIV/0!	0.45	0.29	0.93	#DIV/0!	0.72	1.00	0.15	0.18	0.07	0.35	0.00	*0.07*
	Slope	-0.23	#DIV/0!	#DIV/0!	3.54	2.34	-2.77	#DIV/0!	-4.42	-3.49	-0.56	1.08	0.76	-0.89	-0.01	*0.41*
Construction	*Average*	*20.65*	*32.14*	*#DIV/0!*	*23.42*	*24.35*	*24.36*	*26.61*	*27.01*	*28.26*	*26.76*	*23.80*	*24.34*	*26.20*	*26.88*	*25.06*
	RSQ	0.03	1.00	#DIV/0!	0.40	0.15	0.02	0.03	0.81	0.32	0.28	0.12	0.51	0.48	0.00	*0.03*
	Slope	-0.24	-5.37	#DIV/0!	-1.05	-0.80	-0.44	-0.49	-1.15	1.62	-0.61	-0.27	0.56	1.67	0.03	*-0.15*
Stabilization	*Average*	*26.15*	*23.37*	*17.27*	*23.73*	*22.41*	*20.82*	*25.56*	*27.81*	*30.06*	*26.51*	*24.33*	*25.41*	*24.84*	*#DIV/0!*	*24.78*
	RSQ	0.57	0.00	#DIV/0!	0.22	0.41	0.01	0.08	0.97	0.00	0.16	0.67	0.00	1.00	#DIV/0!	*0.09*
	Slope	-3.11	-0.12	#DIV/0!	0.28	1.54	0.23	0.66	1.40	0.14	-0.23	-0.71	-0.03	-1.40	#DIV/0!	*-0.29*
Composite	Average	23.35	26.88	17.27	25.93	25.71	25.42	27.01	28.83	28.85	27.41	26.86	26.51	26.88	26.80	*26.61*
	RSQ	0.00	0.81	#DIV/0!	0.12	0.33	0.46	0.18	0.28	0.06	0.22	0.41	0.16	0.09	0.00	*0.34*
	Slope	0.02	-1.57	#DIV/0!	-0.45	-0.70	-1.09	-0.56	-0.40	0.23	-0.21	-0.51	-0.28	-0.20	0.02	*-0.33*

KEY:
1. **Bold Green** numbers indicate an R-square value in excess of 0.4. This would be considered a moderate to strong trend.

Attachment C
Montgomery County Habitat Assessment
Data Summary

Table C1. Average of Instream Cover

Time Period	Sample Year	LSLS101	LSLS102	LSLS103B	LSLS103C	LSLS104	LSLS109	LSLS110	LSLS202	LSLS203	LSLS204	LSLS205	LSLS206	LSLS303	LSLS413	Average
Pre-development	1994			12						8	11	14	12	16		*12.17*
	1995	11		13					15	10	12.5	13.5	10	13		*12.25*
	1996	15		16					16	10	14	16	11	18		*14.50*
	1997	12		17	14					13	16	13				*14.17*
	1998			18	15	14	16	16		15	15	12	14	14	15	*14.91*
	1999	15		17	15	15	16	13		8	14	12	10			*13.50*
	2000	13		16	14	14	16	13		13				15		*14.25*
Construction	2001								16	8					14	*12.67*
	2002	17		15	13	10						14	13	15		*13.86*
	2003	17		15	12	9	17	15		13	14	12	15	13		*13.82*
	2004	14		14	16	10.5	11		14	11	12	15	15	15		*13.41*
	2005	17	16	15	13	12	12	11	17	15	15	13	16	16		*14.46*
	2006	15	14	16	15	7	10	13	15.7	14.5	15	14	16	15	12	*13.73*
	2007	9		17	15	9	15		14	9		13				*12.63*
Stabilization	2008	12		12	15	9	11		17	12	10	15				*12.56*
	2009	15		15	15	12	17		14	11	14	8				*13.44*
	2010	16	9	13	15	9	12	11	13	11	9	12				*11.82*
	2011	13	9	14	14	7	14	9		13	15	13	14			*12.27*
	2012	8	9	12	14	10	13	12		10	10	11	15			*11.27*

Pre-development	Average	13.20	#DIV/0!	15.57	14.50	14.33	16.00	14.00	15.50	11.00	13.75	13.42	11.40	15.20	15.00	*13.68*
	RSQ	0.14	#DIV/0!	**0.58**	0.00	0.00	#DIV/0!	**0.75**	**1.00**	0.21	**0.54**	0.39	0.01	0.02	#DIV/0!	*0.42*
	Slope	0.33	#DIV/0!	0.79	0.00	0.00	0.00	-1.50	1.00	0.57	0.70	-0.50	0.07	-0.11	#DIV/0!	*0.33*
Construction	*Average*	*14.83*	*15.00*	*15.33*	*14.00*	*9.58*	*13.00*	*13.00*	*15.34*	*11.75*	*14.00*	*13.50*	*15.00*	*14.80*	*13.00*	*13.51*
	RSQ	**0.54**	**1.00**	**0.53**	0.30	0.09	0.07	**0.43**	0.09	0.11	0.30	0.00	**0.82**	0.19	**1.00**	*0.00*
	Slope	-1.23	-2.00	0.40	0.46	-0.27	-0.50	-0.86	-0.17	0.45	0.60	-0.03	0.70	0.30	-0.40	*0.01*
Stabilization	*Average*	*12.80*	*9.00*	*13.20*	*14.60*	*9.40*	*13.40*	*10.67*	*14.67*	*11.40*	*11.60*	*11.80*	*14.50*	*#DIV/0!*	*#DIV/0!*	*12.27*
	RSQ	0.26	#DIV/0!	0.01	**0.75**	0.07	0.00	0.11	**0.92**	0.08	0.00	0.03	**1.00**	#DIV/0!	#DIV/0!	*0.53*
	Slope	-1.00	0.00	-0.10	-0.30	-0.30	0.10	0.50	-2.00	-0.20	0.10	-0.30	1.00	#DIV/0!	#DIV/0!	*-0.37*
Composite	Average	13.69	11.40	14.83	14.33	10.54	13.85	12.56	15.17	11.36	13.10	12.97	13.42	15.00	13.67	*13.25*
	RSQ	0.02	**0.94**	0.09	0.01	**0.47**	0.16	**0.54**	0.09	0.04	0.09	0.15	**0.51**	0.01	**1.00**	*0.18*
	Slope	-0.07	-1.05	-0.10	0.03	-0.39	-0.21	-0.30	-0.08	0.08	-0.10	-0.12	0.26	-0.04	-0.38	*-0.08*

Table C2. Average of Epibenthic Substrate

Time Period	Sample Year	LSLS101	LSLS102	LSLS103B	LSLS103C	LSLS104	LSLS109	LSLS110	LSLS202	LSLS203	LSLS204	LSLS205	LSLS206	LSLS303	LSLS413	Average
Pre-development	1994			15						16	11	16	12	13		*13.83*
	1995	16		13					16.5	16	13	9	14.5	13.5		*13.94*
	1996	18		13					17	17	17	13	10	13		*14.75*
	1997	16		17	13					18	15	12				*15.17*
	1998			17	14	14	18	11		18	17	10	12	11	9	*13.73*
	1999	11		16	16	16	16	14		16	13	13	16			*14.70*
	2000	12		15	13	16	15	12		18				10		*13.88*
Construction	2001								16	19					16	*17.00*
	2002	14		12	12	11						9	10	14		*11.71*
	2003	16		12	10	14	16	13		14	11	12	8	8		*12.18*
	2004	14		11	13	13.5	14		10	15	15	13	13	15		*13.32*
	2005	15	15	11	13	13	17	9	16	16	16	12	12	16		*13.92*
	2006	12	13	13	13	16	15	16	16.3	13.5	13	15	12	11	9	*13.41*
	2007	17		10	17	17	17		17	17		13				*15.63*
Stabilization	2008	15		11	16	16	15		16	16	15	14				*14.89*
	2009	13		8	12	11	15		15	14	15	13				*12.89*
	2010	17	17	11	17	12	14	15	14	13	13	12				*14.09*
	2011	17	17	12	15	16	16	15		17	15	13	11			*14.91*
	2012	10	14	9	10	12	14	13		17	14	15	16			*13.09*

Pre-development	Average	14.60	#DIV/0!	15.14	14.00	15.33	16.33	12.33	16.75	17.00	14.33	12.17	12.90	12.10	9.00	*14.28*
	RSQ	**0.74**	#DIV/0!	0.21	0.03	**0.75**	**0.96**	0.11	**1.00**	0.29	0.19	0.08	0.16	**0.89**	#DIV/0!	*0.01*
	Slope	-1.23	#DIV/0!	0.36	0.20	1.00	-1.50	0.50	0.50	0.25	0.57	-0.37	0.45	-0.59	#DIV/0!	*0.02*
Construction	*Average*	*14.67*	*14.00*	*11.50*	*13.00*	*14.08*	*15.80*	*12.67*	*15.06*	*15.75*	*13.75*	*12.33*	*11.00*	*12.80*	*12.50*	*13.88*
	RSQ	0.01	**1.00**	0.13	**0.64**	**0.78**	0.13	0.06	0.06	0.15	0.17	**0.58**	**0.40**	0.01	**1.00**	*0.00*
	Slope	0.11	-2.00	-0.20	0.97	1.01	0.30	0.57	0.30	-0.36	0.70	0.80	0.80	0.20	-1.40	*0.04*
Stabilization	*Average*	*14.40*	*16.00*	*10.20*	*14.00*	*13.40*	*14.80*	*14.33*	*15.00*	*15.40*	*14.40*	*13.40*	*13.50*	*#DIV/0!*	*#DIV/0!*	*13.97*
	RSQ	0.10	**0.75**	0.00	0.24	0.04	0.04	**0.75**	**1.00**	0.19	0.13	0.08	**1.00**	#DIV/0!	#DIV/0!	*0.07*
	Slope	-0.60	-1.50	0.00	-0.90	-0.30	-0.10	-1.00	-1.00	0.50	-0.20	0.20	5.00	#DIV/0!	#DIV/0!	*-0.16*
Composite	Average	14.56	15.20	12.56	13.60	14.11	15.54	13.11	15.38	16.14	14.20	12.59	12.21	12.45	11.33	*14.05*
	RSQ	0.03	0.17	**0.58**	0.00	0.04	0.24	0.17	0.07	0.14	0.00	0.08	0.01	0.00	0.02	*0.01*
	Slope	-0.07	0.24	-0.34	0.03	-0.09	-0.13	0.17	-0.10	-0.11	0.02	0.09	0.03	0.01	-0.14	*-0.02*

Table C3. Average of Embeddedness

Time Period	Sample Year	LSLS101	LSLS102	LSLS103B	LSLS103C	LSLS104	LSLS109	LSLS110	LSLS202	LSLS203	LSLS204	LSLS205	LSLS206	LSLS303	LSLS413	Average
Pre-development	1994			14						14	16	13	15	8		*13.33*
	1995	9.5		10					14.5	10.5	10.5	5.5	9	10		*9.94*
	1996	14		16					15	10	14	13	12	11		*13.13*
	1997	16		15	13					13	12	11				*13.33*
	1998			13	14	14	16	10		15	10	13	13	12	9	*12.64*
	1999	16		16	14	15	14	14		9	15	13	12			*13.80*
	2000	16		17	13	14	16	12		14				15		*14.63*
Construction	2001								17	12					11	*13.33*
	2002	18		16	8	16						14	8	11		*13.00*
	2003	16		10	5	14	16	14		13	15	14	8	8		*12.09*
	2004	14		7	9	12.5	16		9	15	15	14	16	14		*12.86*
	2005	16	15	13	14	13	12	8	15	16	16	14	13	15		*13.85*
	2006	16	13	15	10	12	12	10	14.7	13	6	13	14	14	9	*12.26*
	2007	9		12	16	9	12		10	8		12				*11.00*
Stabilization	2008	13		2	10	10	12		9	6	12	8				*9.11*
	2009	12		6	7	6	7		11	12	12	11				*9.33*
	2010	13	13	6	8	7	12	9	10	10	10	4				*9.27*
	2011	12	15	8	9	10	12	13		12	9	8	6			*10.36*
	2012	10	16	10	8	10	11	9		10	14	7	10			*10.45*

Pre-development	Average	14.30	#DIV/0!	14.43	13.50	14.33	15.33	12.00	14.75	12.21	12.92	11.42	12.20	11.20	9.00	*12.97*
	RSQ	**0.62**	#DIV/0!	0.34	0.00	0.00	0.00	0.25	**1.00**	0.00	0.03	0.13	0.01	**0.96**	#DIV/0!	*0.34*
	Slope	1.07	#DIV/0!	0.64	0.00	0.00	0.00	1.00	0.50	0.07	-0.24	0.59	-0.08	1.05	#DIV/0!	*0.40*
Construction	*Average*	*14.83*	*14.00*	*12.17*	*10.33*	*12.75*	*13.60*	*10.67*	*13.14*	*12.83*	*13.00*	*13.50*	*11.80*	*12.40*	*10.00*	*12.63*
	RSQ	**0.54**	**1.00**	0.00	**0.63**	**0.87**	**0.75**	**0.62**	0.25	0.08	**0.51**	**0.69**	**0.55**	**0.57**	**1.00**	*0.31*
	Slope	-1.23	-2.00	0.03	1.71	-1.16	-1.20	-1.57	-0.76	-0.37	-2.60	-0.37	1.70	1.30	-0.40	*-0.24*
Stabilization	*Average*	*12.00*	*14.67*	*6.40*	*8.40*	*8.60*	*10.80*	*10.33*	*10.00*	*10.00*	*11.40*	*7.60*	*8.00*	*#DIV/0!*	*#DIV/0!*	*9.71*
	RSQ	**0.60**	**0.96**	**0.92**	0.08	0.11	0.05	0.00	0.25	0.27	0.01	0.10	**1.00**	#DIV/0!	#DIV/0!	*0.83*
	Slope	-0.60	1.50	1.80	-0.20	0.40	0.30	0.00	0.50	0.80	0.10	-0.50	4.00	#DIV/0!	#DIV/0!	*0.37*
Composite	Average	13.78	14.40	11.44	10.53	11.61	12.92	11.00	12.52	11.81	12.43	11.03	11.33	11.80	9.67	*11.99*
	RSQ	0.12	0.15	0.37	0.22	**0.67**	**0.53**	0.13	0.40	0.07	0.07	0.14	0.10	0.33	0.02	*0.37*
	Slope	-0.17	0.16	-0.46	-0.31	-0.55	-0.42	-0.16	-0.36	-0.12	-0.13	-0.21	-0.17	0.35	-0.04	*-0.19*

KEY:
1. **Bold Green** numbers indicate an R-square value in excess of 0.4. This would be considered a moderate to strong trend.

Attachment C
Montgomery County Habitat Assessment
Data Summary

Table C4. Average of Channel Alteration

Time Period	Sample Year	LSLS101	LSLS102	LSLS103B	LSLS103C	LSLS104	LSLS109	LSLS110	LSLS202	LSLS203	LSLS204	LSLS205	LSLS206	LSLS303	LSLS413	Average
Pre-development	1994			18						16	17	17	17	13		*16.33*
	1995	18.5		17					18.5	16	16.5	17	15.5	18		*17.13*
	1996	18		19					19	16	18	18	18	17		*17.88*
	1997	19		19	19					18	19	17				*18.50*
	1998			19	19	19	18	19		17	19	17	14	18	16	*17.73*
	1999	18		18	18	18	17	18		16	18	18	14			*17.30*
	2000	19		19	17	18	18	19		17				17		*18.00*
Construction	2001								19	19					17	*18.33*
	2002	19		18	16	18						18	15	19		*17.57*
	2003	18		16	15	16	16	19		18	16	15	14	16		*16.27*
	2004	18		15	18	17	16		18	17	15	18	18	19		*17.18*
	2005	18	18	18	19	18	18	15	18	18	18	15	13	18		*17.23*
	2006	18	18	18	18	18	16	18	18	18	18	17	17	18	16	*17.57*
	2007	19		13	16	17	18		16	17		19				*16.88*
Stabilization	2008	19		18	18	17	16		16	14	18	19				*17.22*
	2009	17		16	17	17	16		18	16	17	18				*16.89*
	2010	18	17	18	17	17	15	19	20	10	17	19				*17.00*
	2011	18	18	17	15	18	18	18		17	15	19	18			*17.36*
	2012	19	17	15	17	17	18	19		16	17	19	17			*17.36*

Pre-development	Average	18.50	#DIV/0!	18.43	18.25	18.33	17.67	18.67	18.75	16.57	17.92	17.33	15.70	16.60	16.00	*17.55*
	RSQ	0.06	#DIV/0!	0.24	0.89	0.75	0.00	0.00	1.00	0.15	0.50	0.17	0.54	0.26	#DIV/0!	*0.33*
	Slope	0.06	#DIV/0!	0.18	-0.70	-0.50	0.00	0.00	0.50	0.14	0.39	0.11	-0.63	0.44	#DIV/0!	*0.19*
Construction	*Average*	*18.33*	*18.00*	*16.33*	*17.00*	*17.33*	*16.80*	*17.33*	*17.80*	*17.83*	*16.75*	*17.00*	*15.40*	*18.00*	*16.50*	*17.29*
	RSQ	0.00	#DIV/0!	0.17	0.12	0.02	0.33	0.18	0.69	0.49	0.60	0.07	0.05	0.00	1.00	*0.17*
	Slope	0.00	0.00	-0.46	0.29	0.06	0.40	-0.57	-0.40	-0.24	0.90	0.23	0.30	0.00	-0.20	*-0.12*
Stabilization	*Average*	*18.20*	*17.33*	*16.80*	*16.80*	*17.20*	*16.60*	*18.67*	*18.00*	*14.60*	*16.80*	*18.80*	*17.50*	*#DIV/0!*	*#DIV/0!*	*17.17*
	RSQ	0.04	0.00	0.37	0.33	0.13	0.50	0.00	1.00	0.08	0.33	0.13	1.00	#DIV/0!	#DIV/0!	*0.31*
	Slope	0.10	0.00	-0.50	-0.40	0.10	0.60	0.00	2.00	0.50	-0.40	0.10	-1.00	#DIV/0!	#DIV/0!	*0.08*
Composite	Average	18.34	17.60	17.28	17.27	17.50	16.92	18.22	18.05	16.44	17.23	17.65	15.88	17.30	16.33	*17.35*
	RSQ	0.02	0.42	0.25	0.19	0.22	0.04	0.00	0.09	0.08	0.12	0.20	0.04	0.27	0.02	*0.05*
	Slope	-0.02	-0.11	-0.14	-0.12	-0.08	-0.05	-0.01	-0.07	-0.10	-0.07	0.10	0.06	0.21	-0.02	*-0.02*

Table C5. Average of Sediment Deposit

Time Period	Sample Year	LSLS101	LSLS102	LSLS103B	LSLS103C	LSLS104	LSLS109	LSLS110	LSLS202	LSLS203	LSLS204	LSLS205	LSLS206	LSLS303	LSLS413	Average
Pre-development	1994			12						15	11	12	14	12		*12.67*
	1995	8		10.5					14	11	12.5	7.5	6.5	9.5		*9.94*
	1996	11		8					13	9	14	15	10	10		*11.25*
	1997	15		14	12					10	11	9				*11.83*
	1998			12	10	13	14	9		16	10	13	9	12	12	*11.82*
	1999	14		15	14	14	14	12		6	11	10	8			*11.80*
	2000	14		15	9	16	16	11		14				14		*13.63*
Construction	2001								15	8					9	*10.67*
	2002	13		15	9	17						12	9	11		*12.29*
	2003	15		5	6	15	16	13		13	14	14	9	13		*12.09*
	2004	13		11	7	14.5	9		14	13	14	10	13	9		*11.59*
	2005	15	15	3	12	9	8	15	14	16	12	10	11	15		*11.92*
	2006	15	12	15	11	9	10	8	12.7	11.5	4	10	15	14	12	*11.37*
	2007	9		14	8	8	11		7	11		10				*9.75*
Stabilization	2008	9		6	6	8	12		7	8	11	7				*8.22*
	2009	8		7	10	9	10		7	11	9	7				*8.67*
	2010	11	15	9	7	8	13	11	6	11	11	6				*9.82*
	2011	9	12	11	7	8	6	6		13	9	9	6			*8.73*
	2012	8	10	10	6	8	5	6		14	9	8	9			*8.45*

Pre-development	Average	12.40	#DIV/0!	12.36	11.25	14.33	14.67	10.67	13.50	11.57	11.58	11.08	9.50	11.50	12.00	*11.85*
	RSQ	0.58	#DIV/0!	0.44	0.08	0.96	0.75	0.43	1.00	0.02	0.15	0.00	0.24	0.48	#DIV/0!	*0.23*
	Slope	1.06	#DIV/0!	0.79	-0.50	1.50	1.00	1.00	-1.00	-0.21	-0.30	0.01	-0.67	0.52	#DIV/0!	*0.26*
Construction	*Average*	*13.33*	*13.50*	*10.50*	*8.83*	*12.08*	*10.80*	*12.00*	*12.54*	*12.08*	*11.00*	*11.00*	*11.40*	*12.40*	*10.50*	*11.38*
	RSQ	0.17	1.00	0.03	0.12	0.90	0.21	0.30	0.52	0.14	0.75	0.49	0.72	0.28	1.00	*0.17*
	Slope	-0.51	-3.00	0.49	0.43	-1.96	-0.90	-1.29	-1.05	0.46	-3.20	-0.63	1.40	0.80	0.60	*-0.17*
Stabilization	*Average*	*9.00*	*12.33*	*8.60*	*7.20*	*8.20*	*9.20*	*7.67*	*6.67*	*11.40*	*9.80*	*7.40*	*7.50*	*#DIV/0!*	*#DIV/0!*	*8.78*
	RSQ	0.02	0.99	0.84	0.08	0.13	0.64	0.75	0.75	0.92	0.33	0.31	1.00	#DIV/0!	#DIV/0!	*0.02*
	Slope	-0.10	-2.50	1.20	-0.30	-0.10	-1.80	-2.50	-0.50	1.40	-0.40	0.40	3.00	#DIV/0!	#DIV/0!	*0.05*
Composite	Average	11.69	12.80	10.69	8.93	11.18	11.08	10.11	10.97	11.69	10.83	9.97	9.96	11.95	11.00	*10.87*
	RSQ	0.15	0.28	0.08	0.35	0.66	0.50	0.24	0.53	0.00	0.16	0.30	0.01	0.21	0.02	0.46
	Slope	-0.20	-0.37	-0.18	-0.31	-0.63	-0.54	-0.29	-0.52	0.03	-0.17	-0.24	-0.04	0.22	0.06	*-0.19*

Table C6. Average of Riffle Frequency

Time Period	Sample Year	LSLS101	LSLS102	LSLS103B	LSLS103C	LSLS104	LSLS109	LSLS110	LSLS202	LSLS203	LSLS204	LSLS205	LSLS206	LSLS303	LSLS413	Average
Pre-development	1994			13						17	19	16	15	16		*16.00*
	1995	17		15.5					19	16.5	16.5	10.5	13.5	13.5		*15.25*
	1996	17		19					18	17	17	16	15	15		*16.75*
	1997	18		18	17					19	19	16				*17.83*
	1998			17	16	18	19	12		18	17	14	15	13	6	*15.00*
	1999	16		17	18	17	16	16		17	16	14	13			*16.00*
	2000	16		17	13	19	19	15		19				14		*16.50*
Construction	2001								19	19					9	*15.67*
	2002	18		17	15	17						14	14	16		*15.86*
	2003	19		13	14	16	19	16		16	14	8	15	13		*14.82*
	2004	15		14	16	17.5	18		14	15	14	16	15	13		*15.23*
	2005	17	18	12	18	17	17	10	17	18	17	13	13	17		*15.69*
	2006	17	17	16	16	18	19	18	17.3	16	14	14	15	12	8	*15.52*
	2007	18		4	15	17	17		17	14		13				*14.38*
Stabilization	2008	12		17	17	17	17		16	11	16	8				*14.56*
	2009	16		14	8	17	19		14	13	13	12				*14.00*
	2010	17	18	13	17	17	17	19	16	14	17	16				*16.45*
	2011	17	18	14	17	18	17	18		18	16	16	14			*16.64*
	2012	18	15	18	18	16	14	14		14	18	16	17			*16.18*

Pre-development	Average	16.80	#DIV/0!	16.64	16.00	18.00	18.00	14.33	18.50	17.64	17.42	14.42	14.30	14.30	6.00	*16.19*
	RSQ	0.44	#DIV/0!	0.27	0.36	0.25	0.00	0.52	1.00	0.36	0.23	0.00	0.15	0.30	#DIV/0!	*0.01*
	Slope	-0.27	#DIV/0!	0.46	-1.00	0.50	0.00	1.50	-1.00	0.29	-0.33	0.01	-0.18	-0.28	#DIV/0!	*0.04*
Construction	*Average*	*17.33*	*17.50*	*12.67*	*15.67*	*17.08*	*18.00*	*14.67*	*16.86*	*16.33*	*14.75*	*13.00*	*14.40*	*14.20*	*8.50*	*15.31*
	RSQ	0.02	1.00	0.45	0.10	0.20	0.23	0.00	0.09	0.46	0.07	0.04	0.00	0.09	1.00	*0.28*
	Slope	-0.11	-1.00	-1.66	0.23	0.16	-0.30	0.14	-0.23	-0.59	0.30	0.29	0.00	-0.40	-0.20	*-0.13*
Stabilization	*Average*	*16.00*	*17.00*	*15.20*	*15.40*	*17.00*	*16.80*	*17.00*	*15.33*	*14.00*	*16.00*	*13.60*	*15.50*	*#DIV/0!*	*#DIV/0!*	*15.57*
	RSQ	0.77	0.75	0.02	0.17	0.05	0.50	0.89	0.00	0.47	0.35	0.78	1.00	#DIV/0!	#DIV/0!	0.60
	Slope	1.30	-1.50	0.20	1.10	-0.10	-0.80	-2.50	0.00	1.10	0.70	2.00	3.00	#DIV/0!	#DIV/0!	*0.59*
Composite	Average	16.75	17.20	14.92	15.67	17.25	17.54	15.33	16.73	16.19	16.23	13.68	14.54	14.25	7.67	*15.70*
	RSQ	0.01	0.18	0.08	0.00	0.12	0.21	0.14	0.45	0.34	0.15	0.00	0.09	0.04	0.29	*0.07*
	Slope	-0.04	-0.18	-0.17	-0.02	-0.06	-0.15	0.21	-0.23	-0.23	-0.11	-0.02	0.06	-0.07	0.20	*-0.04*

KEY:
1. **Bold Green** numbers indicate an R-square value in excess of 0.4. This would be considered a moderate to strong trend.

Attachment C
Montgomery County Habitat Assessment
Data Summary

Table C7. Average of Channel Flow

Time Period	Sample Year	LSLS101	LSLS102	LSLS103B	LSLS103C	LSLS104	LSLS109	LSLS110	LSLS202	LSLS203	LSLS204	LSLS205	LSLS206	LSLS303	LSLS413	Average
Pre-development	1994			16						19	14	16	17	15		*16.17*
	1995	10		15.5					15	17	11.5	15	13.5	11.5		*13.63*
	1996	10		15					16	17	17	16	14	15		*15.00*
	1997	14		15	13					17	16	17				*15.33*
	1998			15	10	11	14	11		18	15	16	15	17	17	*14.45*
	1999	13		15	15	15	15	17		18	15	17	15			*15.50*
	2000	14		16	13	14	15	16		18				14		*15.00*
Construction	2001								15	19					17	*17.00*
	2002	11		12	12	10						15	11	12		*11.86*
	2003	15		14	12	12	17	15		19	15	13	14	13		*14.45*
	2004	15		13	14	14	14		14	15	14	16	14	12		*14.09*
	2005	14	17	13	17	15	14	11	15	17	16	14	13	15		*14.69*
	2006	10	14	14	14	14	14	14	15.3	15	17	16	15	16	17	*14.66*
	2007	14		11	15	13	14		12	17		17				*14.13*
Stabilization	2008	10		16	15	15	15		9	12	15	17				*13.78*
	2009	11		9	9	12	10		13	14	9	14				*11.22*
	2010	11	15	9	9	14	9	16	9	18	14	13				*12.45*
	2011	9	11	9	10	12	9	12		19	15	18	16			*12.73*
	2012	8	15	11	9	10	9	12		13	9	15	16			*11.55*

Pre-development	Average	12.20	#DIV/0!	15.36	12.75	13.33	14.67	14.67	15.50	17.71	14.75	16.17	14.90	14.50	17.00	*15.01*
	RSQ	0.64	#DIV/0!	0.03	0.10	0.52	0.75	0.60	1.00	0.00	0.17	0.41	0.04	0.07	#DIV/0!	*0.00*
	Slope	0.79	#DIV/0!	-0.04	0.50	1.50	0.50	2.50	1.00	0.00	0.41	0.26	-0.13	0.22	#DIV/0!	*-0.01*
Construction	*Average*	*13.17*	*15.50*	*12.83*	*14.00*	*13.00*	*14.60*	*13.33*	*14.26*	*17.00*	*15.50*	*15.17*	*13.40*	*13.60*	*17.00*	*14.41*
	RSQ	0.00	1.00	0.05	0.46	0.43	0.50	0.18	0.25	0.39	0.64	0.38	0.53	0.76	#DIV/0!	*0.02*
	Slope	-0.03	-3.00	-0.14	0.69	0.63	-0.60	-0.57	-0.29	-0.51	0.80	0.49	0.70	1.00	0.00	*-0.10*
Stabilization	*Average*	*9.80*	*13.67*	*10.80*	*10.40*	*12.60*	*10.40*	*13.33*	*10.33*	*15.20*	*12.40*	*15.40*	*16.00*	*#DIV/0!*	*#DIV/0!*	*12.35*
	RSQ	0.53	0.00	0.27	0.44	0.66	0.62	0.75	0.00	0.13	0.09	0.00	#DIV/0!	#DIV/0!	#DIV/0!	*0.21*
	Slope	-0.60	0.00	-1.00	-1.10	-1.00	-1.30	-2.00	0.00	0.70	-0.60	0.00	0.00	#DIV/0!	#DIV/0!	*-0.30*
Composite	Average	11.81	14.40	13.25	12.47	12.93	13.00	13.78	13.33	16.78	14.17	15.59	14.46	14.05	17.00	*14.09*
	RSQ	0.11	0.25	0.61	0.12	0.01	0.56	0.06	0.50	0.22	0.11	0.02	0.01	0.00	#DIV/0!	*0.43*
	Slope	-0.14	-0.35	-0.34	-0.18	-0.04	-0.45	-0.11	-0.35	-0.17	-0.13	-0.04	0.03	-0.01	0.00	*-0.18*

Table C8. Average of Bank Vegetation

Time Period	Sample Year	LSLS101	LSLS102	LSLS103B	LSLS103C	LSLS104	LSLS109	LSLS110	LSLS202	LSLS203	LSLS204	LSLS205	LSLS206	LSLS303	LSLS413	Average
Pre-development	1994			9						8	7	7.5	7.5	8.5		*7.92*
	1995	7		8					8.5	7	7	6	5.25	8		*7.09*
	1996	7		7					7	6.5	5.5	5.5	7	9		*6.81*
	1997	5.5		6	8					5	8	4				*6.08*
	1998			8	3	7	9	7		8	8	7	6	8	6.5	*7.05*
	1999	8		8.5	8.5	9	9	9		8	8	6	6.5			*8.05*
	2000	3		8	5	6	8	8		7				8		*6.63*
Construction	2001								8	8					6.5	*7.50*
	2002	7		7	5	5						5.5	5	4		*5.50*
	2003	8		5	4	4	8	8		5.5	7	5	6	8		*6.23*
	2004	7		6	7	5	5		8	5	5	5	8	7		*6.18*
	2005	8	9	8	8	6.5	7.5	8	8	8	8	6	7	9		*7.77*
	2006	8	8	8	6	5.5	7	6	7.8	5.5	6.5	5.5	6	7	4.5	*6.52*
	2007	6.5		7	7	6.5	6.5		6	4		3.5				*5.88*
Stabilization	2008	6		5	5	6.5	6.5		5	3.5	5	6				*5.39*
	2009	6.5		5	5.5	3.5	8		6	5.5	5.5	4				*5.50*
	2010	5	7.5	4.5	4	5.5	5	7	8	7	4.5	4				*5.64*
	2011	7.5	3	5	4	4	5.5	6		5	5	5	4			*4.91*
	2012	5	4.5	2.5	3.5	4.5	6	5.5		5	3.5	2	4			*4.18*

Pre-development	Average	6.10	#DIV/0!	7.79	6.13	7.33	8.67	8.00	7.75	7.07	7.25	6.00	6.45	8.30	6.50	*7.09*
	RSQ	0.26	#DIV/0!	0.01	0.03	0.11	0.75	0.25	1.00	0.00	0.32	0.07	0.05	0.19	#DIV/0!	*0.04*
	Slope	-0.48	#DIV/0!	-0.04	-0.35	-0.50	-0.50	0.50	-1.50	0.02	0.30	-0.17	-0.10	-0.08	#DIV/0!	*-0.06*
Construction	*Average*	*7.42*	*8.50*	*6.83*	*6.17*	*5.42*	*6.80*	*7.33*	*7.56*	*6.00*	*6.63*	*5.08*	*6.40*	*7.00*	*5.50*	*6.51*
	RSQ	0.01	1.00	0.25	0.38	0.55	0.02	0.57	0.40	0.35	0.02	0.22	0.17	0.35	1.00	*0.01*
	Slope	-0.04	-1.00	0.31	0.49	0.39	-0.10	-0.57	-0.24	-0.45	0.15	-0.21	0.30	0.70	-0.40	*-0.05*
Stabilization	*Average*	*6.00*	*5.00*	*4.40*	*4.40*	*4.80*	*6.20*	*6.17*	*6.33*	*5.20*	*4.70*	*4.20*	*4.00*	*#DIV/0!*	*#DIV/0!*	*5.12*
	RSQ	0.02	0.43	0.53	0.75	0.21	0.23	0.96	0.96	0.10	0.53	0.56	#DIV/0!	#DIV/0!	#DIV/0!	*0.64*
	Slope	-0.10	-1.50	-0.50	-0.45	-0.35	-0.35	-0.75	1.50	0.25	-0.35	-0.70	0.00	#DIV/0!	#DIV/0!	*-0.30*
Composite	Average	6.56	6.40	6.53	5.57	5.61	7.00	7.17	7.23	6.19	6.23	5.15	6.02	7.65	5.83	*6.36*
	RSQ	0.01	0.71	0.53	0.13	0.32	0.53	0.53	0.19	0.30	0.48	0.41	0.29	0.11	0.86	*0.55*
	Slope	-0.02	-0.69	-0.22	-0.13	-0.18	-0.22	-0.16	-0.10	-0.14	-0.16	-0.15	-0.12	-0.11	-0.27	*-0.14*

Table C9. Minimum of Bank Vegetation

Time Period	Sample Year	LSLS101	LSLS102	LSLS103B	LSLS103C	LSLS104	LSLS109	LSLS110	LSLS202	LSLS203	LSLS204	LSLS205	LSLS206	LSLS303	LSLS413	Average
Pre-development	1994			9						8	6	7	7	8		*7.50*
	1995	7		8					8.5	6.5	6.5	6	5	7.5		*6.88*
	1996	7		7					7	6	5	5	5	9		*6.38*
	1997	5		6	8					5	8	3				*5.83*
	1998			8	3	7	9	7		8	8	7	6	8	6	*7.00*
	1999	8		8	8	9	9	9		8	8	6	6			*7.90*
	2000	3		8	5	5	8	8		7				8		*6.50*
Construction	2001								8	8					6	*7.33*
	2002	7		7	4	5						5	5	4		*5.29*
	2003	8		5	4	4	8	8		5	7	5	6	8		*6.18*
	2004	7		6	7	5	5		8	5	5	5	8	7		*6.18*
	2005	8	9	8	8	6	7	8	8	8	8	6	7	9		*7.69*
	2006	8	8	8	6	5	7	6	7.7	5.5	6	5	6	7	4	*6.37*
	2007	6		7	7	6	6		5	4		3				*5.50*
Stabilization	2008	5		5	5	6	6		5	3	5	5				*5.00*
	2009	6		4	5	3	8		6	5	5	4				*5.11*
	2010	4	7	4	4	5	5	7	8	7	4	4				*5.36*
	2011	7	3	5	3	4	5	6		5	5	5	4			*4.73*
	2012	5	4	2	3	4	6	5		5	3	2	4			*3.91*

Pre-development	Average	6.00	#DIV/0!	7.71	6.00	7.00	8.67	8.00	7.75	6.93	6.92	5.67	5.80	8.10	6.00	*6.85*
	RSQ	0.23	#DIV/0!	0.03	0.04	0.25	0.75	0.25	1.00	0.02	0.53	0.02	0.01	0.00	#DIV/0!	*0.00*
	Slope	-0.47	#DIV/0!	-0.07	-0.40	-1.00	-0.50	0.50	-1.50	0.07	0.50	-0.11	-0.03	0.01	#DIV/0!	*-0.01*
Construction	*Average*	*7.33*	*8.50*	*6.83*	*6.00*	*5.17*	*6.60*	*7.33*	*7.34*	*5.92*	*6.50*	*4.83*	*6.40*	*7.00*	*5.00*	*6.36*
	RSQ	0.07	1.00	0.25	0.49	0.41	0.08	0.57	0.40	0.29	0.00	0.24	0.17	0.35	1.00	*0.03*
	Slope	-0.11	-1.00	0.31	0.63	0.26	-0.20	-0.57	-0.36	-0.42	0.00	-0.26	0.30	0.70	-0.40	*-0.06*
Stabilization	*Average*	*5.40*	*4.67*	*4.00*	*4.00*	*4.40*	*6.00*	*6.00*	*6.33*	*5.00*	*4.40*	*4.00*	*4.00*	*#DIV/0!*	*#DIV/0!*	*4.82*
	RSQ	0.02	0.52	0.42	0.90	0.17	0.15	1.00	0.96	0.20	0.50	0.42	#DIV/0!	#DIV/0!	#DIV/0!	*0.53*
	Slope	0.10	-1.50	-0.50	-0.60	-0.30	-0.30	-1.00	1.50	0.40	-0.40	-0.50	0.00	#DIV/0!	#DIV/0!	*-0.26*
Composite	Average	6.31	6.20	6.39	5.33	5.29	6.85	7.11	7.12	6.06	5.97	4.88	5.75	7.55	5.33	*6.14*
	RSQ	0.03	0.80	0.55	0.15	0.37	0.56	0.55	0.19	0.26	0.37	0.33	0.11	0.06	0.86	*0.51*
	Slope	-0.05	-0.74	-0.24	-0.15	-0.20	-0.24	-0.18	-0.11	-0.14	-0.16	-0.13	-0.07	-0.08	-0.27	*-0.14*

KEY:
1. **Bold Green** numbers indicate an R-square value in excess of 0.4. This would be considered a moderate to strong trend.

Attachment C
Montgomery County Habitat Assessment
Data Summary

Table C10. Average of Bank Stability

Time Period	Sample Year	LSLS101	LSLS102	LSLS103B	LSLS103C	LSLS104	LSLS109	LSLS110	LSLS202	LSLS203	LSLS204	LSLS205	LSLS206	LSLS303	LSLS413	Average
Pre-development	1994			6.5						8.5	7	7	8	6.5		*7.25*
	1995	6.5		7.25					9	8.5	6.75	6	5.75	6.5		*7.03*
	1996	5		6					9	7	5	6	5	8		*6.38*
	1997	5.5		6	6					6	6	5				*5.75*
	1998			6	3	7.5	6	6		8	7	4	5	7	5.5	*5.91*
	1999	5.5		8	6	6	8	8		9	6	5.5	6.5			*6.85*
	2000	3		8	5	6	7	7.5		7				7		*6.31*
Construction	2001								9	4.5					6	*6.50*
	2002	4.5		6	4.5	5						5	5	3.5		*4.79*
	2003	6		6	4	4	7	7		5	7	4	5	7		*5.64*
	2004	7		6	7	5.25	5		7	4	4	4	7	5		*5.57*
	2005	7	9	7	5	5.5	6	7	8	7	7	7	6	7		*6.81*
	2006	6	8	8	4	5	5	6	8.8	5.5	7	4	7.5	5.5	5.5	*6.13*
	2007	5.5		7	4	6	7		8	5.5		3.5				*5.81*
Stabilization	2008	6.5		4.5	5	6	7		7	4	7	5				*5.78*
	2009	4.5		5.5	5	3	3.5		6	6	3.5	3.5				*4.50*
	2010	5.5	8	6	4	5.5	5	7	8.5	6.5	5	3.5				*5.86*
	2011	5.5	3.5	6	3.5	4	6	8		7	8	3	5			*5.41*
	2012	6	4.5	3.5	3.5	4	4	4.5		5.5	3.5	3	3			*4.09*

Pre-development	Average	5.10	#DIV/0!	6.82	5.00	6.50	7.00	7.17	9.00	7.71	6.29	5.58	6.05	7.00	5.50	*6.50*
	RSQ	0.58	#DIV/0!	0.25	0.00	0.75	0.25	0.52	#DIV/0!	0.03	0.05	0.58	0.17	0.06	#DIV/0!	*0.25*
	Slope	-0.48	#DIV/0!	0.21	0.00	-0.75	0.50	0.75	0.00	-0.09	-0.09	-0.41	-0.25	0.06	#DIV/0!	*-0.13*
Construction	*Average*	*6.00*	*8.50*	*6.67*	*4.75*	*5.13*	*6.00*	*6.67*	*8.16*	*5.25*	*6.25*	*4.58*	*6.10*	*5.60*	*5.75*	*5.89*
	RSQ	0.08	1.00	0.62	0.04	0.44	0.00	0.57	0.07	0.24	0.07	0.04	0.69	0.18	1.00	*0.04*
	Slope	0.14	-1.00	0.34	-0.13	0.24	0.00	-0.29	-0.09	0.24	0.30	-0.13	0.60	0.40	-0.10	*0.06*
Stabilization	*Average*	*5.60*	*5.33*	*5.10*	*4.20*	*4.50*	*5.10*	*6.50*	*7.17*	*5.80*	*5.40*	*3.60*	*4.00*	*#DIV/0!*	*#DIV/0!*	*5.13*
	RSQ	0.00	0.55	0.05	0.88	0.15	0.15	0.48	0.36	0.30	0.04	0.75	1.00	#DIV/0!	#DIV/0!	*0.24*
	Slope	0.00	-1.75	-0.15	-0.45	-0.30	-0.35	-1.25	0.75	0.40	-0.25	-0.45	-2.00	#DIV/0!	#DIV/0!	*-0.25*
Composite	Average	5.59	6.60	6.29	4.63	5.20	5.88	6.78	8.03	6.36	5.98	4.65	5.73	6.30	5.67	*5.91*
	RSQ	0.02	0.67	0.19	0.14	0.37	0.34	0.09	0.36	0.27	0.07	0.52	0.18	0.16	0.02	*0.44*
	Slope	0.03	-0.64	-0.09	-0.08	-0.16	-0.17	-0.06	-0.12	-0.14	-0.06	-0.16	-0.10	-0.12	-0.01	*-0.10*

Table C11. Minimum of Bank Stability

Time Period	Sample Year	LSLS101	LSLS102	LSLS103B	LSLS103C	LSLS104	LSLS109	LSLS110	LSLS202	LSLS203	LSLS204	LSLS205	LSLS206	LSLS303	LSLS413	Average
Pre-development	1994			6						8	6	7	8	6		*6.83*
	1995	6.5		7					9	8.5	6.5	6	5.5	6		*6.88*
	1996	5		6					9	6	5	6	4	8		*6.13*
	1997	5		6	6					6	6	4				*5.50*
	1998			6	3	7	6	6		8	7	4	5	7	5	*5.82*
	1999	5		8	6	6	8	8		9	6	5	6			*6.70*
	2000	3		8	5	5	7	7		7				7		*6.13*
Construction	2001								9	4					5	*6.00*
	2002	4		6	3	5						5	5	3		*4.43*
	2003	6		6	4	4	7	7		5	7	4	5	7		*5.64*
	2004	7		6	7	5	5		7	4	4	4	7	5		*5.55*
	2005	7	9	7	5	5	5	7	8	7	7	7	6	7		*6.69*
	2006	6	8	8	4	5	4	6	8.7	5.5	6	4	7	5	5	*5.87*
	2007	5		6	4	5	6		8	4		3				*5.13*
Stabilization	2008	6		4	5	5	6		7	4	6	5				*5.33*
	2009	4		4	4	2	2		5	5	3	3				*3.56*
	2010	4	8	5	4	4	5	7	8	6	4	3				*5.27*
	2011	5	3	6	3	4	5	8		6	8	2	4			*4.91*
	2012	5	4	3	3	3	3	4		5	3	3	3			*3.55*

Pre-development	Average	4.90	#DIV/0!	6.71	5.00	6.00	7.00	7.00	9.00	7.50	6.08	5.33	5.70	6.80	5.00	*6.28*
	RSQ	0.73	#DIV/0!	0.42	0.00	1.00	0.25	0.25	#DIV/0!	0.00	0.04	0.63	0.16	0.20	#DIV/0!	*0.16*
	Slope	-0.51	#DIV/0!	0.29	0.00	-1.00	0.50	0.50	0.00	0.00	0.07	-0.51	-0.28	0.16	#DIV/0!	*-0.10*
Construction	*Average*	*5.83*	*8.50*	*6.50*	*4.50*	*4.83*	*5.40*	*6.67*	*8.14*	*4.92*	*6.00*	*4.50*	*6.00*	*5.40*	*5.00*	*5.61*
	RSQ	0.05	1.00	0.20	0.01	0.15	0.17	0.57	0.08	0.06	0.00	0.07	0.63	0.14	#DIV/0!	*0.02*
	Slope	0.14	-1.00	0.20	0.09	0.09	-0.30	-0.29	-0.10	0.14	0.00	-0.20	0.50	0.40	0.00	*0.05*
Stabilization	*Average*	*4.80*	*5.00*	*4.40*	*3.80*	*3.60*	*4.20*	*6.33*	*6.67*	*5.20*	*4.80*	*3.20*	*3.50*	*#DIV/0!*	*#DIV/0!*	*4.52*
	RSQ	0.04	0.57	0.00	0.89	0.08	0.08	0.52	0.11	0.32	0.01	0.52	1.00	#DIV/0!	#DIV/0!	*0.15*
	Slope	-0.10	-2.00	0.00	-0.50	-0.20	-0.30	-1.50	0.50	0.30	-0.10	-0.50	-1.00	#DIV/0!	#DIV/0!	*-0.22*
Composite	Average	5.22	6.40	6.00	4.40	4.64	5.31	6.67	7.87	6.00	5.63	4.41	5.46	6.10	5.00	*5.57*
	RSQ	0.01	0.67	0.27	0.17	0.57	0.48	0.09	0.40	0.35	0.11	0.48	0.17	0.10	#DIV/0!	*0.50*
	Slope	-0.02	-0.71	-0.12	-0.11	-0.20	-0.25	-0.07	-0.15	-0.16	-0.08	-0.17	-0.10	-0.11	0.00	*-0.12*

Table C12. Minimum of Buffer

Time Period	Sample Year	LSLS101	LSLS102	LSLS103B	LSLS103C	LSLS104	LSLS109	LSLS110	LSLS202	LSLS203	LSLS204	LSLS205	LSLS206	LSLS303	LSLS413	Average
Pre-development	1994			10						9	8	8	2	9		*7.67*
	1995	9		9.5					9.5	3	7	4.5	2	8		*6.56*
	1996	7		10					8	8	6	6	3	9		*7.13*
	1997	9		10	9					7	7	4				*7.67*
	1998			8	9	10	6	8		6	9	6	3	5	7	*7.00*
	1999	10		10	10	10	7	9		8	9	5	1			*7.90*
	2000	9		8	8	10	6	8		5				6		*7.50*
Construction	2001								9	5					6	*6.67*
	2002	8		8	7	10						3	3	9		*6.86*
	2003	10		8	5	8	7	8		6	7	8	1	10		*7.09*
	2004	10		9	8	7	4		9	5	9	5	2	9		*7.00*
	2005	10	10	8	8	8	4	8	9	5	9	9	2	5		*7.31*
	2006	10	10	8	7	7	4	9	7.7	5.5	8	6	4	5	6	*6.94*
	2007	4		5	8	6	4		9	3		8				*5.88*
Stabilization	2008	5		9	6	5	5		8	5	7	9				*6.56*
	2009	5		6	7	8	5		8	6	7	7				*6.56*
	2010	8	10	6	8	6	3	8	10	7	7	7				*7.27*
	2011	8	9	5	6	6	3	9		7	8	6	2			*6.27*
	2012	8	9	7	6	6	5	8		8	9	9	3			*7.09*

Pre-development	Average	8.80	#DIV/0!	9.36	9.00	10.00	6.33	8.33	8.75	6.57	7.67	5.58	2.20	7.40	7.00	*7.35*
	RSQ	0.23	#DIV/0!	0.33	0.10	#DIV/0!	0.00	0.00	1.00	0.02	0.28	0.22	0.04	0.66	#DIV/0!	*0.11*
	Slope	0.26	#DIV/0!	-0.25	-0.20	0.00	0.00	0.00	-1.50	-0.14	0.34	-0.36	-0.08	-0.61	#DIV/0!	*0.07*
Construction	*Average*	*8.67*	*10.00*	*7.67*	*7.17*	*7.67*	*4.60*	*8.33*	*8.74*	*4.92*	*8.25*	*6.50*	*2.40*	*7.60*	*6.00*	*6.82*
	RSQ	0.19	#DIV/0!	0.39	0.25	0.74	0.50	0.57	0.12	0.28	0.16	0.30	0.17	0.73	#DIV/0!	*0.11*
	Slope	-0.57	0.00	-0.46	0.31	-0.63	-0.60	0.29	-0.09	-0.25	0.30	0.66	0.30	-1.30	0.00	*-0.07*
Stabilization	*Average*	*6.80*	*9.33*	*6.60*	*6.60*	*6.20*	*4.20*	*8.33*	*8.67*	*6.60*	*7.60*	*7.60*	*2.50*	*#DIV/0!*	*#DIV/0!*	*6.75*
	RSQ	0.75	0.75	0.27	0.03	0.00	0.08	0.00	0.75	0.94	0.78	0.01	1.00	#DIV/0!	#DIV/0!	*0.09*
	Slope	0.90	-0.50	-0.50	-0.10	0.00	-0.20	0.00	1.00	0.70	0.50	-0.10	1.00	#DIV/0!	#DIV/0!	*0.08*
Composite	Average	8.13	9.60	8.03	7.47	7.64	4.85	8.33	8.72	6.03	7.80	6.50	2.33	7.50	6.33	*7.00*
	RSQ	0.13	0.63	0.62	0.39	0.74	0.48	0.00	0.00	0.01	0.02	0.21	0.03	0.09	0.62	*0.21*
	Slope	-0.13	-0.14	-0.23	-0.17	-0.34	-0.20	0.01	-0.01	-0.03	0.02	0.14	0.03	-0.14	-0.11	*-0.04*

KEY:
1. **Bold Green** numbers indicate an R-square value in excess of 0.4. This would be considered a moderate to strong trend.

Table C13. Average of Buffer

Time Period	Sample Year	LSLS101	LSLS102	LSLS103B	LSLS103C	LSLS104	LSLS109	LSLS110	LSLS202	LSLS203	LSLS204	LSLS205	LSLS206	LSLS303	LSLS413	Average
Pre-development	1994			10						9	9	8.5	3.5	9		*8.17*
	1995	9		9.75					9.5	3.25	8	4.5	2.5	8.75		*6.91*
	1996	8		10					8.5	8.5	7	6.5	4	9		*7.69*
	1997	9.5		10	9.5					7	8	5.5				*8.25*
	1998			8.5	9	10	8	9		6	9.5	7	3.5	7.5	7.5	*7.77*
	1999	10		10	10	10	8.5	9.5		8.5	9.5	5.5	2.5			*8.40*
	2000	9		9	8.5	10	8	9		5				8		*8.31*
Construction	2001								9.5	5.5					7.5	*7.50*
	2002	8.5		9	8	10						5	3	9		*7.50*
	2003	10		8	6.5	8	8.5	9		6	8	8	3	10		*7.73*
	2004	10		9	8.5	8	6.5		9	7.5	9.5	6	4.5	9		*7.95*
	2005	10	10	9	8.5	8.5	6	8	9	7	9.5	9	5	7		*8.19*
	2006	10	10	9	8	7.5	6	9.5	8	7	9	7	6	7	7.5	*7.96*
	2007	5.5		5.5	8.5	7	6.5		9	4.5		8				*6.81*
Stabilization	2008	5.5		9	7.5	6.5	7		8.5	5	8	9				*7.33*
	2009	7		7	8	8	7		8.5	7	8	7				*7.50*
	2010	8.5	10	7	8	6.5	5.5	9	10	8	8	7.5				*8.00*
	2011	8.5	9	6	7.5	6	6	9.5		7.5	8.5	6.5	4.5			*7.23*
	2012	8.5	9	7.5	7	7	6.5	8.5		8	9	9	6			*7.82*

Pre-development	Average	9.10	#DIV/0!	9.61	9.25	10.00	8.17	9.17	9.00	6.75	8.50	6.25	3.20	8.45	7.50	*7.93*
	RSQ	0.21	#DIV/0!	0.26	0.16	#DIV/0!	0.00	0.00	**1.00**	0.02	0.18	0.10	0.06	**0.62**	#DIV/0!	*0.27*
	Slope	0.16	#DIV/0!	-0.14	-0.20	0.00	0.00	0.00	-1.00	-0.14	0.23	-0.24	-0.08	-0.22	#DIV/0!	*0.13*
Construction	*Average*	*9.00*	*10.00*	*8.25*	*8.00*	*8.17*	*6.70*	*8.83*	*8.90*	*6.25*	*9.00*	*7.17*	*4.30*	*8.40*	*7.50*	*7.66*
	RSQ	0.19	#DIV/0!	0.30	0.23	**0.69**	**0.47**	0.02	**0.40**	0.00	0.30	0.30	**0.94**	**0.68**	#DIV/0!	*0.01*
	Slope	-0.43	0.00	-0.41	0.20	-0.46	-0.45	0.07	-0.15	-0.02	0.30	0.43	0.80	-0.70	0.00	*-0.02*
Stabilization	*Average*	*7.60*	*9.33*	*7.30*	*7.60*	*6.80*	*6.40*	*9.00*	*9.00*	*7.10*	*8.30*	*7.80*	*5.25*	*#DIV/0!*	*#DIV/0!*	*7.58*
	RSQ	**0.78**	**0.75**	0.33	0.32	0.04	0.24	0.25	**0.75**	**0.68**	**0.78**	0.00	**1.00**	#DIV/0!	#DIV/0!	*0.11*
	Slope	0.75	-0.50	-0.40	-0.15	-0.10	-0.20	-0.25	0.75	0.65	0.25	-0.05	1.50	#DIV/0!	#DIV/0!	*0.07*
Composite	Average	8.59	9.60	8.51	8.20	8.07	6.92	9.00	8.95	6.68	8.57	7.03	4.00	8.43	7.50	*7.74*
	RSQ	0.12	**0.63**	**0.60**	**0.44**	**0.81**	**0.56**	0.02	0.01	0.00	0.00	0.21	**0.50**	0.11	#DIV/0!	*0.05*
	Slope	-0.10	-0.14	-0.19	-0.12	-0.29	-0.17	-0.01	-0.01	0.02	0.01	0.11	0.15	-0.08	0.00	*-0.02*

Table C14. Composite Habitat Score

Time Period	Sample Year	LSLS101	LSLS102	LSLS103B	LSLS103C	LSLS104	LSLS109	LSLS110	LSLS202	LSLS203	LSLS204	LSLS205	LSLS206	LSLS303	LSLS413	Average
Pre-development	1994			151						156	145	150	140	141		*147.17*
	1995	135		144.5					166.5	134.5	136.5	111	109.5	135.5		*134.13*
	1996	143		152					163	140	146	143	122	151		*145.00*
	1997	151		159	148					144	152	124				*146.33*
	1998			156	128	152	161	132		161	152	131	121	142	123	*141.73*
	1999	150		167	159	160	159	157		141	149	131	119			*149.20*
	2000	134		165	129	155	161	147		151				145		*148.38*
Construction	2001								170	140					133	*147.67*
	2002	150		149	120	139						127	106	131		*131.71*
	2003	164		123	103	128	164	153		139	143	122	111	134		*134.91*
	2004	151		127	138	136	131		141	134	136	132	143	139		*137.09*
	2005	162	170	133	149	138	137	125	162	160	159	135	127	158		*147.31*
	2006	151	153	157	133	130	132	140	159.2	137.5	132	132	143	139	118	*139.76*
	2007	130		120	141	129	144		139	121		127				*131.38*
Stabilization	2008	126		119	132	130	139		131	104	137	128				*127.33*
	2009	128		110	115	113	131		133	128	123	112				*121.44*
	2010	141	155	114	122	119	123	146	141	130	126	112				*129.91*
	2011	138	131	119	117	117	127	138		148	137	125	112			*128.09*
	2012	120	132	112	110	114	117	122		131	123	119	126			*120.55*

Pre-development	Average	142.60	#DIV/0!	156.36	141.00	155.67	160.33	145.33	164.75	146.79	146.75	131.67	122.30	142.90	123.00	*144.56*
	RSQ	0.00	#DIV/0!	**0.77**	0.05	0.14	0.00	0.36	**1.00**	0.02	**0.44**	0.04	0.15	0.11	#DIV/0!	*0.20*
	Slope	0.22	#DIV/0!	3.25	-2.60	1.50	0.00	7.50	-3.50	0.68	2.07	-1.54	-2.04	0.77	#DIV/0!	*1.09*
Construction	*Average*	*151.33*	*161.50*	*134.83*	*130.67*	*133.33*	*141.60*	*139.33*	*154.24*	*138.58*	*142.50*	*129.17*	*126.00*	*140.20*	*125.50*	*138.55*
	RSQ	0.32	**1.00**	0.02	**0.44**	0.21	0.21	0.39	0.36	0.08	0.01	0.14	**0.67**	0.36	**1.00**	*0.05*
	Slope	-3.66	-17.00	-1.06	5.89	-1.20	-3.90	-5.71	-3.55	-1.64	-1.00	0.94	9.00	4.00	-3.00	*-0.73*
Stabilization	*Average*	*130.60*	*139.33*	*114.80*	*119.20*	*118.60*	*127.40*	*135.33*	*135.00*	*128.20*	*129.20*	*119.20*	*119.00*	*#DIV/0!*	*#DIV/0!*	*125.46*
	RSQ	0.00	**0.72**	0.04	**0.63**	**0.42**	**0.84**	**0.96**	**0.89**	**0.55**	0.09	0.01	**1.00**	#DIV/0!	#DIV/0!	*0.07*
	Slope	-0.20	-11.50	-0.50	-4.20	-2.80	-4.80	-12.00	5.00	7.40	-1.40	-0.50	14.00	#DIV/0!	#DIV/0!	*-0.69*
Composite	Average	142.13	148.20	137.64	129.60	132.86	140.46	140.00	150.57	138.89	139.77	127.12	123.29	141.55	124.67	*137.32*
	RSQ	0.14	**0.74**	**0.63**	0.23	**0.87**	**0.77**	0.18	**0.58**	0.23	**0.41**	0.21	0.00	0.00	0.21	**0.55**
	Slope	-0.89	-4.58	-2.73	-1.56	-3.10	-3.07	-0.96	-2.17	-1.15	-1.13	-0.81	0.09	0.05	-0.87	*-1.24*

KEY:
1. **Bold Green** numbers indicate an R-square value in excess of 0.4. This would be considered a moderate to strong trend.

Attachment D

Montgomery County BIBI and Habitat

Correlation Analysis

Table D1. Overall (1994-2012) Correlation Table

	Bank Stability	Bank Stability (min)	Bank Vegetation	Bank Vegetation (min)	Buffer	Buffer (min)	Channel Alteration	Channel Flow	Composite Habitat Score	Embeddedness	Epibenthic Substrate	Instream Cover	Riffle Frequency	Sediment Deposit	xBIBI Score	xBiotic Index	xNumber EPT Taxa	xProportion of Dominant Taxa	xProportion of EPT Individuals	xProportion of Hydropsyche & Cheumatopsyche	xProportion of Shredders	xRatio of Scrapers	xTaxa Richness
Bank Stability	1.00																						
Bank Stability (min)	0.97	1.00																					
Bank Vegetation	0.88	0.88	1.00																				
Bank Vegetation (min)	0.86	0.88	0.99	1.00																			
Buffer	0.22	0.29	0.37	0.39	1.00																		
Buffer (min)	0.34	0.41	0.46	0.47	0.93	1.00																	
Channel Alteration	0.00	0.03	0.04	0.06	0.18	0.13	1.00																
Channel Flow	0.79	0.80	0.79	0.79	0.35	0.38	0.27	1.00															
Composite Habitat Score	0.78	0.82	0.86	0.86	0.57	0.61	0.39	0.89	1.00														
Embeddedness	0.44	0.53	0.64	0.67	0.62	0.60	0.39	0.68	0.87	1.00													
Epibenthic Substrate	0.42	0.31	0.26	0.23	-0.16	-0.17	0.44	0.56	0.35	0.06	1.00												
Instream Cover	0.16	0.27	0.40	0.43	0.36	0.30	0.37	0.31	0.54	0.63	-0.17	1.00											
Riffle Frequency	0.15	0.18	0.03	0.03	0.50	0.57	0.54	0.23	0.41	0.40	0.21	0.05	1.00										
Sediment Deposit	0.47	0.58	0.63	0.67	0.62	0.64	0.16	0.58	0.80	0.89	-0.21	0.64	0.31	1.00									
BIBI Score	0.50	0.53	0.63	0.64	0.34	0.45	-0.04	0.34	0.51	0.38	-0.12	0.43	0.03	0.50	1.00								
Biotic Index	-0.55	-0.61	-0.62	-0.63	-0.39	-0.60	-0.21	-0.35	-0.58	-0.41	0.03	-0.32	-0.32	-0.55	-0.68	1.00							
Number EPT Taxa	0.24	0.16	0.05	-0.01	-0.06	0.14	0.12	0.00	0.03	-0.23	0.31	-0.23	0.41	-0.21	0.10	-0.40	1.00						
Proportion of Dominant Taxa	-0.39	-0.36	-0.32	-0.29	-0.22	-0.43	-0.08	-0.15	-0.31	-0.14	-0.06	0.02	-0.45	-0.24	-0.14	0.67	-0.71	1.00					
Proportion of EPT Individuals	0.58	0.59	0.64	0.63	0.40	0.61	0.04	0.39	0.56	0.37	-0.01	0.24	0.28	0.51	0.83	-0.91	0.49	-0.62	1.00				
Proportion of Hydropsyche & Cheumatopsyche	0.31	0.19	0.23	0.16	0.00	0.04	-0.50	0.10	0.03	-0.10	0.01	-0.30	-0.05	-0.04	0.15	0.07	0.41	-0.24	0.22	1.00			
Proportion of Shredders	0.22	0.31	0.32	0.35	0.37	0.42	0.48	0.24	0.44	0.32	0.10	0.56	0.26	0.37	0.63	-0.62	0.03	-0.03	0.52	-0.54	1.00		
Ratio of Scrapers	-0.03	0.09	0.19	0.26	0.07	0.04	0.03	0.00	0.14	0.32	-0.38	0.42	-0.24	0.38	0.35	-0.24	-0.62	0.15	0.11	-0.56	0.33	1.00	
Taxa Richness	0.26	0.19	0.01	-0.05	-0.05	0.09	0.23	0.02	0.06	-0.22	0.35	-0.10	0.42	-0.23	0.06	-0.24	0.86	-0.50	0.29	0.31	0.13	-0.63	1.00

KEY:

1. **Bold Green** numbers indicate an R value in excess of 0.4. This would be considered a moderate to strong trend.

Attachment D

Montgomery County BIBI and Habitat

Correlation Analysis

Table D2. Pre-development Period Correlation Table

	Bank Stability	Bank Stability (min)	Bank Vegetation	Bank Vegetation (min)	Buffer	Buffer (min)	Channel Alteration	Channel Flow	Composite Habitat Score	Embeddedness	Epibenthic Substrate	Instream Cover	Riffle Frequency	Sediment Deposit	xBIBI Score	xBiotic Index	xNumber EPT Taxa	xProportion of Dominant Taxa	xProportion of EPT Individuals	xProportion of Hydropsyche & Cheumatopsyche	xProportion of Shredders	xRatio of Scrapers	xTaxa Richness
Bank Stability	1.00																						
Bank Stability (min)	0.98	1.00																					
Bank Vegetation	0.78	0.80	1.00																				
Bank Vegetation (min)	0.70	0.75	0.98	1.00																			
Buffer	-0.22	-0.29	0.10	0.12	1.00																		
Buffer (min)	-0.01	-0.09	0.24	0.23	0.95	1.00																	
Channel Alteration	-0.91	-0.88	-0.85	-0.79	0.18	0.02	1.00																
Channel Flow	0.14	0.01	0.33	0.24	0.83	0.89	-0.22	1.00															
Composite Habitat Score	-0.13	-0.21	0.14	0.12	0.96	0.93	0.14	0.87	1.00														
Embeddedness	-0.29	-0.35	-0.01	-0.01	0.94	0.82	0.28	0.74	0.96	1.00													
Epibenthic Substrate	-0.35	-0.39	-0.32	-0.38	0.30	0.41	0.54	0.27	0.34	0.22	1.00												
Instream Cover	-0.88	-0.84	-0.54	-0.46	0.29	0.06	0.81	-0.08	0.30	0.46	0.27	1.00											
Riffle Frequency	-0.42	-0.53	-0.56	-0.64	0.51	0.53	0.58	0.47	0.54	0.50	0.78	0.26	1.00										
Sediment Deposit	-0.17	-0.24	0.00	0.02	0.82	0.67	0.09	0.64	0.79	0.88	-0.19	0.27	0.29	1.00									
xBIBI Score	0.15	0.23	0.59	0.70	0.08	-0.04	-0.42	-0.03	0.01	0.07	-0.68	0.09	-0.80	0.22	1.00								
xBiotic Index	-0.14	-0.26	-0.36	-0.50	0.26	0.24	0.30	0.40	0.46	0.47	0.43	0.25	0.71	0.30	-0.60	1.00							
xNumber EPT Taxa	0.11	0.03	-0.24	-0.33	-0.29	-0.10	-0.08	0.00	-0.35	-0.49	0.33	-0.53	0.35	-0.44	-0.65	-0.01	1.00						
xProportion of Dominant Taxa	-0.42	-0.32	0.03	0.17	0.13	-0.10	0.27	-0.22	0.12	0.30	-0.32	0.71	-0.43	0.25	0.71	-0.22	-0.88	1.00					
xProportion of EPT Individuals	0.44	0.44	0.73	0.77	0.11	0.17	-0.72	0.26	-0.02	-0.11	-0.50	-0.45	-0.60	0.08	0.71	-0.70	0.01	0.06	1.00				
xProportion of Hydropsyche & Cheumatopsyche	0.61	0.48	0.42	0.28	-0.05	0.08	-0.76	0.46	-0.01	-0.13	-0.32	-0.69	-0.09	0.08	0.00	0.11	0.45	-0.58	0.48	1.00			
xProportion of Shredders	-0.68	-0.55	-0.27	-0.10	0.13	-0.06	0.64	-0.37	0.05	0.19	0.11	0.79	-0.13	0.03	0.36	-0.30	-0.59	0.82	-0.16	-0.90	1.00		
xRatio of Scrapers	0.00	0.15	0.30	0.45	0.03	-0.11	0.02	-0.33	0.02	0.14	-0.40	0.32	-0.58	0.13	0.68	-0.39	-0.87	0.82	0.11	-0.60	0.68	1.00	
xTaxa Richness	-0.09	-0.14	-0.63	-0.73	-0.44	-0.35	0.30	-0.29	-0.40	-0.42	0.39	-0.21	0.51	-0.43	-0.91	0.41	0.74	-0.71	-0.63	0.10	-0.42	-0.68	1.00

KEY:

1. **Bold Green** numbers indicate an R value in excess of 0.4. This would be considered a moderate to strong trend.

Attachment D

Montgomery County BIBI and Habitat

Correlation Analysis

Table D3. Construction Period Correlation Table

	Bank Stability	Bank Stability (min)	Bank Vegetation	Bank Vegetation (min)	Buffer	Buffer (min)	Channel Alteration	Channel Flow	Composite Habitat Score	Embeddedness	Epibenthic Substrate	Instream Cover	Riffle Frequency	Sediment Deposit	xBIBI Score	xBiotic Index	xNumber EPT Taxa	xProportion of Dominant Taxa	xProportion of EPT Individuals	xProportion of Hydropsyche & Cheumatopsyche	xProportion of Shredders	xRatio of Scrapers	xTaxa Richness
Bank Stability	1.00																						
Bank Stability (min)	0.93	1.00																					
Bank Vegetation	0.93	0.92	1.00																				
Bank Vegetation (min)	0.90	0.93	0.99	1.00																			
Buffer	0.33	0.61	0.48	0.58	1.00																		
Buffer (min)	0.16	0.46	0.39	0.49	0.95	1.00																	
Channel Alteration	0.26	0.10	0.39	0.35	0.05	-0.03	1.00																
Channel Flow	0.80	0.71	0.77	0.75	0.09	-0.02	0.37	1.00															
Composite Habitat Score	0.86	0.86	0.97	0.98	0.55	0.44	0.55	0.76	1.00														
Embeddedness	0.33	0.46	0.63	0.68	0.70	0.73	0.52	0.18	0.72	1.00													
Epibenthic Substrate	0.63	0.36	0.52	0.44	-0.40	-0.54	0.50	0.78	0.50	-0.04	1.00												
Instream Cover	0.02	0.28	0.16	0.23	0.77	0.83	-0.28	-0.41	0.14	0.50	-0.73	1.00											
Riffle Frequency	0.11	0.18	0.39	0.41	0.59	0.61	0.70	-0.01	0.54	0.86	-0.15	0.46	1.00										
Sediment Deposit	-0.30	0.01	-0.04	0.06	0.71	0.88	-0.17	-0.44	0.02	0.56	-0.83	0.85	0.55	1.00									
xBIBI Score	0.28	0.43	0.39	0.42	0.56	0.68	-0.14	0.04	0.35	0.39	-0.40	0.74	0.40	0.63	1.00								
xBiotic Index	0.09	-0.07	-0.28	-0.34	-0.52	-0.68	-0.33	0.13	-0.37	-0.89	0.30	-0.50	-0.77	-0.72	-0.34	1.00							
xNumber EPT Taxa	0.25	0.10	0.37	0.30	-0.13	-0.10	0.36	-0.04	0.32	0.47	0.33	0.07	0.34	-0.10	-0.04	-0.42	1.00						
xProportion of Dominant Taxa	0.04	-0.05	-0.30	-0.33	-0.33	-0.51	-0.31	0.14	-0.35	-0.83	0.18	-0.43	-0.70	-0.58	-0.34	0.95	-0.64	1.00					
xProportion of EPT Individuals	-0.03	0.09	0.31	0.34	0.41	0.63	0.24	-0.10	0.35	0.78	-0.31	0.55	0.72	0.71	0.62	-0.90	0.43	-0.93	1.00				
xProportion of Hydropsyche & Cheumatopsyche	0.65	0.57	0.44	0.39	0.10	-0.07	-0.19	0.15	0.30	-0.08	0.24	0.25	-0.18	-0.28	0.25	0.39	0.34	0.24	-0.26	1.00			
xProportion of Shredders	0.26	0.45	0.47	0.53	0.64	0.77	0.09	0.32	0.51	0.54	-0.26	0.51	0.50	0.64	0.83	-0.50	-0.25	-0.39	0.66	-0.18	1.00		
xRatio of Scrapers	-0.45	-0.25	-0.15	-0.08	0.34	0.60	0.03	-0.26	-0.05	0.42	-0.60	0.42	0.50	0.80	0.51	-0.70	-0.19	-0.59	0.77	-0.68	0.71	1.00	
xTaxa Richness	0.78	0.68	0.68	0.62	0.15	-0.03	0.09	0.34	0.56	0.25	0.49	0.12	0.01	-0.32	0.04	0.09	0.63	-0.06	-0.09	0.86	-0.22	-0.68	1.00

KEY:

1. **Bold Green** numbers indicate an R value in excess of 0.4. This would be considered a moderate to strong trend.

Attachment D

Montgomery County BIBI and Habitat

Correlation Analysis

Table D4. Stabilization Period Correlation Table

	Bank Stability	Bank Stability (min)	Bank Vegetation	Bank Vegetation (min)	Buffer	Buffer (min)	Channel Alteration	Channel Flow	Composite Habitat Score	Embeddedness	Epibenthic Substrate	Instream Cover	Riffle Frequency	Sediment Deposit	xBIBI Score	xBiotic Index	xNumber EPT Taxa	xProportion of Dominant Taxa	xProportion of EPT Individuals	xProportion of Hydropsyche & Cheumatopsyche	xProportion of Shredders	xRatio of Scrapers	xTaxa Richness
Bank Stability	1.00																						
Bank Stability (min)	0.98	1.00																					
Bank Vegetation	0.65	0.50	1.00																				
Bank Vegetation (min)	0.71	0.56	0.99	1.00																			
Buffer	-0.14	-0.15	-0.04	-0.03	1.00																		
Buffer (min)	-0.08	-0.06	-0.08	-0.08	0.98	1.00																	
Channel Alteration	-0.09	0.09	-0.79	-0.75	-0.30	-0.20	1.00																
Channel Flow	0.83	0.89	0.28	0.30	-0.41	-0.27	0.33	1.00															
Composite Habitat Score	0.97	0.96	0.54	0.62	-0.07	-0.03	0.01	0.74	1.00														
Embeddedness	-0.52	-0.40	-0.89	-0.83	-0.07	-0.09	0.75	-0.32	-0.32	1.00													
Epibenthic Substrate	0.84	0.90	0.23	0.29	-0.50	-0.41	0.41	0.93	0.83	-0.10	1.00												
Instream Cover	0.06	-0.09	0.63	0.58	-0.56	-0.63	-0.61	-0.05	-0.09	-0.55	-0.06	1.00											
Riffle Frequency	0.17	0.27	-0.42	-0.30	0.33	0.33	0.54	0.07	0.40	0.63	0.29	-0.80	1.00										
Sediment Deposit	0.41	0.33	0.45	0.53	0.65	0.57	-0.47	-0.13	0.53	-0.22	-0.01	-0.22	0.48	1.00									
xBIBI Score	0.32	0.17	0.67	0.72	-0.30	-0.44	-0.56	-0.10	0.35	-0.29	0.13	0.68	-0.13	0.42	1.00								
xBiotic Index	-0.78	-0.72	-0.72	-0.76	-0.46	-0.47	0.47	-0.39	-0.77	0.64	-0.34	0.08	-0.19	-0.79	-0.27	1.00							
xNumber EPT Taxa	0.90	0.84	0.72	0.78	-0.45	-0.44	-0.17	0.71	0.86	-0.48	0.81	0.40	-0.01	0.27	0.62	-0.57	1.00						
xProportion of Dominant Taxa	-0.84	-0.75	-0.86	-0.90	-0.23	-0.23	0.55	-0.43	-0.81	0.72	-0.42	-0.17	-0.05	-0.73	-0.49	0.96	-0.74	1.00					
xProportion of EPT Individuals	0.79	0.67	0.89	0.93	0.24	0.21	-0.64	0.33	0.76	-0.72	0.34	0.24	0.01	0.76	0.57	-0.94	0.72	-0.99	1.00				
xProportion of Hydropsyche & Cheumatopsyche	-0.40	-0.52	0.14	0.15	-0.35	-0.52	-0.39	-0.60	-0.36	0.12	-0.39	0.67	-0.31	-0.04	0.72	0.41	0.00	0.20	-0.09	1.00			
xProportion of Shredders	0.68	0.63	0.61	0.66	0.60	0.60	-0.45	0.27	0.71	-0.53	0.23	-0.21	0.30	0.87	0.21	-0.98	0.44	-0.90	0.89	-0.41	1.00		
xRatio of Scrapers	0.19	0.13	0.26	0.30	-0.83	-0.91	0.00	0.15	0.21	0.07	0.39	0.65	-0.15	-0.20	0.75	0.25	0.58	-0.02	0.06	0.68	-0.35	1.00	
xTaxa Richness	0.80	0.75	0.63	0.65	-0.68	-0.65	-0.07	0.77	0.70	-0.47	0.82	0.52	-0.21	-0.05	0.52	-0.34	0.95	-0.54	0.51	0.02	0.18	0.66	1.00

KEY:

1. **Bold Green** numbers indicate an R value in excess of 0.4. This would be considered a moderate to strong trend.

Attachment D. Environmental Site Design Literature Review

MEMORANDUM

CENTER FOR WATERSHED PROTECTION
8390 Main Street, 2nd Floor
Ellicott City, MD 21043
410.461.8323
FAX 410.461.8324
www.cwp.org
www.stormwatercenter.ne

Date: April 3, 2013

To: Mary Dolan and Valdis Lazdins,
Montgomery County Planning Department

From: Center for Watershed Protection

RE: Ten Mile Creek Watershed Environmental Analysis in Support of the Clarksburg Master Plan Limited Amendment

SUBJ: Environmental Site Design Literature Review

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1. Introduction and Background

Stage 4 of the Clarksburg Master Plan is planned to occur in the headwaters of Ten Mile Creek, a very sensitive and high quality tributary of Little Seneca Creek located in Montgomery County, Maryland. Although the previous three stages of development were developed with relatively stringent stormwater criteria of the Special Protection Area, there was some degradation in the hydrology, stream morphology/habitat, water quality and biology in the tributaries of Little Seneca Creek that these projects impacted, particularly during the construction phase (MCDEP, 2012). In anticipation of Stage 4, it is critical to understand the potential for stream degradation in Ten Mile Creek, as well as the ability of current stormwater management technologies to mitigate these impacts.

The memo summarizes the hydrologic, water quality, habitat/geomorphic and biological impacts of development and the effectiveness of sediment and stormwater control practices in following four sections:

- *Post Construction Impacts* summarizes the impacts of stormwater runoff and the built environment on water resources. The impacts described in this section focus on development without stormwater controls in place.
- *Stormwater Management* identifies the benefits of stormwater management controls, with a focus on differences between traditional stormwater management and Environmental Site Design.
- *Construction Impacts* describes impacts occurring during the construction process, *and*
- *Erosion and Sediment Control (ESC)* reviews the effectiveness of ESC practices in mitigating these impacts.

2. Post Construction Impacts

The impacts of land use change on water resources have long been documented. While many different land cover parameters have been linked to stream degradation, impervious cover has been used as a measure in many studies due to its ease of measurement and its reliability as a predictor of the health of water resources. The model was originally presented by Schueler (1994), as a management tool and as a linear relationship between stream quality and watershed impervious cover. Over the years, this model has been tested and, while it has been supported by many studies, "Reformulated Impervious Cover Model" (Schueler et al., 2009; Figure 1) was proposed in 2009 based on newer studies. In this model, impervious cover represents a range of stream quality. This is particularly true at lower levels of impervious cover, where pervious land cover, location of land development, and other issues exert a stronger influence.

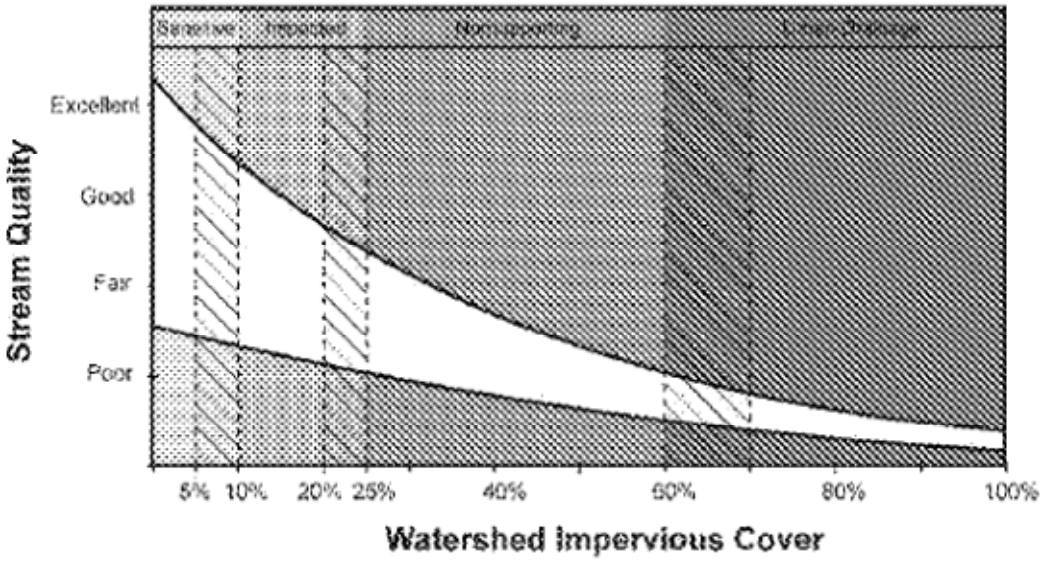


Figure 1. Reformulated Impervious Cover Model (Schueler et al., 2009)

In Montgomery County as a whole, data have been supportive of this model of stream health (Figure 2). While there is a wide range of variability at low levels of impervious cover, no "Excellent" streams are found above ~12% impervious cover, no "Good" streams are found above ~20% impervious cover, and no "Fair" streams are found above ~37% impervious cover. These data suggest that impervious cover is an important driver in Montgomery County, but also that stream health must be influenced by other factors, particularly at low levels of impervious cover.

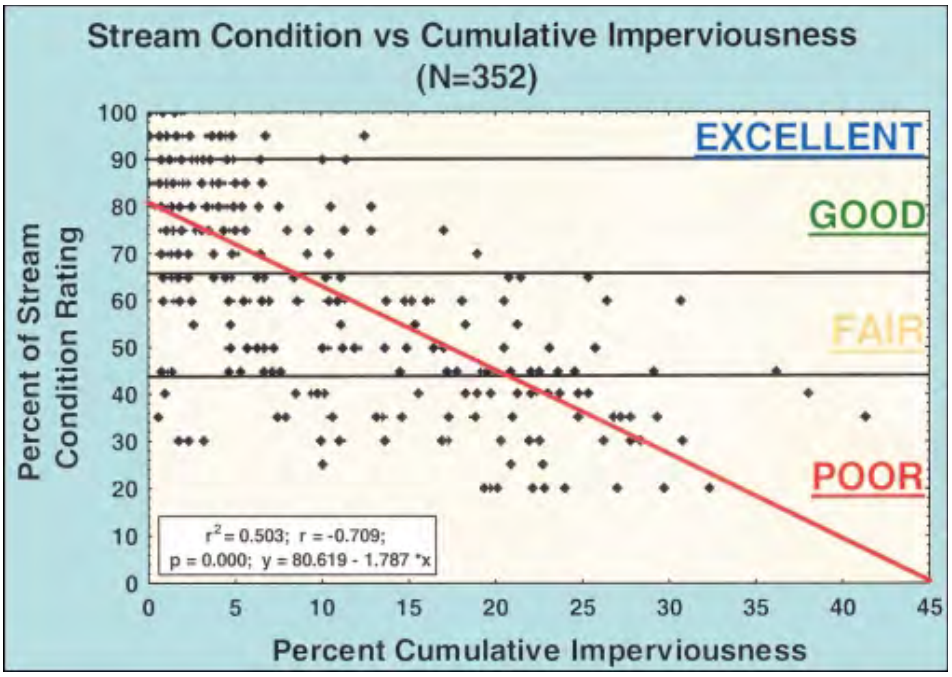


Figure 2. Relationship Between Stream Condition and Impervious Cover in Montgomery County Streams (MCDEP, 2003)

Hydrologic Impacts

While impervious cover is a useful tool, other measures of watershed development, some of which are strongly correlated with impervious cover, have also been evaluated as predictors of stream condition (Table 1). Some of these measures are highly specific, and may be important to our understanding of development in Ten Mile Creek. For example, GIS metrics such as the "clumpiness," (a representation of how contiguous each land use is) or "patchiness" (which indicates fragmented land use) of different classes of land cover can help understand the importance of the *location* of land disturbance. Forest cover may be important, particularly at low levels of development, where the presence of agricultural land may result in stream degradation. For example, an evaluation of Montgomery County streams (Goetz et al., 2003) demonstrated correlations between impervious cover, watershed tree cover, and riparian tree cover on stream health (Figure 3). Based on these results, the authors of this study suggested that guidelines for excellent stream health rating were no more than 6% impervious with at least 65% forested buffers, and no more than 10% impervious with at least 60% buffered for a rating of good.

Table 1. Measures of Land Development Other than Impervious Cover

Soil Disturbance or compaction
Effective Impervious Cover
Forest Cover
Developed Land or Urban Land
Population Density
Road Density
Number of stream crossings
Forest/Disturbed/Impervious cover in riparian buffer
“Patchiness” or “Clumpiness” of forest or urban land cover
Agricultural or cropland cover
Population Density
Land Cover Class
Land Use Category

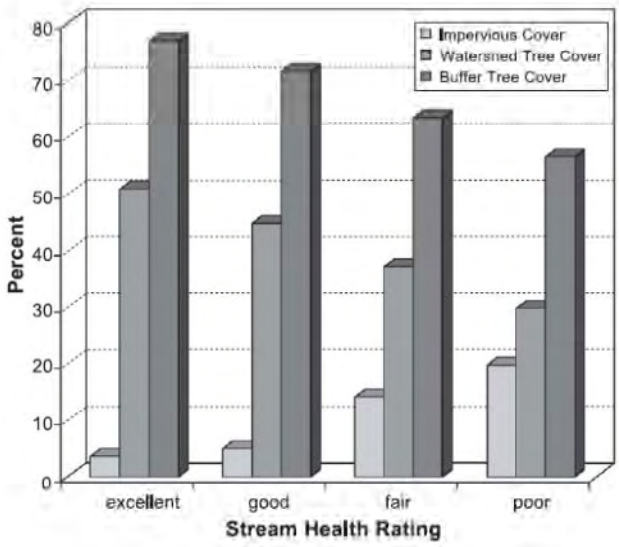


Figure 3. Relationship of Land Cover to Stream Health (Goetz et al., 2003)

While these data support the notion that land cover other than imperviousness is important, researchers have come to different conclusions regarding the relative importance of each component of land cover. One challenge of interpreting these data is that these land use measures are often correlated with one another. For example, further study in Montgomery County found a *negative* correlation between riparian buffer forest cover and watershed impervious cover, and a positive correlation between riparian forest cover and watershed-wide forest cover (Snyder et al., 2005). As a result, researchers have attempted to "tease out" the importance of each land cover in determining water quality. Of particular interest to the watershed manager is the influence of the riparian corridor in mitigating development impacts.

Riparian Corridor

Stream buffers are an integral part of watershed planning, and provide direct benefits to stream habitat. However, the benefit of stream buffers appears to be overwhelmed by watershed factors such as intense development. While some researchers finding benefits of riparian corridor at all levels of development (e.g., Moore and Palmer, 2005), others find that a forested buffer is most effective in combination with watershed-wide forest cover or limited impervious cover. This particularly true in the steep Piedmont region, where channelized flows can bypass the buffer. For example, Roy et al. (2007), in a study of Georgia streams, found that riparian buffers are most effective at improving fish diversity at impervious cover of 15% or less. Others, such as Snyder et al. (2005), found a relationship between riparian corridor composition (e.g., forested versus urban), but found that *watershed* variables such as impervious cover or forested cover in the entire drainage area are a more powerful predictor of stream health. Fitzpatrick (2005) found no relationship between riparian cover and habitat or hydrologic characteristics, citing possible channelization and point source discharges as a possible confounding factor. Other studies have reached similar conclusions, citing riparian corridor as a "co-predictor," along with urban land use of in-stream quality or a "necessary element" but not a guarantee of good quality (e.g., Urban et al., 2006, Booth, 2002, Kratzer et al., 2006, Ourso, 2003).

2.1 Hydrologic Impacts

Hydrologic impacts originate from a shift in the hydrologic cycle that occurs with land development (Figure 4). This shift typically results in a modified hydrograph including higher runoff volumes, "flashier" hydrology, and decreased baseflow. In addition quantifying these impacts, recent research has focused on understanding how these hydrologic impacts in turn cause degradation in stream habitat and morphology, as well as in-stream biology.

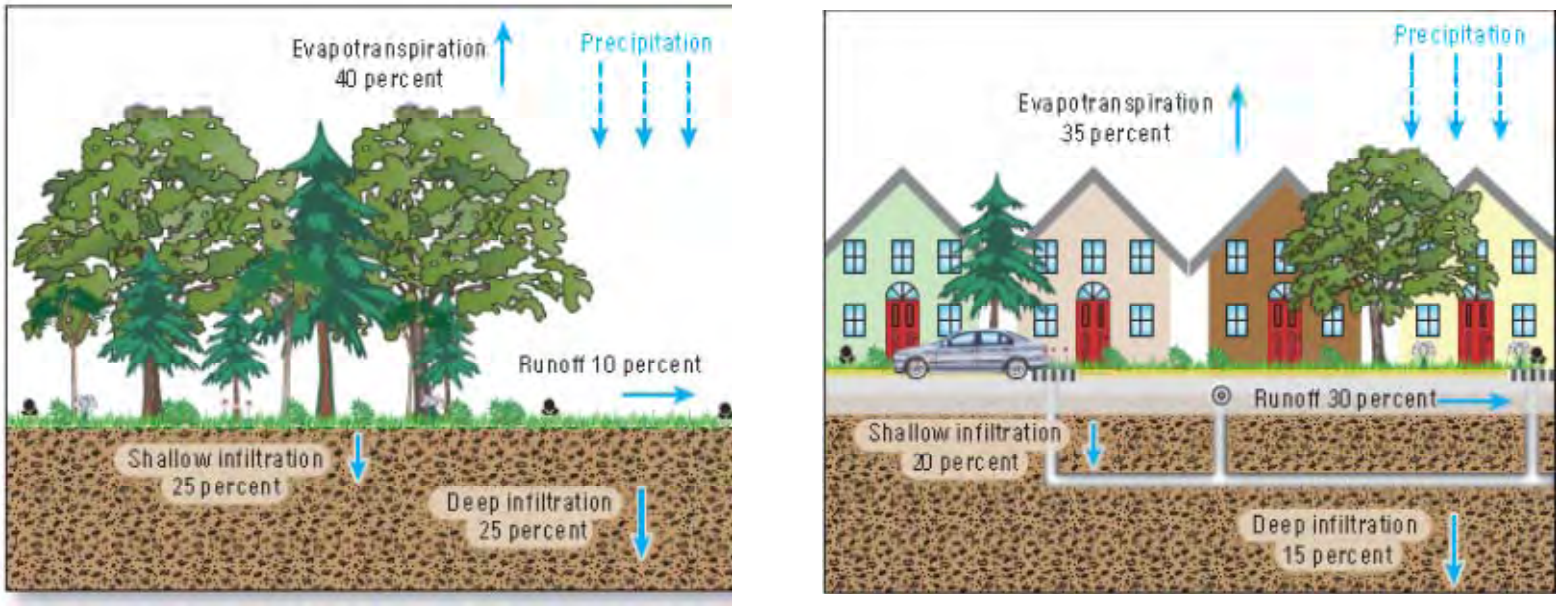


Figure 4. Change in Water Balance with Development (Coles et al., 2012)

Increased Runoff Volume

Several studies have documented increased stormwater runoff volumes resulting from land development. This increase in runoff volume is a result of the introduction of impervious cover to the landscape, compaction during and after construction, and loss of forest cover. Hydrologic models (e.g., NRCS, 1986) have documented the influence of land cover and soil type. In the first three stages of the Clarksburg development plan, the runoff coefficient increased (Figure 5), and in the amount of infiltration and evaporation decreased (Figure 6), as impervious cover and land clearing occurred in the watershed. In the corresponding years, a corresponding undisturbed stream, Soper's Branch, did not experience these changes in hydrology.

The effects of impervious cover and changing land cover on runoff volume appear to be most pronounced at the very small catchment scale. For instance, Dietz and Clausen (2008) measured an increase in annual runoff volume from 0.1 cm/year to 50 cm/year when a 4.2-acre suburban development increased from 0% to 30% impervious cover, with a logarithmic increase in runoff coefficient. At the larger watershed scale, these effects are somewhat dampened. The "Simple Method" (Schueler, 1987), based on data at the catchment scale, finds a linear rather than logarithmic relationship between stormwater runoff and watershed impervious cover at the catchment scale.



Figure 5. Comparison of runoff coefficient in a developing tributary of Little Seneca Creek (Clarksburg) versus a control stream Soper Branch (MCDEP, 2012)

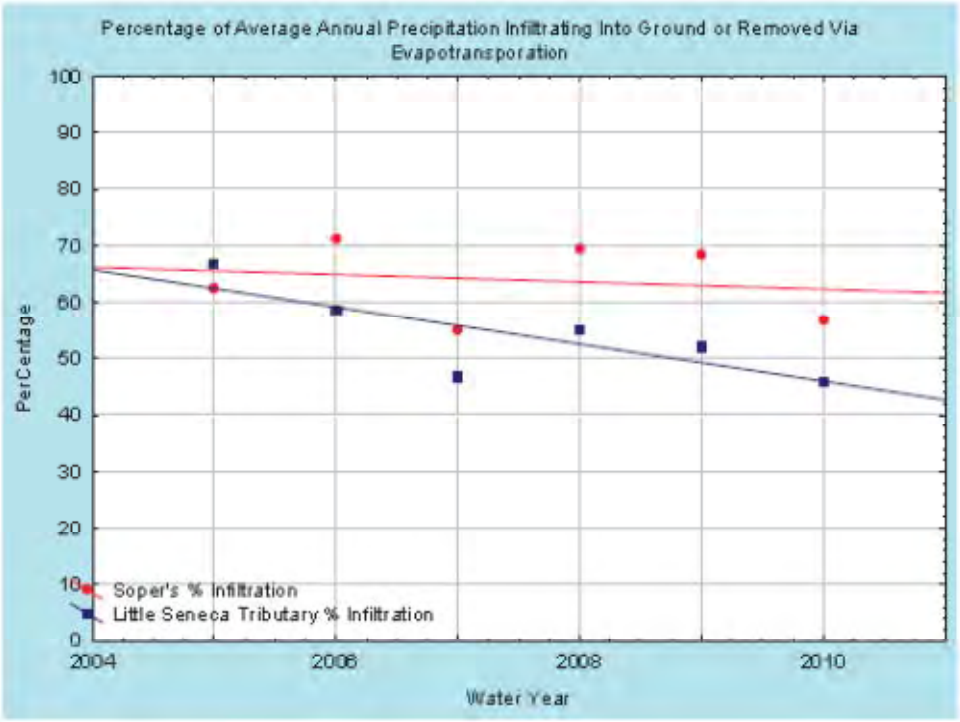


Figure 6. "Runoff Reduction" volume in a developing Little Seneca tributary (Clarksburg)

Another physical change that may compound the impact of development on hydrology is the compaction and disturbance of soils during and after the construction process. The impacts of soil compaction are well documented (Table 2), yet the specific response to soil compaction is dependent on a number of factors such as soil texture and organic matter (Saxton and Rawls, 2006), and depth of the soil profile (Hursch, 1944). These studies point to the need to better understand soil compaction when sizing stormwater management practices (see Section 3 of this report).

Table 2. Studies Documenting the Impacts of Soil Compaction

Finding	Study
Finds that lawns constructed earlier than 2000 had lower curve number than those built post 2000, and that both had lower curve numbers than disturbed soils.	Woltemade, 2010
Disturbed soils have infiltration rates <2.0 cm/hr, compared to 32 cm/hr for forested lands.	Kays et al., 1980
Storage in the agricultural soil profile is about 1/3 as much in disturbed forest due to stripping of upper soil layers	Hursch, 1944
Construction activity or compaction treatments reduced infiltration rates 70 to 99 percent.	Gregory et al., 2006
Infiltration rate is inversely related to soil compaction in sandy soils. In clayey soils, soil moisture is also an important parameter.	Pitt al., 2005

Flashiness

Flashiness (Figure 7) is an important hydrologic metric because of its influence on stream habitat and biology. It occurs as a result of the increased runoff volume, combined with increased runoff velocity, or shorter time of concentration. While there are many specific metrics used to describe flashiness, the resulting stream hydrology has four basic characteristics (Coles et al., 2012): 1) Increased magnitude of the peak discharge; 2) decreased duration of peak flows; 3) increased rate of decline or recession, and 4) increased frequency of high flow events. Flashiness has been documented at varying degrees of urbanization (Table 3). In the early stages of development in the Clarksburg SPA, MCDEP (2012) documented a decrease in stream flashiness, as well as time of concentration, or the time required for a drop of water to travel from the most hydrologically remote point in the subcatchment to the point of collection (Figure 8).

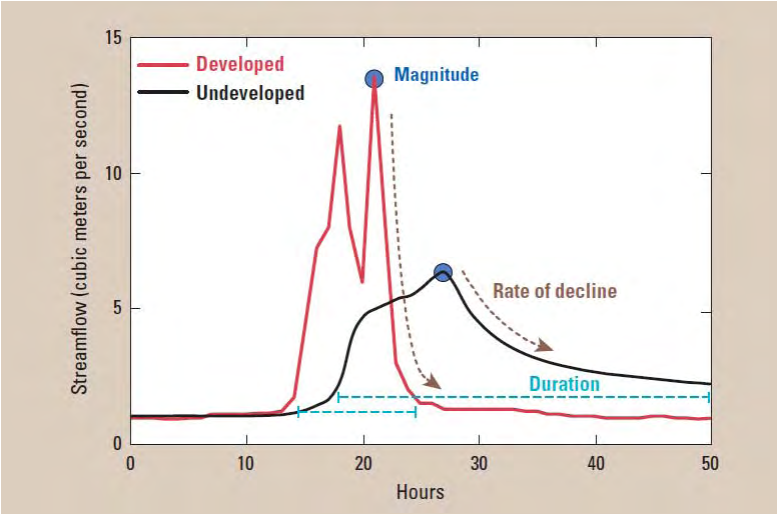


Figure 7. Stream Flashiness (Coles et al., 2012)

Table 3. Selected Studies of Stream Flashiness

Measure of Flashiness	Source	Result
2-year peak	Fitzpatrick, 2005	At less than 30% IC, 2-year peak increased linearly. At greater than 30% IC, results were dependent on other watershed characteristics.
Flashiness	Jarnagin, 2007	Watersheds with less than 20% 'urban' development displayed background levels of stream flashiness and mean flashiness increased with urban development density thereafter
Flashiness	Roy et al., 2005	Increased imperviousness was positively correlated with the frequency of storm events and rates of the rising and falling limb of the hydrograph (i.e., storm ‘‘flashiness’’) during most seasons.
Peak Flows	Moglen et al. (2004)[1]	A study in the Maryland Piedmont: ~65% urban catchments had 3–4 times greater 2 yr peak flows than in forested catchment.

1: As reported in O’Driscoll (2010)
IC: Impervious Cover

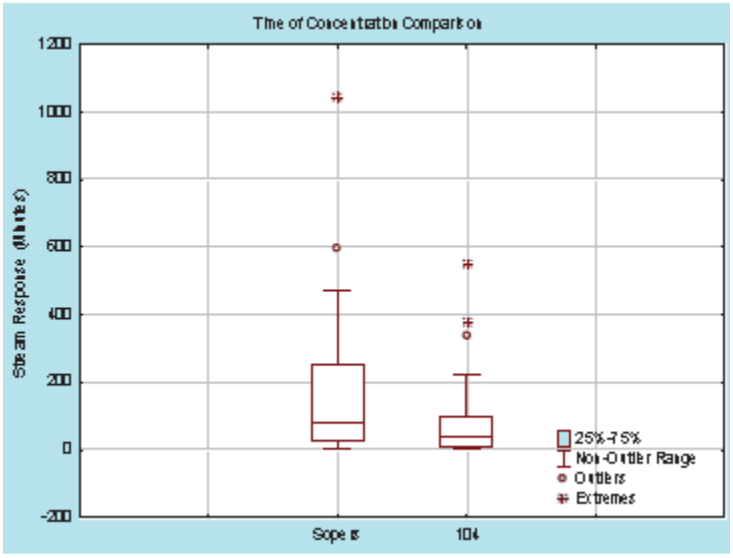


Figure 8. Time of Concentration is lower in the developed "Tributary 104" versus undeveloped Sopers Branch

Decrease in baseflow

Natural baseflows are typically correlated with healthy macroinvertebrate and fish communities. Most studies indicate that stream baseflow decreases with increased land development (e.g., Moglen, 2004), although some studies contradict this claim (e.g., Coles et al., 2004). Because this impact is somewhat less well documented, ongoing monitoring in Ten Mile Creek should document changes in baseflow over time. Ten Mile Creek appears to be losing some upstream baseflow through infiltration back into groundwater in the lower reaches closer to Little Seneca Lake. (Van Ness, 2013) The baseflow in Ten Mile Creek is, however, remarkably reliable, with baseflow typically continuing in most drought events. The biological communities in Ten Mile Creek appear to be well adapted to current baseflow conditions, and any alteration of those conditions would be expected to have negative impacts on stream health.

2.2 Impacts on Water Quality

Concentrations of pollutants in urban runoff concentrations are significantly higher for many pollutants compared to typical concentrations in non-urban land uses. This typically results in higher in-stream pollutant concentrations in urban areas as well. Urban streams typically have higher concentrations of nutrients, metals, hydrocarbons, and bacteria than the equivalent size agricultural or forested watershed (CWP, 2003). Sources of these pollutants include vehicles, sewage (in the form of illicit discharges), fertilizers, and even atmospheric deposition onto paved surfaces.

Urbanizing watersheds often contribute to higher in-stream temperatures. For example, Urban (2006), found a significant correlation between urban land development and in-stream temperatures in a study of Connecticut streams. At the site level, Jones and Hunt (2010) documented high runoff temperatures on urban parking lots. Early monitoring in the SPAs of Montgomery County reflects little thermal impact on the majority of sites monitored. This may reflect the effectiveness of installed practices at these sites at reducing downstream temperatures (MCDEP, 2012), which include a significant amount of infiltration practices.

2.3 Impacts on Habitat and Stream Morphology

Stream morphology and habitat quality are also impacted by the changes in stream hydrology that result from land development, combined with the direct impacts to the stream corridor. The primary driver for changes in stream morphology is the altered hydrology resulting from increased impervious cover and loss of natural soils and forest. The resulting change in hydrology increases stream power, and consequently results in erosion and enlargement of stream channels. At as low as 7-10% impervious cover, we start to see destabilization and accelerated erosion of streams, as evidenced by an enlarged cross-sectional profile, including both stream widening and downcutting. This phenomenon has been documented in Tributary 104 of Seneca Creek (MCDEP, 2012), with data showing a decrease in stream cross sectional area following sediment deposition from construction, followed by channel enlargement, for a net 15% increase in channel area from 2002 to 2010. The channel depth increased by over 50% during this time period.

The combination of this active channel erosion and direct impacts to the riparian corridor and stream bed result in degraded stream habitat. While these results are not universal, typical impacts of impervious cover include stream straightening (i.e., decrease in sinuosity), as was also documented in Tributary 104 of Seneca Creek (MCDEP, 2012), increase in “embeddedness” of channel sediment, and decrease in depth diversity. Often, these and other measures are integrated into a combination metric such as “fish habitat.” While the relationship between urban development and channel geometry are fairly consistent, habitat factors are less reliably influenced by watershed urbanization. One reason for this result is that highly localized effects, such as riparian vegetation (Cianfrani, 2006), past stream alteration (Fitzpatrick, 2005), or geologic features such as stream slope (Fitzpatrick, 2005) can strongly influence these habitat metrics.

Table 4. Some Studies of Geomorphology and Habitat Impacts

Study	Measure of Habitat Quality	Finding (s)
Coleman et al., 2006	Channel enlargement	Channel enlargement ratio is related to IC by a logarithmic relationship. In eastern streams, impacts begin IC at about 7-10%
Cianfrani et al., 2006	bankfull geometry, sediment grain size, large woody debris	These variables were positively correlated with IC. Study concludes that local factors (e.g., riparian vegetation) also influence habitat metrics. Streams with IC <13% and >24% responded differently to urbanization.
Booth, 2000	Fish habitat	At greater than 10% IC, most observed fish habitat is "degraded."An intact riparian corridor is necessary, but not sufficient to preserve fish habitat
Moglen et al., 2004	Channel Enlargement/ Channel Erosion	At 20% IC, channel erosion accounts for 40% of annual sediment loads.
Booth, 2000 Coles et al., 2004	Channel Stability 89 Habitat metrics	At greater than 10% impervious, most stream channels are unstable. Only 11 of the 89 individual metrics responded to urbanization. However integrated habitat scores showed decline with urbanization.
Ourso, 2006	Range of metrics	Sinuosity, embeddedness, and % bank erosion correlated with IC
Fitzpatrick, 2005	Several habitat metrics	No significant relationship, possibly due to past disturbance.

IC: Impervious Cover

Impacts to and Loss of Headwater and Zero Order Streams

Another impact of land development is the loss of headwater and zero order streams. Headwater streams are typically first order, intermittent to perennial streams that originate in upland areas. Zero order streams are ephemeral channels that serve to convey concentrated surface runoff during storm events to the headwater streams. In Ten Mile Creek many of the headwater streams are fed by cool water springs and seeps, which help to maintain flow and support healthy and diverse stream communities. This is particularly important for Stage 4 of the Clarksburg Master Plan, which occurs primarily in the headwaters of a sensitive stream system. These streams are crucial to stream hydrology, chemistry, and biology, and are often channelized or otherwise eliminated during the development process. In addition, these streams are the most vulnerable to the impacts of channel erosion, since hydrologic "flashiness" is most pronounced at the small catchment scale. Headwater streams are important to the hydrologic and nutrient balances in stream systems. They comprise 70% of water volume and 65% of nitrogen to 2nd order streams, and 55% of water volume and 40% of nitrogen to 4thand higher-order streams (Alexander et al., 2007). In addition, they support diverse aquatic biota. For example, in a study by Meyer et al. (2007), three unmapped (i.e., zero order) streams supported

over 290 macroinvertebrate taxa. Headwater streams provide benefits downstream by offering a refuge from temperature and flow extremes, competitors, predators, and introduced species; serving as a source of colonists; providing spawning sites and rearing areas; being a rich source of food; and creating migration corridors throughout the landscape (Meyer et al., 2007).

2.4 Biology

Of all stream indicators, biological indicators are most reliably predicted by changes in urban development (Table 5), largely because they integrate impacts to hydrology, habitat and chemistry. One underlying source of these changes is the shift in food source. Since urban land typically has higher nutrient loads than forested land, and can result in less forest cover in the watershed and riparian corridor, we see a shift from particulate to dissolved organic carbon as a food source, resulting in a shift in the macroinvertebrate community. Of the five functional feeding groups used to describe macroinvertebrates in Montgomery County (shredders, scrapers, predators, collectors and filterers), shredders represent highly sensitive taxa that rely on intact plants (usually in the form of leaves) to survive. As development occurs, the food sources switches from particulate to dissolved organic carbon, and shedders are replaced by collectors, filterers and predators.

The modified flow regime of the urban environment also results in direct impacts to fish and macroinvertebrate through the sheer energy of the modified flow regime. This, coupled with channel degradation and sediment loads that "smother" in-stream habitats, combine to reduce diversity of both macroinvertebrate and fish populations. The reduced sinuosity and depth diversity resulting from modifications to stream hydrology are damaging to fish in particular. Finally, fish, amphibians and aquatic are impacted by direct impacts to the stream system such as road crossings, and loss of headwater streams and small wetlands.

As urbanization occurs, the most sensitive taxa begin to disappear first (Coles et al., 2012). In Ten Mile Creek, it will be important to understand how the community changes over time with development. Biological monitoring in Montgomery County has been ongoing for decades, and includes a suite of fish and macroinvertebrate metrics. These metrics are assembled into an Index of Biotic Integrity (IBI), which integrates several individual scores (e.g., richness or diversity). Another approach that may be valid in the county is to develop a "Biological Condition Gradient," which integrates several location-specific metrics to develop a six tier gradient of streams from "Native Condition" to "Severe Alteration of Structure and Function." This approach may be helpful in future monitoring of SPAs to detect or report small changes in community structure as sensitive species begin to disappear.

Table 5. Impacts to Stream Biology

Study	Measure of Biological Condition	Findings
Alberti et al., 2007	B-IBI	In a study of 42 streams, the number of road crossings and patch size were better predictors of IBI than IC alone.
Belucci, 2007	Macroinvertebrate % of community[1]	At greater than 12% IC, no streams met Connecticut's criteria for stream biology.
Booth, 2000	B-IBI	At upper levels of IC, there is steady decline in IBI, but degradation can occur at lower levels of IC.
Coles et al., 2004	126 macroinvertebrate metrics, 92 fish, 164 algae	Of these, metrics, about 20% were strongly correlated with an "urban land index"
DeGasperi, 2009	B-IBI	Correlated with urban land and IC, and negatively correlated with forest cover
Fitzpatrick, 2005	Fish IBI	Strongly correlated with urban land
Houlahan, 2003	Amphibian Species Richness	Correlated with land use w/in 3000 feet of a wetland.
Kennen, 2010	Macroinvertebrates	Urban land, road density, a measure of forest contiguousness and percent urban land in the buffer are all predictive of an integrated measure of macroinvertebrate health.
Ourso, 2006	Measures of macroinvertebrate richness, abundance, and shredder abundance	Significant correlation for these parameters. Taxa richness begins to decline at IC as low as 1.2%.
MDNR, ND	Salamanders/ brook trout	At as low as 0.3% IC can lose some very sensitive species. About half of the salamander species remaining at 2% IC. Brook trout affected above 4% IC
Morgan and Cushman, 2005	Fish IBI	Relates fish IBI scores to urban development in coastal plain and Eastern Piedmont MD streams. In Eastern Piedmont, we see breakpoints at 10% and 25% urbanized areas. Some difference between 1st-3rd order streams, but see a decline in all.
Miltner et al., 2003	B-IBI	Significant decline at 13.8% urban land use, and second inability to meet aquatic life criteria at 27% urban land
Roy et al., 2007	Measures of fish assemblage	Some metrics best predicted by % urban land, but % forest cover in the stream reach important for some metrics at <15% IC
Moore and Palmer, 2005	Macroinvertebrate: EPT Richness, Total Richness, FFG Richness	Biodiversity declined directly with increases in urban (versus agricultural) land use. Riparian buffer lead to higher levels of diversity at all sites
Urban et al., 2006	Macroinvertebrate: EPT and species richness	Half of the taxa disappeared at a density of 10 houses/ha, and sensitive species (EPT) declined from 34% to 11% of total population.
Robbo and Kiesecker, 2004	Amphibian Larvae Richness	Number of amphibians in upland wetlands decreased as % forest (w/in 1km) decreased. Also influenced by wetland hydroperiod

IC: Impervious Cover

2.5 Relationship between Hydrology and Habitat/ Biology

As indicated in Figure 1, hydrology is an important driver in determining stream health, and has a direct influence on water quality, stream morphology/habitat and biology. Since one of the primary goals of stormwater management, and Environmental Site Design in particular, is to restore natural hydrology, we need to understand how hydrology is related to stream health. That is to say, if we manage hydrology correctly, will we in turn minimize degradation in the downstream channel?

While this review focuses on discrete types of impacts (e.g., impacts to biology versus impacts to hydrology), it is important to understand that these impacts act collectively so that, while mitigating one impact will influence in-stream condition, a comprehensive approach is needed to understand the stream system as a whole. Recent work by the USGS (Kashuba, 2012) presents an informative framework for understanding these impacts (Figure 9). The model was developed with data from New England streams, and is helpful in predicting the relative certainty of attaining a given in-stream result by managing impacts such as hydrology and water quality. Unfortunately, the model does not account for ESD practices, and only looked at very large watersheds (around 200 square kilometers and up). While the specific data in this model cannot be directly used to predict in-stream response to development in Ten Mile Creek, the result serves as a framework for understanding watershed response. For example, while hydrologic impacts are related to in-stream habitat and water quality, these factors are also directly impacted by land cover.

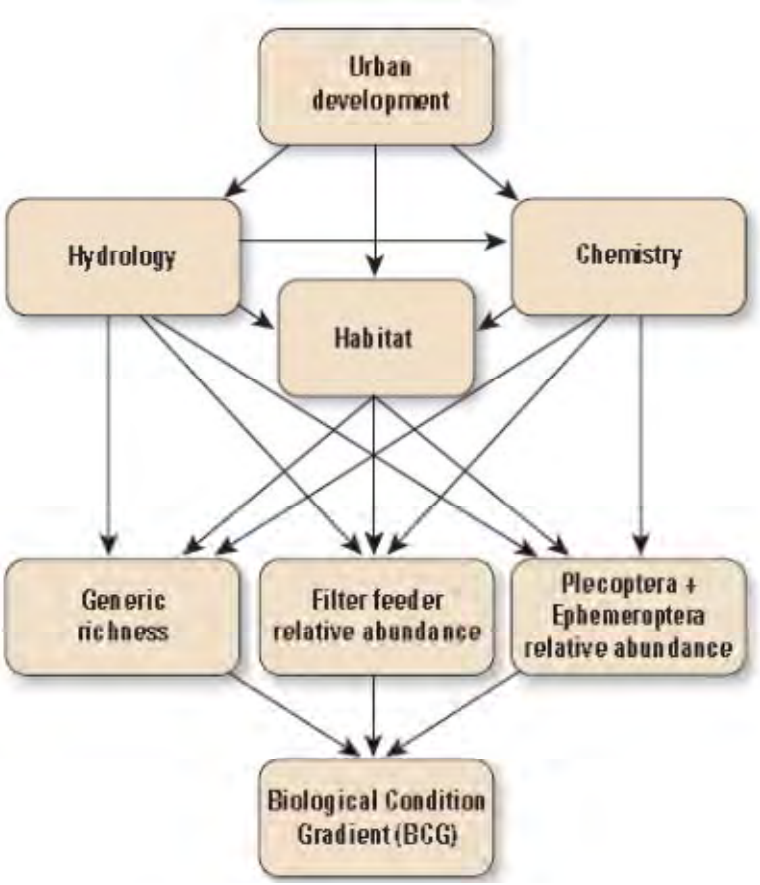


Figure 9. Network Describing Northeast Stream Conditions (Kashuba, 2012; figure from Coles et al., 2012).

Several studies, particularly in recent years, have attempted to the impacts of impervious cover from the impacts of the *responses* to impervious cover (Table 6). For example, several studies have separated hydrology as an independent variable to determine its impacts. In Kashuba's (2012) model, the output is the probability of achieving a given condition (e.g., probability of achieving a given BCG score). This model could be used to predict, for example, how controlling hydrology from development would increase the likelihood of a good outcome in terms of biological diversity. While no such specific model has been developed for streams outside of New England, the concept can be applied elsewhere. To do so, however, would require modifying the New England model to account for ESD, and to recalibrate it to account for local watershed sizes and conditions. Taken as a whole, it appears that hydrology plays a very strong role on instream habitat, but does not account for all of the impacts to instream biology that occur with urbanization.

Table 6. Studies relating Hydrology, Water Quality, Habitat and Biology

Study	Relationships Identified
King et al., 2011	Riparian cover, acidity, conductivity and woody debris (a combination of habitat and water quality variables) predicted macroinvertebrate community, but measures of urban land explained some variability not predicted by these variables alone.
Roy et al., 2007	Specific metrics of fish diversity were impacted by hydrologic variables including: altered storm flows in summer and autumn, % fine bed sediment in riffles. Overall, hydrologic variables explained 22 to 66% of the variation in fish assemblage richness and abundance.
Kennen et al., 2010	Study of 67 northeastern streams developed models to predict macroinvertebrate assemblage, as well as presence of specific taxa based on hydrologic variables. The most important variables are mean April flow, duration of high flows, and seasonal low flows.
DeGasperi et al., 2009	In King County, WA, analyzed 15 hydrologic variables to find those that are successful in predicting in-stream biology. Selected variables included High Pulse Count and High Pulse Duration
Fitzpatrick (2005)	Developed relationships between Fish IBI and several hydrologic or habitat variables, but found that urban land was a better predictor than any of these derivative variables.
Coleman et al., 2005	Study reports a relationship between flow and channel geometry

3. Stormwater Management and Environmental Site Design

Development in Stage 4 of the Clarksburg Master Plan will be required to use Environmental Site Design (ESD). If this stormwater management technique is successful, it is likely that some of the impacts typically associated with land development can be reduced. There are very few large-scale applications of ESD and consequently we could find no direct evidence of the impacts of ESD on in-stream biota. However, several studies have evaluated ESD, as well as individual practices, for benefits to hydrology and water quality.

3.1 What does ESD Mean in Maryland?

Maryland state law defines Environmental Site Design (ESD) as "using small-scale stormwater management practices, non-structural techniques, and better site planning to mimic natural hydrologic runoff characteristics and minimize the impact of land development on water resources."

In practice, the Maryland Stormwater Design Manual has laid out a process for achieving this goal that uses the 1-year rainfall (about 2.6"), as a target storm event. In the standards, ESD practices such as rain gardens, permeable pavement and green roofs, are the first choice to capture enough of this event so that the "curve number" from the site is equivalent to the curve number from woods in good condition. This means that a site with very little impervious cover would have a smaller design storm than a paved site. If it is impossible to meet these requirements with a list of ESD practices defined in the manual, then traditional stormwater management can be used to detain the remaining storm volume. So, although the goal is to reduce the runoff from the 2.6" storm event to the equivalent runoff of woods in good condition, this can be accomplished by capturing as little as the runoff from the 1" storm.

In addition to site planning that minimizes disturbance and conserves natural areas, the Maryland Stormwater Manual (MDE, 2009) identifies a list of ESD Practices (Table 7) that include three major categories: Alternative Surfaces, Nonstructural Practices and Micro-Scale Practices. All of these practices share two characteristics that make them different from most traditional stormwater practices: treating stormwater closer to its source, and reducing the volume (rather than only the peak) of stormwater runoff.

While the Maryland Stormwater Manual does address soil compaction for *practices*, it does not introduce a factor of safety or account for changes in the storage and infiltration rates of soils in the *landscape* due to disturbance and alteration during construction. Analysis conducted as a part of this study should consider soil compaction, and soil restoration measures should perhaps be required as a part of the stormwater plan. For an example, consult New York State's Stormwater Regulations (NYSDEC, 2010), which explicitly require soil restoration or oversizing of stormwater practices to account for runoff from compacted soils. Going beyond the requirements of the Maryland Stormwater management Manual, such as providing deep (24 inch) soil decompaction with organic matter amendment, is a potential strategy to provide extra protection for high-quality or sensitive watersheds.

Table 7. ESD Practices (MDE, 2012)

Alternative Surfaces
• A-1. Green Roofs
• A-2. Permeable Pavements
• A-3. Reinforced Turf
Non-Structural Practices
• N-1. Disconnection of Rooftop Runoff
• N-2. Disconnection of Non-Rooftop Runoff
• N-3. Sheetflow to Conservation Areas
Micro-Scale Practices
• M-1. Rainwater Harvesting
• M-2. Submerged Gravel Wetlands
• M-3. Landscape Infiltration
• M-4. Infiltration Berms
• M-5. Dry Wells
• M-6. Micro-Bioretention
• M-7. Rain Gardens
• M-8. Swales
• M-9. Enhanced Filters

3.2 Can Individual "ESD Practices" Theoretically Reproduce a Natural Hydrograph?

In order to reproduce a natural hydrograph, a stormwater practice needs to first reduce the volume of runoff. This is a stark difference from traditional stormwater management, which focuses on reproducing the peak runoff for a range of storm events rather than the runoff volume. A review of stormwater BMP effectiveness literature evaluated the "runoff reduction" capability of a range of practices. The results, as indicated in Table 8, indicate that the ESD practices are much more effective than most traditional stormwater practices at reducing the volume of stormwater runoff from a given storm event.

The data in Table 8 represent average effectiveness at "runoff reduction" based on a literature review of available BMP studies. These data represent average values from available individual practice studies. In these data, "runoff reduction" includes evaporation, infiltration and "extended filtration," which would be exemplified by very slow release, perhaps from an underdrain below a filtering practice such as bioretention.

It is unclear, however, if reducing runoff volume alone is enough to reproduce a natural hydrograph. Two recent studies of bioretention practices came to different conclusions regarding this question. In North Carolina, Debusk et al. (2011) found no significant difference between outflow from a bioretention cell and the hydrograph of a nearby natural stream system. In Maryland, on the other hand, Olszewski and Davis (2013) performed virtually the same experiment and found that the bioretention cell did meet *volumetric* goals, but failed to reproduce the natural hydrograph's shape due to differing flow *duration*. This paper proposes using flow-duration curves from natural streams as a design tool for ESD practices.

Table 8. Runoff Reduction of Stormwater Practices (Hirschman et al., 2008)

Practice	Runoff Reduction (RR) (%)
Green Roof	*45 to 60*
Rooftop Disconnection	*25 to 50*
Raintanks and Cisterns	40
Permeable Pavement	*45 to 75*
Grass Channel	*10 to 20*
Bioretention	*40 to 80*
Dry Swale	*40 to 60*
Wet Swale	*0*
Infiltration	*50 to 90*
ED Pond	*0 to 15*
Soil Amendments	*50 to 75*
Sheetflow to Open Space	*50 to 75*
Filtering Practice	*0*
Wetland/ Wet Pond	*0*

3.3 Can ESD Practices Remove Pollutants?

Recently, the Chesapeake Bay Program convened a panel of experts to estimate pollutant removal effectiveness of "Runoff Reduction" versus "Stormwater Treatment" practices. The results indicate that practices that reduce the volume of runoff are typically more effective at removing pollutants as well. Although ESD can incorporate both Stormwater Treatment and Runoff Reduction practices, one distinction of ESD is that its approach incorporates practices that reduce runoff volume on the site. The curve in Figure 10 represents the presumed phosphorus reduction based on the storm captured by these practices. It is important to note that, while Maryland's standard targets about a 2.7" storm, the actual capture in ESD practices may be lower, so that a "mixed" efficiency might better characterize the site. The "bump" achieved by ESD practices is somewhat less impressive for sediment, which is effectively removed by traditional stormwater practices, and for nitrogen, which is mobile in ground water, and thus presumed to be less effectively removed by infiltration practices. Other pollutants that are mobile in groundwater, such as deicing salt, will move unimpeded into shallow groundwater, and could pose long-term problems for local streams.

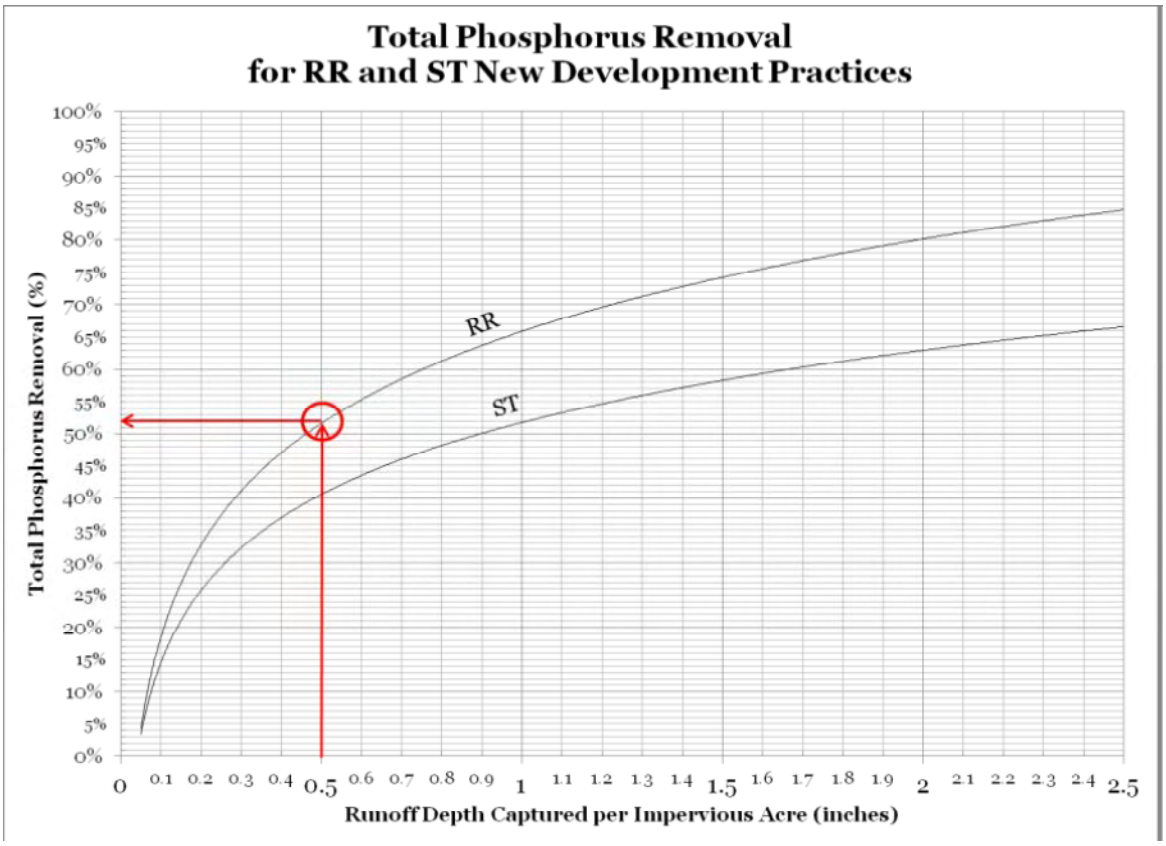


Figure 10. Phosphorus Removal Curve for "Runoff Reduction" (i.e., ESD) versus traditional stormwater management (Schueler and Lane, 2012)

When compared with traditional stormwater practices, ESD practices are in general superior at reducing downstream temperature increases. For example, according to Galli (1990) and Jones and Hunt (2010), stormwater ponds increase runoff temperatures. Results for ESD are more encouraging. Jones and Hunt (2008) showed that bioretention cells, and especially small cells, were able to reduce runoff temperatures. According to Winston et al. (2011), filter strips can also reduce runoff temperatures. Finally, Jones and Hunt (2012) found that landscape measures such as tree canopy, using light colored or less pavement, and use of underground conveyances can reduce runoff temperatures.

3.4 What are Important Program Components for Implementing Maryland's ESD Regulations in Ten Mile Creek?

There are two potential issues that need to be addressed to effectively implement ESD in Ten Mile Creek. First, the site infiltration and runoff calculations should consider soil compaction and, second, maintenance, or lack thereof, should be accounted for.

Site runoff volume computations in the MDE stormwater manual (MDE, 2010) are derived from a combination of soil type and impervious cover calculations. These calculations do not account for soil compaction and, although the manual does discuss infiltration testing and soil restoration for *practices*, there is no required method to effectively address soil compaction in the *landscape* (e.g., open fields that are compacted by construction. The State Stormwater Manual requires only a few inches of surface

scarification of compacted soils. Montgomery County, however, requires about 6 inches of tilling for compacted soils, with 4 inches of topsoil added. This provides greater benefits than the State Manual requirements, but still falls short of the benefits provided by deep (24 inches) soil decompaction with organic matter amendment. The analysis conducted as a part of this study should consider soil compaction, and a possible regulatory tool would be to require soil restoration as a condition of site development. (See New York State's Stormwater Management Design Manual (NYSDEC, 2010) as an example. In addition, the "Equivalent Curve Number" methodology used at the state level should be modeled for this study to ensure that hydrologic assumptions are consistent.

Maintenance is a challenge for any stormwater practice. For example, Hirschman et al. (2009), in a field survey of BMPs in the James River Basin found that at least 50% of all stormwater BMPs were in need of maintenance. With the advent of ESD, more and more small practices will be implemented at the site level. Analyses should assume that some fraction of BMP storage is lost over time, with the potential consideration of oversizing practices to account for this lost storage. Programmatically, assurances should be made to ensure that practices are made through chain of custody agreements, inspections, and strong legal agreements for small practices on private property.

3.5 When Entire Sites or Catchments Implement ESD, What Is the Result?

While it is useful to understand the impact of individual practices, ESD should really be implemented the whole site or catchment level, and include a mix of site planning techniques and small micro-scale stormwater practices. A combination of modeling and monitoring studies provide some insight into the hydrological and water quality performance of ESD as a "whole site" practice (Table 9). Most of these studies are model-based, but both the model-based studies and monitoring studies point to some of the same trends. ESD is in general far superior to traditional stormwater management at reproducing natural stream flows. However, ESD has some limitations. For example, "tight" soils or soil compaction appears to be a major limitation for infiltration practices in the modeling studies. In addition, both modeling and monitoring studies point to the fact that ESD is most effective for small storm events. In Selbig and Bannerman (2008), a couple of small storms accounted for a much higher pollutant load in the ESD system. Further, it appears from several of the studies that, while infiltration practices can be very effective, these should be combined with land cover controls that reduce disturbance and impervious cover. Although these studies show hydrology-related ESD benefits, as indicated earlier, stream health depends on more than good hydrology. As a result, the findings of these studies cannot be used to estimate the effects of ESD on receiving stream biological communities and ecosystems. Similarly, while these studies show improvements in water quality using ESD, only a few of the pollutants that come from developed land are typically modeled or monitored. As with the results of the hydrology studies, the water quality results cannot be used to estimate ESD impacts to biological and overall stream ecosystem health.

Table 9. Results of ESD Development or Catchment Scale Studies

Study	Study Characteristics	Findings
Brander et al., 2004	Modeling Study: Evaluates four site layouts, including a cluster development a grid pattern, and two others. Compares runoff volumes for design storms	• Cluster designs that preserve open space create the least runoff. • Strategic placement of infiltration practices can reduce runoff for any development type. • Soil compaction during construction can hamper efforts to achieve runoff reductions. • Infiltration practices most effective for small storm events.
Burns et al., 2012	Study compares hydrographs of a forested and an adjacent urban (28% IC) watershed. Follows this with modeling of the urban watershed with traditional or on-lot stormwater practices.	• The uncontrolled runoff from the urban watershed had three times as much annual runoff and summer and winter baseflow. • Modeling the urban watershed with the use of a wetland system was ineffective at reproducing the natural hydrograph. • Models of the use of on-site practices showed more promise for producing the natural hydrograph.
Dietz and Clausen, 2008.	Jordan Cove: Monitored two side-by-side developments. The ESD development utilized distributed runoff controls throughout and had 20% (versus 45%) IC.	• As the conventional development was implemented, there was an exponential rise in runoff volume, while there was no relationship between runoff volume and IC in the ESD subdivision. • The same patterns held for nutrient export.
Holman-Dobbs et al., 2003	Models stream flow and annual runoff volume for various storm events comparing a pre-developed, “high impact” (50% IC, no stormwater management) and “low impact” development (50% IC, infiltration practices)	• Infiltration practices are most effective for small storm events and on soils with high infiltration rates.
Selbig and Bannerman, 2008	Monitoring study of two side-by-side developments. The ESD site has similar IC, but utilizes infiltration, including swales and an infiltration basin.	• Average annual runoff was significantly lower for the ESD site, and infiltration was most effective for smaller storm events. • While the ESD site typically better at pollutant removal, there were two years where pollutant loading from the ESD site was higher due to one or two very large storm events that were not captured by on-site practices. • Temperature from the LID site was somewhat elevated, but it is unclear if the reduced volumes combined with this temperature result in lower thermal loadings.
Zimmerman et al., 2010	Monitors runoff from a neighborhood retrofit with rain gardens, and a green roof.	• For both applications, significant runoff reduction can be achieved for small storm events. • Results for water quality were mixed, with loads from both the green roof and the retrofit neighborhood having higher loads than conventional land use for some pollutants.

IC: Impervious Cover

3.6 In-Stream Effects from an ESD Development: North Creek, City of Surrey, BC, Canada

There are very few examples documenting the in-stream impacts resulting from ESD development. However, North Creek, in the City of Surrey, BC, Canada offers some valuable insights (Page and Lilley, 2010). The East Clayton neighborhood was transformed from very low density rural land to high density residential over the period from 1999 to 2009, incorporating a full suite of ESD practices, as well as traditional detention. The neighborhood drains to North Creek, which was intensively monitored throughout the development period.

Results: Hydrology

The hydrologic results indicate that ESD practices have reduced storm flows, but increased mean annual flow. This implies that the innovative stormwater practices were effective at increasing baseflow, and in fact increased baseflow beyond pre-developed conditions.

Results: Chemistry and Biology

- Specific conductivity increased significantly over the monitoring period. The study authors conclude that this measure may be a surrogate for other urban pollutants.

- Temperature increased over the study period, probably due to the presence of a large stormwater pond at the outlet of the development.
- Turbidity was relatively constant but increased during the initial clearing and grading phase.
- Loss of sensitive taxa over the 10 year period.
- B-IBI (Benthic Index of Biological Integrity) increased, but this increase was largely driven by abundance of Turbellarian flatworms. This effect on the B-IBI masks an overall decline in biological health, as indicated by the loss of sensitive taxa. As a result, documenting the effects of ESD on stream biology may require the use of more specific indices of biological integrity, such as functional feeding group, or individual taxa metrics.
- The study is currently at the halfway point, and further monitoring will be needed to determine if the decline in stream biological health observed so far will continue, or whether recovery will occur over a longer period of time.

4. Construction Impacts

In addition to the soil compaction discussed in Section 2 of this report, construction impacts stream systems through increased soil disturbance and resulting sediment loads and turbidity. Concentrations of sediment in construction site runoff are significantly higher than in runoff from urban or forested lands. In the study by page and Lilley (2010) described above, in-stream turbidity increased during construction even though the City of Surrey was implementing innovative stormwater controls. Some studies have documented in-stream responses to development. For example, Gage et al. (2004) reported changes in alkalinity, dissolved oxygen, and macroinvertebrate community in response to “disturbance” in urbanizing watersheds in North Carolina. Miltner et al. (2003) reported a similar result, with a decrease in macroinvertebrate IBI at as low as 4% impervious cover during the land development process. This decline was attributed to land disturbance during the construction process.

A similar trend was found in the early stages of the Clarksburg Plan. During the peak construction period (2003-2007), IBI scores declined and began to recover again (Figure 11). At the same time, functional feeding groups were affected during the construction period, with a loss of almost all shredder species, and a dramatic increase in collectors and substantial increase in predators. After construction, there has been some recovery in shredder populations, with a corresponding decline in shredders. It is unclear if either the IBI or the species composition will return to predevelopment levels.

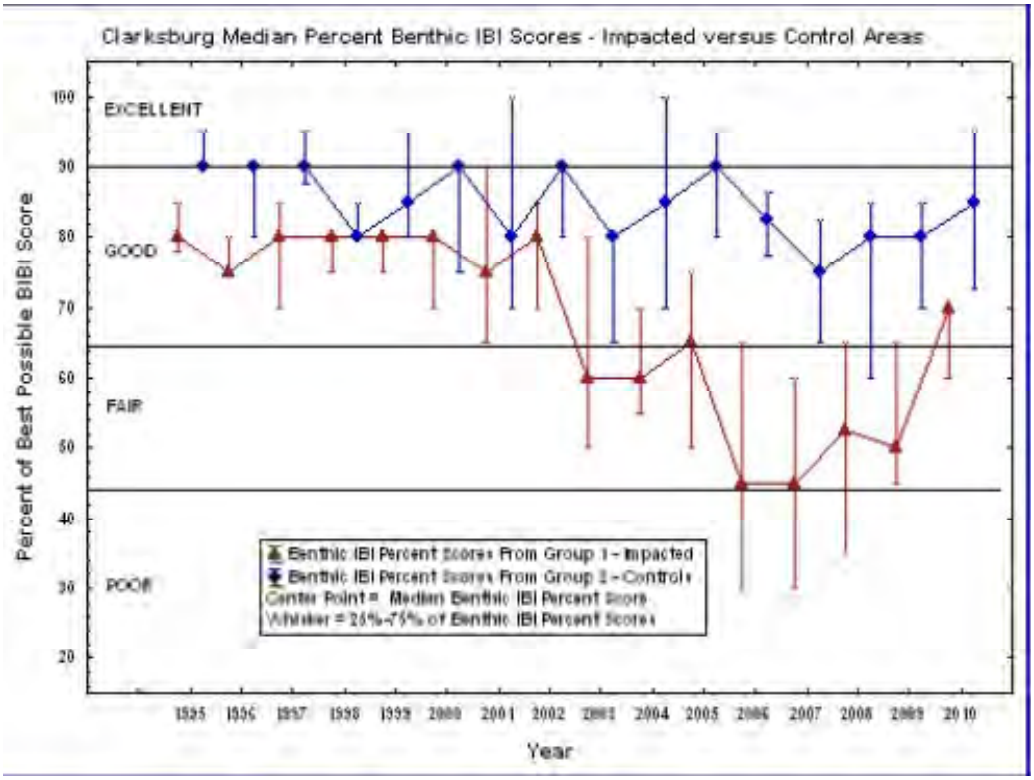


Figure 11. Benthic IBI Scores decline during the peak construction period in Clarksburg, and begin to recover (MCDEP, 2010).

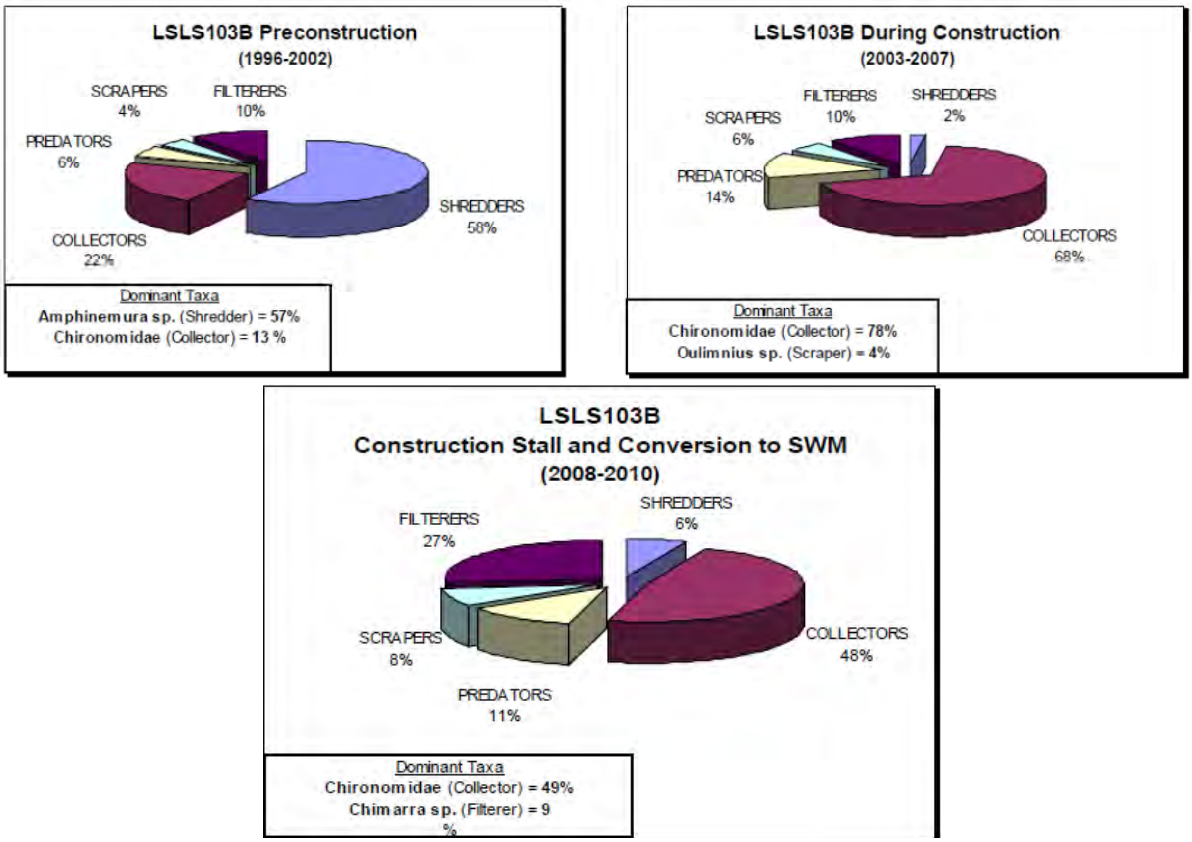


Figure 12. Functional Feeding Groups switched during construction, with a dramatic loss in shredder species, and significant increases in collectors and predators (MCDEP, 2010).

5. Erosion and Sediment Control (ESC) Practices

Currently, the Chesapeake Bay Program estimates that ESC practices remove 25% of TN, and 40% of TSS and TP (Baldwin, 2007). On the surface, these estimates of sediment removal, in particular, seem low compared to published values, particularly for "Enhanced" ESC practices. For example, recent research on the use of polyacrylamide in combination with sediment traps (McLaughlin, 2009) and Filter Socks (Faucette, 2008) are very encouraging, suggesting greater than 90% reduction in turbidity for sediment traps, and better than 90% sediment reduction for filter socks. Initial monitoring from construction sites in the SPAs of Montgomery County also demonstrated high removal efficiencies, with an average removal rate of approximately 70% TSS.

Although these practices can be effective individually, the greatest challenges to implementing effective ESC practices are related to site compliance. In an interesting study by Reice and Carmin (2000) in North Carolina, in-stream macroinvertebrates (EPT) were measured upstream, at the site, and downstream of construction sites in three counties, with varying strictness of ESC regulations. While EPT values were lower at the construction site than upstream in all cases, the decline was significantly lower in highly regulated counties.

Another challenge of implementing effective ESC practices is the uncertainty surrounding rainfall patterns. The rate of erosion is dramatically increased during large storm events, and intense summer

storms can account a significant amount of annual sediment load, and can overwhelm stormwater practices installed on site. Grading limits that are proposed to be in effect during the construction of Stage 4 of the Clarksburg Plan will help to minimize the risk associated with large areas of exposed soil, and should be strictly enforced during the construction of Stage 4.

6. Conclusions and Recommendations

Impacts of Stormwater Runoff and Land Development

- In addition to thresholds identified by the Impervious Cover Model (e.g., 10%), available data suggest that degradation in stream biology begins to happen at much lower levels of impervious cover.
- Riparian corridor preservation is a very useful tool for protecting in-stream habitat and biology, but appears to be the most effective when coupled with watershed impervious cover of 15 to 20% or less.
- Headwater and zero order streams are extremely important, particularly given the high quality nature of Ten Mile Creek, and presence of important amphibian species.
- The B-IBI is currently used to classify streams in Montgomery County and while this is an excellent indicator of general stream health, other metrics should be considered for tracking subtle changes in the quality of stream biology in Ten Mile Creek.
- The relationship between hydrology and in-stream aquatic biota has been documented, but no model has been calibrated to Montgomery County's data. An analysis of specific flow characteristics and measures of in stream biology would be very helpful in understanding future development in Ten Mile Creek and elsewhere in Montgomery County.
- Ongoing maintenance is a challenge for any stormwater management practice, and analyses should consider loss of function and storage in stormwater BMPs over time.
- Hydrologic assumptions inherent in MDE's stormwater regulations should be modeled at a site level to ensure consistency, and account for soil compaction.
- Although MDE requirements allow for the combination of ESD techniques and traditional stormwater detention, detention practices should be avoided if possible due to potential stream warming effects.

Impacts of Construction and ESC

- A decrease in stream habitat and biology during construction has been documented in several studies. Biological monitoring should be conducted immediately downstream of construction sites to detect initial indications of stream degradation.
- ESC regulations should be strictly enforced, with special emphasis on proposed clearing and grading limits.
- The scientific literature indicates that ESD should perform better than traditional stormwater management, but will still not be sufficient to mitigate all of the negative environmental impacts from development.
- ESD can be supplemented with more stringent site design criteria, and/or combined with land use-based measures that reduce development footprint and impervious surfaces, to provide additional protection for high-quality or sensitive watersheds.

References

Alberti, M., D. Booth, K. Hill, B. Coburn, and C. Avollo. The Impact of Urban Patterns of Aquatic Ecosystems: An Empirical Analysis in Puget Lowland Sub-Basins. Landscape Urban Planning, 80(4), 345-361

Alexander, R., E. Boyer, R. Smith, G. Schwarz and R. Moore, 2007. The role of headwater streams in downstream water quality. Journal of American Water Resources Association. 43(1): 41-59.

Baldwin, A., 2007. Urban Erosion and Sediment Control Best Management Practice Definition and Nutrient and Sediment Reduction Efficiencies For use in calibration of the Chesapeake Bay Program's Phase 5.0 Watershed Model: Draft. Prepared for: Chesapeake Bay Program Urban Stormwater Workgroup. Anapolis, MD

Belucci, C., 2007. Stormwater and Aquatic Life: Making the Connection Between Impervious Cover and Aquatic Life Impairments for TMDL Development in Connecticut Streams. Proceedings, TMDL 2007, 1003-1018

Booth, D. 2000. Forest cover, impervious surface area, and the mitigation of urbanization impacts in King County, WA. prepared for King County Water and Land Resource Division. University of Washington. Seattle, WA.

Booth, D., and D. Hartley and R. Jackson, 2002. Forest Cover, Impervious-Surface Area, and the Mitigation of Stormwater Impacts. Journal of the American Water Resources Association. 38(3):836-845

Brander, K., K. Owen and K. Potter, 2004. Modeled impacts of development type on runoff volume and infiltration performance. Journal of the American Water Resources Association (2004): 961-969

Burns, M., T. Fletcher, C. Walsh, A. Ladson and B. Hatt, 2012. Hydrologic shortcomings of conventional urban stormwater management and opportunities for reform. Landscape and Urban Planning. 105 (2012) 230–240

Center for Watershed Protection, 2003. Impacts of Impervious Cover on Aquatic Systems. Ellicott City, MD.

Cianfrani, C., W. Hession, and D. Rizzo, 2006. Watershed Imperviousness Impacts on Stream Channel Condition in S.E. Pennsylvania. Journal of the American Water Resources Association (JAWRA), 42(4): 941-956

Coleman, D., C. MacRae and E. Stein., 2005. Effects of Increases in Peak Flows and Imperviousness on the Morphology of Southern California Streams. Southern California Coastal Research Project, Costa Mesa, CA

Coles, J., T. Cuffney, G. McMahon, and K. Beaulieu, 2004. The Effects of Urbanization on the Biological, Physical and Chemical Characteristics of Coastal New England Streams.

Coles, J.F., McMahon, Gerard, Bell, A.H., Brown, L.R., Fitzpatrick, F.A., Scudder Eikenberry, B.C., Woodside, M.D., Cuffney, T.F., Bryant, W.L., Cappiella, Karen, Fraley-McNeal, Lisa, and Stack, W.P., 2012, Effects of urban developmenton stream ecosystems in nine metropolitan study areas across the United States: U.S. Geological SurveyCircular 1373, 138 p.

Debusk, K., W. Hunt and D. Line, 2011. Bioretention Outflow: Does It Mimic Nonurban Watershed Shallow Interflow? J. Hydrol. Eng.(16):274-279.

DeGasperi, C., H. Berge, K. Whiting, J. Buckley, J. Cassin and R. Fuerstenberg, 2009. Linking hydrologic alteration to biological impairment in urbanizing streams of the Puget Lowland, Washington. Journal of the American Water Resources Association, 45(2): 512-533

Dietz, M. and J. Clausen, 2008. Stormwater runoff and export changes with development in a traditional and low impact subdivision. Journal of Environmental Management, 87:560–566

Faucette, L.B., L.M. Risse, M.A. Nearing, J.W. Gaskin, and L.T. West. , 2004. Runoff, erosion, and nutrient losses from compost and mulch blankets under simulated rainfall. Journal of Soil and Water Conservation July/August 2004 vol. 59 no. 4 154-160

Fitzpatrick, F., M. Diebel, and M. Harris, 2005. Effect of urbanization on the geomorphology, habitat, hydrology, and fish-index of biological integrity of streams in the Chicago area, Illinois and Wisconsin. American Fisheries Society Symposium (47):87-115.

Gage, M. S., A. Spivar, and C.J. Paradise. 2004. Effects of Land Use and Disturbance on Benthic Insects in Headwater Streams Draining Small Watersheds North of Charlotte, NC. Southeastern Naturalist. 3(2): 345-358.

Galli, J. 1990. Thermal impacts associated with urbanization and stormwater best management practices. Metropolitan Washington Council of Governments. Washington, D.C.

Goetz, Scott J, IKONOS imagery for resource management: Tree cover, impervious surfaces, and riparian buffer analyses in the mid-Atlantic region, (2003), Remote Sensing of the Environment 88, pp. 195-208.

Gregory, J.H., M.D. Dukes, P.H. Jones, and G.L. Miller, 2006, Effect of urban soil compaction on infiltration rate. Journal of Soil and Water Conservation 61(3): 117-124

Hirschman, D., K. Collins and T. Schueler, 2008. Technical Memorandum: The Runoff Reduction Method. Prepared by: Center for Watershed Protection and Chesapeake Stormwater Network. Ellicott City, MD

Hirschman, D., L. Woodworth and S. Drescher, 2009. Stormwater BMPs in Virginia's James River Basin: An Assessment of Field Conditions & Programs. Center for Watershed Protection. Ellicott City, MD.

Holman-Dobbs, J., A. Bradley, and K. Potter. 2003. Evaluation of hydrologic benefits of infiltration based urban stormwater management. Journal of the American Water Resources Association 39(l):205-215.

Houlahan, J.E., and C.S. Findlay. 2003. The Effects of Adjacent Land Use on Wetland Amphibian Species Richness and Community Composition. Canadian Journal of Fisheries and Aquatic Sciences. 60(9): 1078-1094.

Hursh, Charles R, 1944.Water Storage Limitations in Forest Soil Profiles, Soil Science Society of America, Proceedings, Vol. 8, (1944)

Jarnagin, S. T. 2007. Historical analysis of the relationship of streamflow flashiness with population density, imperviousness, and percent urban land cover in the Mid-Atlantic region (PDF) (103pp, 5.7MB) Internal Report APM 408. United States Environmental Protection Agency, Office of Research and Development, Environmental Photographic Interpretation Center (EPIC), Reston VA, September 2007, EPA/600/X-07/021, 100p.

Jones, M.P. and W.F. Hunt. 2009. Bioretention Impact on Runoff Temperature in Trout Sensitive Waters.Journal of Environmental Engineering, 135(8): 577-585.

Jones, M.P. and W.F. Hunt. 2010. Effect of Stormwater Wetlands and Wet Ponds on Runoff Temperature in Trout Sensitive Waters. Journal of Irrigation and Drainage Engineering. 136(9): 656-661.

Jones, M.P., W.F. Hunt, and R.J. Winston. 2012. Effect of Urban Catchment Composition on Runoff Temperature. Journal of Environmental Engineering. 138(12): 1231-1236.

Kashuba, Roxolana, McMahon, Gerard, Cuffney, T.F., Qian, Song, Reckhow, Kenneth, Gerritsen, Jeroen, and Davies, Susan, 2012, Linking urbanization to the Biological Condition Gradient (BCG) for stream ecosystems in the Northeastern United States using a Bayesian network approach: U.S. Geological Survey Scientific Investigations Report 2012–5030, 48 p.

Kays, E.L. , 1980. Relationship of Forest Destruction and Soil Disturbance to Increased Flooding in the Suburban North Carolina Piedmont. Metro. Tree Impr. Alliance (METRIA) Proc. 3:118-125.

Kennen, J., K. Murray and K. Beaulieu. Determining hydrologic factors that influence stream macroinvertebrate assemblages in the northeastern US. Ecohydrol. 3, 88–106 (2010)

King, Ryan S, How Novel is too Novel? Stream Community Thresholds at Exceptionally Low Levels of Catchment Urbanization, Ecol Appl 21.1659-1678 (1)

Kratzer, E., J. Jackson, D. Arscott, A. Aufdemkampe, C. Dow, L. Kaplan, J. Newbold, and B. Sweeney. 2006. Macroinvertebrate Distribution in Relation to Land Use and Water Chemistry in New York City Drinking-Water-Wupply Watersheds. J. N. Am. Benthol. Soc. 25(4): 954-976.

Maryland Department of the Environment (MDE), 2009. Maryland Stormwater Design Manual. Available at:
http://www.mde.state.md.us/programs/Water/StormwaterManagementProgram/MarylandStormwaterDesignManual/Pages/programs/waterprograms/sedimentandstormwater/stormwater_design/index.aspx

Maryland Department of Natural Resources, 2012. River/Stream Management Strategy, Guiding Principles.
http://www.dnr.state.md.us/streams/pdfs/RiverStream_MgtStrat_GuidingPrinciples_092612.pdf

Maryland Department of Natural Resources (undated) Impacts of Impervious Cover on Maryland Streams. Stream Health Fact Sheet.
http://www.dnr.state.md.us/streams/pdfs/ImperviousFactSheet.pdf

Mclaughlin R. A., S.E. King and G.D. Jennings, 2009. Improving construction site runoff quality with fiber check dams and polyacrylamide. Journal of Soil and Water Conservation March/April 2009 vol. 64 no. 2 144-154

Meyer, J., D. Strayer, J. Wallace, S. Eggert, G. Helfman and N. Leonard. 2007. The contribution of headwater streams to biodiversity in river networks.Journal of American Water Resources Association 43(1): 86-103

Miltner, R, D. White, and C. Yoder. 2004. The Biotic Integrity of Streams in Urban and Suburbanized Landscapes. Landscape and Urban Planning. 69.

Moglen, G.E.; Nelson, K.C.; Palmer, M.A.; Pizzuto, J.E.; Rogers, C.E.; Hejazi, M.I. Hydro-ecologic responses to land use in a small urbanizing watershed within the Chesapeake Bay Watershed. In Ecosystems and Land Use Change; DeFries, R., Asner, G.P., Houghton, R.A., Eds.; AGU Geophysical Monograph Series: Washington DC, USA, 2004; Volume 153, pp. 41-60.

Montgomery County Department of Environmental Protection (MCDEP). 2003. Countywide Stream Protection Strategy, 2003 Update.

MCDEP, 2012. Special Protection Area Program Report, 2010. Available at: http://www6.montgomerycountymd.gov/content/dep/downloads/spa_reports/2010_SPA_Report.pdf

Moore, A. and M. Palmer. 2005. Invertebrate diversity in agricultural and urban headwater streams. Ecological Applications. 15: 1169-1177.

Morgan, R.P., and S.F. Cushman. 2005. Urbanization Effects on Stream Fish Assemblages in Maryland, USA. J. N. Am. Benthol. Soc. 24(3): 643-655.

Resources Conservation Service (NRCS). 1986. Technical Release 55: Urban Hydrology for Small Watersheds, 2nd Edition. Washington, D.C.

New York State Department of Environmental Conservation (NYSDEC), 2010. New York State Stormwater Management Design Manual. Avaialble at: http://www.dec.ny.gov/chemical/29072.html

O'Driscoll, M., S. Clinton, A. Jefferson, A. Manda and S. McMillan, 2010. Urbanization Effects on Watershed Hydrology and In-Stream Processes in the Southern United States. Water 2010, pp 605-648. www.mdpi.com/2073-4441/2/3/605/pdf

Olszewski, J. and A. Davis, 2013. Comparing the Hydrologic Performance of a Bioretention Cell with Predevelopment Values. Journal of Irrigation and Drainage Engineering, 139:124-130

Ourso, R., and A. Frenzel. 2003. Identification of Linear and Threshold Responses in Streams along a Gradient of Urbanization in Anchorage, Alaska. Hydrobiologia. 501: 117-131.

Page, N. and P. Lilly, 2010. Analysis of Streamflow, Water Quality, and Benthic Community Changes in North Creek (1999–2009). Prepared for: City of Surrey, British Columbia

Pitt, R. S. Chen, S. Clark and J. Lantrip. 2005. Soil structure effects associated with urbanization and the benefits of soil amendments. World Water and Environmental Resources Congress. Conference Proceedings. American Society of Civil Engineers. Anchorage, AK.

Pitt, R., T. Brown and R. Morchque. 2004. National Stormwater Quality Database. Version 2.0. University of Alabama and Center for Watershed Protection. Final Report to U.S. Environmental Protection Agency.

Reice, S. 2000. Regulating Sedimentation and Erosion Control into Streams: What Really Works and Why. In: National Conference for Urban Water Resource Management and Protection. Chicago, IL. Pp. 291-295

Roy, A., B. Freeman and M. Freeman. 2007. Riparian influences on stream fish assemblage structure on urbanizing streams. Landscape Ecology.

Roy, A., M. Freeman, B. Freeman, S. Wenger, J. Meyer, W. Ensign. 2006. Importance of Riparian Forests in Urban Catchments Contingent on Sediment and Hydrologic Regimes. Environmental Management. 37(4): 523-539

Roy, A., M. Freeman, B. Freeman, S. Wenger, W. Ensign and J. Meyer. 2005. Investigating hydrologic alteration as a mechanism of fish assemblage shifts in urbanizing streams. J. N. Am. Benthol. Soc.,24(3):656–678

Rubbo, M.J., and J.M. Kiesecker. 2005. Amphibian Breeding Distribution in an Urbanized Landscape. Conservation Biology. 19: 504-511

Saxton, K. and W. Rawls, 2006. Soil Water Characteristic Estimates by Texture and Organic Matter for Hydrologic Solutions. Soil Sci. Soc. Am. J. 70:1569–1578.

Schueler, T., L. Fraley-McNeal and K. Cappiella, 2009. Is Impervious Cover Still Important? : Review of Recent Research. Journal of Hydrologic Engineering, 14(4): 309-315.

Schueler, T., 1994. The Importance of Imperviousness. Watershed Protection Techniques, 1(3): 100-111.

Schueler, T. 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban Best Management Practices. MWCOG. Washington, D.C.

Schueler, T. and C. Lane. 2012. Recommendations of the Expert Panel to Define Removal Rates for New State Stormwater Performance Standards. Chesapeake Stormwater Network, Ellicott City, MD

Selbig, S.R. and Bannerman, R.T. (2008) A comparison of runoff quantity and quality from two small basins undergoing implementation of conventional-and low-impact-development (LID) strategies: Cross Plains, Wisconsin, water years 1999-2005: US Geological Survey Scientific Investigations Report 2008-5008, 57 p.

Snyder, C.D., J.A. Young, R. Villela, and D.P. Lemarie. 2003. Influences of Upland and Riparian Land Use on Stream Biotic Integrity. Landscape Ecology 18: 647-664.

Urban, M., D. Skelly, D. Burchsted, W. Price and S. Lowry. 2006. Stream communities across a rural-urban landscape gradient. Diversity and Distributions. 12: 337-350

Van Ness, K. 2012. Personal Communication.

Winston, R.J., W.F. Hunt, and W.G. Lord. 2011. Thermal Mitigation of Urban Stormwater by Level Spreader - Vegetative Filter Strips. Journal of Environmental Engineering. 137(8), 707-716.

Woltemade, Christopher J., 2010. Impact of Residential Soil Disturbance on Infiltration Rate and Stormwater Runoff. Journal of the American Water Resources Association (JAWRA) 46(4): 700-711.

Zimmerman, M.J., Waldron, M.C., Barbaro, J.R., and Sorenson, J.R., 2010. Effects of Low-Impact Development (LID) Practices on Streamflow, Runoff Quantity, and Runoff Quality in the Ipswich River Basin, Massachusetts: A Summary of Field and Modeling Studies. USGS Circular 136

Attachment E. Spatial Watershed Analysis

MEMORANDUM

Date: June 13, 2013

To: Mary Dolan and Valdis Lazdins, Montgomery County Planning Department

From: Biohabitats and Brown and Caldwell, a Joint Venture

RE: Ten Mile Creek Watershed Environmental Analysis in Support of the Clarksburg Master Plan Limited Amendment

SUBJ: Spatial Watershed Analysis

The Ten Mile Creek watershed in northwestern Montgomery County is the focus of an environmental analysis study in support of the Limited Amendment to the Clarksburg Master Plan, being undertaken by the Maryland-National Capital Park and Planning Commission (M-NCPPC) Montgomery County Planning Department. This environmental analysis is being conducted for the Planning Department by Biohabitats and Brown and Caldwell, a Joint Venture, with support from the Center for Watershed Protection. It is being done in collaboration with Montgomery County Department of Environmental Protection (DEP) and Montgomery County Department of Permitting Services (DPS).

As the purpose of this study is to determine the baseline environmental conditions in order to evaluate potential watershed response to development within the Ten Mile Creek watershed, this analysis focuses on subwatersheds upstream of the USGS gage station and those that have the potential to be directly affected by development. These subwatersheds are referred to as the "study area."

The 1994 Clarksburg Master Plan allows for development in the eastern portion of the watershed. This memorandum presents a Spatial Watershed Analysis of both existing conditions and implementation of the 1994 Master Plan. The intent of this analysis is to identify areas that have high resource value and support watershed health. This memorandum is intended to provide a description of that analysis, the methods used, supporting maps, and a description of the results.

NOTE: Planimetric information shown in this document is based on copyrighted GIS Data from M-NCPPC, and may not be copied or reproduced without express written permission from M-NCPPC.

METHODS

The conceptual basis of this analysis is centered on Geographical Information System (GIS) information that can be used to map important watershed health characteristics or attributes such as forested areas, wetlands, streams, and green infrastructure, etc. The areas (or in GIS terminology "polygons") in the watershed where these important attributes occur were assigned a value of 1 point, and the areas where they did not occur were assigned a value of 0. These attribute maps were overlaid on each other and analyzed to help identify, define the areal extent of, and measure and describe areas that contribute to watershed health.

Attribute Data

Available existing GIS data pertaining to natural resource attributes that are important for water quality and ecological health were collected. These data were provided by the Montgomery County Planning Department and DEP. Mapping summarizing these attributes is included in the report "Existing Conditions in the Ten Mile Creek Study Area, in support of the Limited Amendment to the Clarksburg Master Plan" prepared for the Planning Department by the Joint Venture.

The attribute data used in this analysis includes:

- Steep Slopes, >15%
- Steep Slopes, >25%
- Erodible Soils
- Hydric Soils
- Forest
- Interior Forest
- 100-Year Floodplain
- Perennial/Intermittent Streams with associated 175' Buffer
- Ephemeral Channels with associated 25' Buffer
- Wetlands and associated 25' Buffer
- Springs, Seeps & Seasonal Ponds with associated 25' Buffer

The attributes selected for the spatial analysis align with Montgomery County's Environmental Guidelines and DEP's definition of environmentally sensitive areas (Montgomery County Department of Park and Planning, 2000). To provide for growth while protecting Montgomery County's natural resources, all proposals for development in Montgomery County are reviewed in terms of environmental impact and protection before being approved by the planning Board. The Guidelines for Environmental Management of Development in Montgomery County provides guidance "regarding appropriate techniques to protect natural resources during the development process" (Montgomery County Department of Park and Planning, 2000). These guidelines are "applied to protect sensitive environmental features on development plans" (Montgomery County Department of Park and Planning, 2000). Sensitive areas include streams and their buffers, 100-year floodplains, habitat of threatened and endangered species, erodible soils and steep slopes (Montgomery County Department of Park and Planning, 2000).

In addition, any development activity within a Special Protection Area (SPA), unless exempted, must go through a water quality review process by completing monitoring and reporting according to the approved Water Quality Plan and county regulations. An element of the Water Quality Plan includes the preservation of environmentally sensitive areas and priority forest conservation areas. Environmentally sensitive areas "refers to areas having beneficial features to the natural environment, including but not limited to: steep slopes; habitat for Federal and/or State rare, threatened, and endangered species; 100-year ultimate floodplains; streams; seeps; springs; wetlands, and their buffers: priority forest stands; and other natural features in need of protection" (Montgomery County Department of Environmental Protection, 2012).

Data Layers Created in GIS Information Inventory

For each attribute included in this analysis, a data layer was created in GIS to display conditions within the study area. All attribute layers were then overlaid and combined for use in one map to contain all available baseline data and ensure that all data would be compatible in the analysis (e.g., interior forest and buffer boundaries). That map represents an inventory of information available for this analysis.

Below is a description of each attribute used in this analysis.

- **Steep Slopes >15% and >25%:** Steep slopes are a sensitive environmental feature addressed in the Guidelines for Environmental Management of Development in Montgomery County and can influence buffer widths of other sensitive environmental features and/or can prohibit certain development activities. Steep slopes are defined as having a gradient equal to or greater than 25 percent. However, in SPAs, steep slopes are slopes greater than 15 percent. The guidelines recommend that steep slopes should be incorporated into open space and/or remain undisturbed (Montgomery County Department of Park and Planning, 2000).

- **Erodible Soils:** Erodible soils are soil classified as having "severe hazard of erosion by the NRCS" in the 1995 Soil Survey of Montgomery County (Montgomery County Department of Park and Planning, 2000). As mentioned in the Guidelines for Environmental Management of Development in Montgomery County, erodible soils should be incorporated into open space when possible and managed appropriately during construction. Erodible soils in conjunction with steep slopes can influence the buffer width around natural resources (i.e. streams and wetlands) (Montgomery County Department of Park and Planning, 2000).

- **Hydric Soils:** Hydric soils are "soils that formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part" (Soil Survey, 2013). The hydric soil category rating of a soil map unit indicates the proportion of a map unit that meets the hydric soil definition (Soil Survey, 2013). The presence of hydric soils indicates a potential condition for a wetland resource and a potential limitation with respect to development (i.e. depth to saturated zone and slow water movement) (Soil Survey, 2013).

- **Forest:** A forest, as defined by the County's Forest Conservation Law (1992 L.M.C., ch. 4, § 1), is a "biological community dominated by trees and other woody plants (including plant communities, the understory, and forest floor) covering a land area which is 10,000 square feet or greater and at least 50 feet wide. Among the numerous ecosystem services forests provide are food and cover for

wildlife, temperature regulation, carbon sequestration and nutrient cycling. All forest polygons were included in the spatial analysis.

- **Interior Forest:** Montgomery County designates interior forest as 1) contiguous forest tracts consisting of a minimum of 50 acres in size with 10 or more acres of forest more than 300 feet from the nearest forest edge, or 2) a riparian forest with an average minimum width of 300 feet and at least 50 acres in size. These forest interiors that can support forest interior dwelling birds that require large forest areas to breed and maintain viable populations (Jones, McCann, & McConville, 2000).

- **100-year Floodplain:** The 100-year floodplain is the land area within the limits of the 100-year storm flow water elevation which have a 1 percent annual chance of occurring. Floodplain guidelines in the Guidelines for Environmental Management of Development in Montgomery County "are based on existing State and County regulations that govern development activities in these areas" (Montgomery County Department of Park and Planning, 2000). The guidelines restrict or even prohibit new development within the 100-year floodplain to prevent flood hazards and conserve habitats (Montgomery County Department of Park and Planning, 2000).

- **Perennial/Intermittent Streams:** Streams consist of either perennial (continually flowing) or intermittent (seasonally flowing) channels that convey concentrations of groundwater and stormwater runoff along with various dissolved and suspended materials across the landscape. Streams and their riparian corridor (terrestrial area transitioning from a water body to an upland) perform various biophysical and biogeochemical processes, including uptake of nutrients and pollutants and provide other ecosystem services, such as freshwater and habitat for wildlife. The importance of streams and their associated riparian corridor is recognized in stream buffer requirements described in the County's Environmental Guidelines (Montgomery County Department of Park and Planning, 2000), and is represented in the spatial analysis the DEP stream layer and associated 175-foot buffer along each side of the stream.

- **Ephemeral Channels:** Ephemeral channels are defined channels that are above the groundwater table and convey flow only during and shortly after a rain event. These channels are situated at the top of a watershed where water first concentrates and typically have direct connections to a stream channel. As a conduit into perennial/intermittent streams, protection of the quality of these channels is an important component of stream health. Ephemeral channels are regulated by the U.S. Army Corps under the authority of the Clean Water Act (1972) and are represented in the spatial analysis as the regulated stream channel and include an unregulated 25-foot buffer strip to account for their role in stream health. The basis for the 25-foot buffer is consistent with the minimum buffer around non-tidal wetlands regulated by Maryland Department of Environment (MDE) and U.S. Army Corps guidance on maintaining buffer strips for water quality considerations (Fischer and Fischenich, 2000 and Fischer, 2002).

- **Wetlands:** A wetland is an area "inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions" (Environmental Laboratory, 1987). Some environmental benefits that wetlands provide include water purification, flood protection, groundwater recharge and streamflow maintenance, and wildlife habitat. Wetlands are also a

natural resource that may be subject to regulatory jurisdiction under Section 404 of the Clean Water Act or Section 10 of the Rivers and Harbors Act (Environmental Laboratory, 1987). From a regulatory perspective, environmental protection and permitting requirements are in place at the federal and state level for construction related activities within or adjacent to wetland resources. In the GIS analysis, a buffer of 25 feet was assigned around mapped wetlands. The 25-foot buffer is regulated by MDE under the authority of the Maryland Non-tidal Wetlands Protection Act (1989).

- **Springs, Seeps, and Seasonal Pools:** A seep is defined as a water feature exclusively fed by groundwater and does not typically flow, whereas a spring is a water feature fed by groundwater that flows intermittently or constantly (Montgomery County Department of Environmental Protection, 2012). Seeps and springs in the headwaters of tributaries to Ten Mile Creek are necessary to maintain base flows in headwater streams and to provide habitat for trout and other sensitive aquatic species that rely on cool, clean water (Montgomery County Planning Department & Montgomery County Department of Environmental Protection, 2013).

  A seasonal pool or vernal pool is a small, temporary body of water not directly connected to a flowing stream. Seasonal pools are important because they support unique habitat for amphibians and aquatic invertebrates (Stanko, et. al., 2010).

  Springs seeps and seasonal pools are regulated by MDE under the authority of Maryland Non-tidal Wetlands Protection Act and were buffered by 25 feet as discussed for the wetlands. In the GIS analysis, a buffer of 25 feet was assigned around mapped springs, seeps, and seasonal pools.

Attribute Conversion to Metrics-Scoring Methodology

Each attribute included in this analysis has associated with it a benefit to **watershed health**. In order to allow the GIS software to help identify areas with important watershed health characteristics, numerical values are assigned to different attribute areas, using a simple presence/absence approach (Table 1). If an attribute has a positive effect, then the areas in which that attribute are present are assigned a value of one. Areas where the attribute does not occur are assigned a value of zero.

For instance, research has shown that forested areas enhance the rate of runoff infiltration, filter and cleanse pollutants from stormwater, and provide habitat for many species of plants and animals. These characteristics are beneficial to watershed health. Therefore, forested areas (and the mapped polygons or areas associated with them in GIS) are assigned a numerical value of one in the forest attribute GIS layer. Areas that are not mapped as forested are assigned a value of zero.

The strategy of using the same numerical value of one for the presence of each one of the beneficial attributes is intentional. This analysis is intended to identify areas that are important to watershed health, without necessarily weighting one attribute's value more than another's. Using the zero/one ranking strategy assigns the same value of benefit to each attribute. Ranking watershed attributes and documenting their relative values in the scientific literature is beyond the scope of this analysis.

Table 1. Attribute Summary and Metric Scores

Attribute	Score	
	Present	Absent
Steep Slopes, >15% – presence/absence	1	0
Steep Slopes, >25% – presence/absence	1	0
Erodible Soils – presence/absence	1	0
Hydric Soils– presence/absence	1	0
Forest – presence/absence	1	0
Interior Forest – presence/absence	1	0
FEMA 100-Year Floodplain – presence/absence	1	0
Perennial/Intermittent Streams – presence/absence	1	0
Ephemeral Channels – presence/absence	1	0
Wetlands – presence/absence	1	0
Springs, Seeps, and Pools – presence/absence	1	0
Maximum Possible Score	**11**	

Composite Map

Using GIS, attribute layers can be overlain to display on top of one another, and also combined and summed such that attribute values are "stacked up" in each area of the map. When the layers are overlain, all the values associated with each attribute layer are assigned their corresponding point on the ground in the watershed. The resulting composite map will have all the boundaries of every attribute, which creates numerous intersecting boundaries and creates many areas where multiple attributes may overlap. The polygons created when all the attributes are overlain contain all of the values for all the attributes that pertain to that particular area in the watershed. GIS sums all the values of the attributes for each point on the ground and the attribute sum is assigned to each polygon created. The result is a map with many polygons or areas. Each polygon has an attribute total score associated with it. The lowest possible score for a mapped area is zero (no attributes present) The highest possible score for a mapped area is equal to the number of attributes used in the analysis is 11.

An algorithm in ArcGIS software (Natural Breaks-Jenks Classification) was used to create statistical categories for the range of possible values. The algorithm combines two methods. The first is Natural Breaks, where the data is partitioned into categories based on natural groups in distribution (low points in the data histogram). The second is the Jenks Classification, a method of statistical data classification that partitions data into classes using an algorithm that calculates groupings of data values based on the data distribution. Jenks optimization seeks to reduce variance within groups and maximize variance between groups. The number of categories that the Natural Breaks-Jenks Classification algorithm computes is determined by the user. For this analysis, the data was additionally analyzed using three and five categories. GIS was then used to create a map with different color shades for each three- and five-category analysis.

Alternative Analysis- Forest Interior Not Included

An alternative analysis using the methodology described above was conducted with the forest interior layer removed. This alternative analysis had a maximum potential score of 10 versus 11. The reasoning behind this alternative analysis was to more directly evaluate stream quality as opposed to overall watershed health.

RESULTS

Existing Conditions

The composite natural resource attribute scores for the Ten Mile Creek study area are summarized in Figure 1, Figure 1a and Table 2. Figures 1 and 1a utilize a different shade of green to represent the total number of attributes that occur at a point on the landscape in the analysis. The darker green areas have higher numbers of attributes present and are generally associated with the presence of the stream system and its buffer areas, forested areas, and wetlands.

When including forest interior, 11 natural resource attributes were analyzed and the maximum number of attributes present at any location in the study area is nine. Without forest interior the maximum number of natural resource attributes present at any location is eight. The total land area occupied by natural resource attributes is summarized in Table 2.

Table 2. Summary of Land Area and Natural Resources Attribute Scores

Attribute/Natural Resources Score	With Forest Interior		Without Forest Interior	
	Area (Acres)	% of Study Area	Area (Acres)	% of Study Area
0	1,154.6	38%	1,154.6	38%
1	683.4	22%	821.7	27%
2	515.3	17%	475.2	16%
3	319.9	11%	305.1	10%
4	216.9	7%	181.5	6%
5	105.3	3%	92.5	3%
6	44.0	1%	14.1	0%
7	6.3	<1%	1.6	0%
8	0.7	<1%	<0.	<1%
9	<0.1	<1%	N/A	N/A

Figure 2 (with forest interior) and Figure 2a (without forest interior) are composite maps that use the Natural Breaks/Jenks Classification to create three statistical categories; the baseline attribute data is grouped accordingly, and illustrated using three different shades of green. The darker green indicators a higher presence of natural resource attributes. The consolidation of the data into fewer groups may be helpful in differentiating areas of somewhat similar score values. The total land area occupied by natural resource attributes is summarized Table 3.

Table 3. Natural Resources Attribute Scores, Grouped into Three Categories, and their Corresponding Areas

Attribute Scores/Categories	With Forest Interior		Without Forest Interior	
	Area (Acres)	% of Study Area	Area (Acres)	% of Study Area
0	1,154.6	38%	1,154.6	38%
1 to 2	1,198.7	39%	1,296.9	43%
3 to 9	693.0	23%	594.7	20%

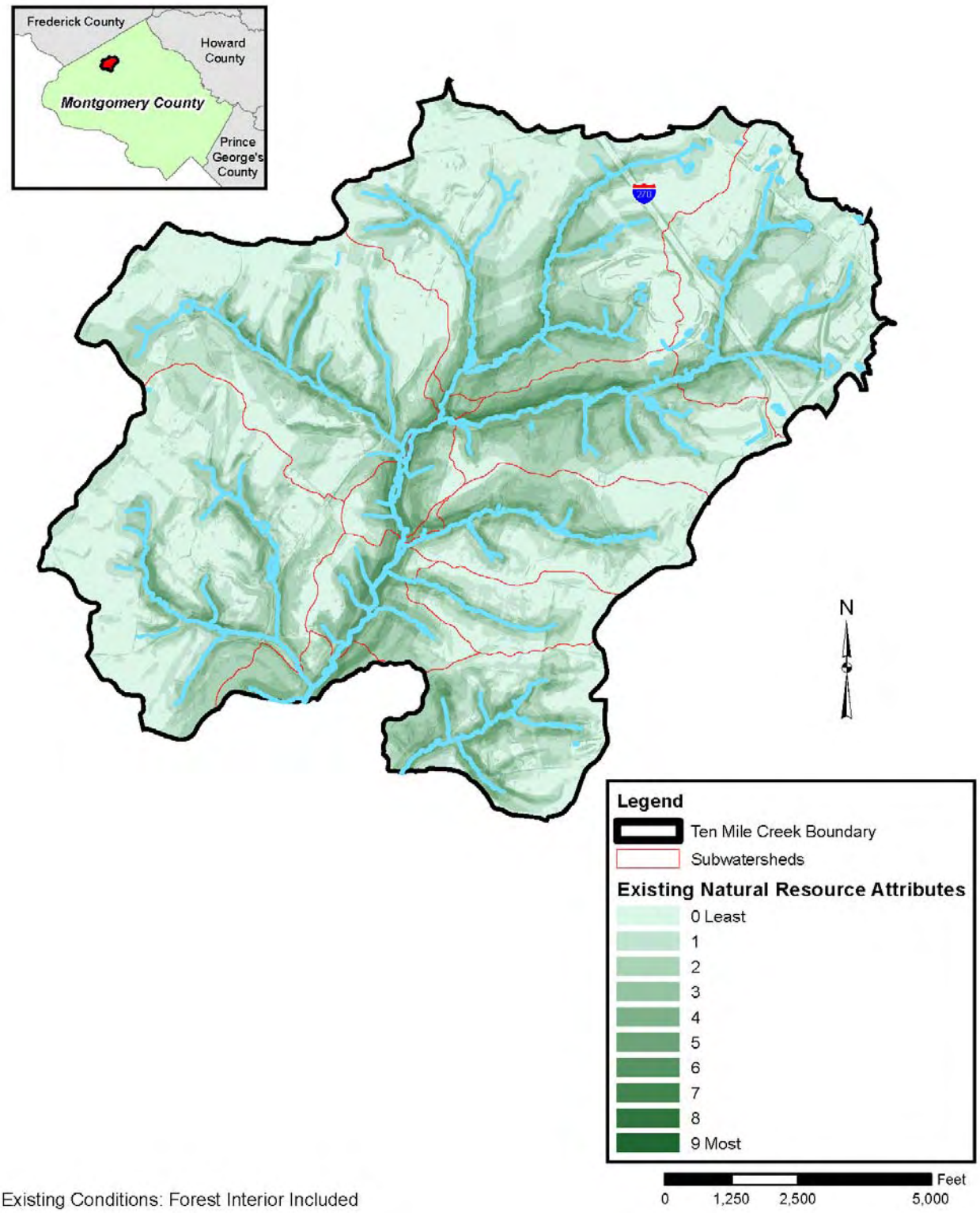


Figure 1a. Natural Resources Attribute Scores for Existing Conditions, Forest Interior Included

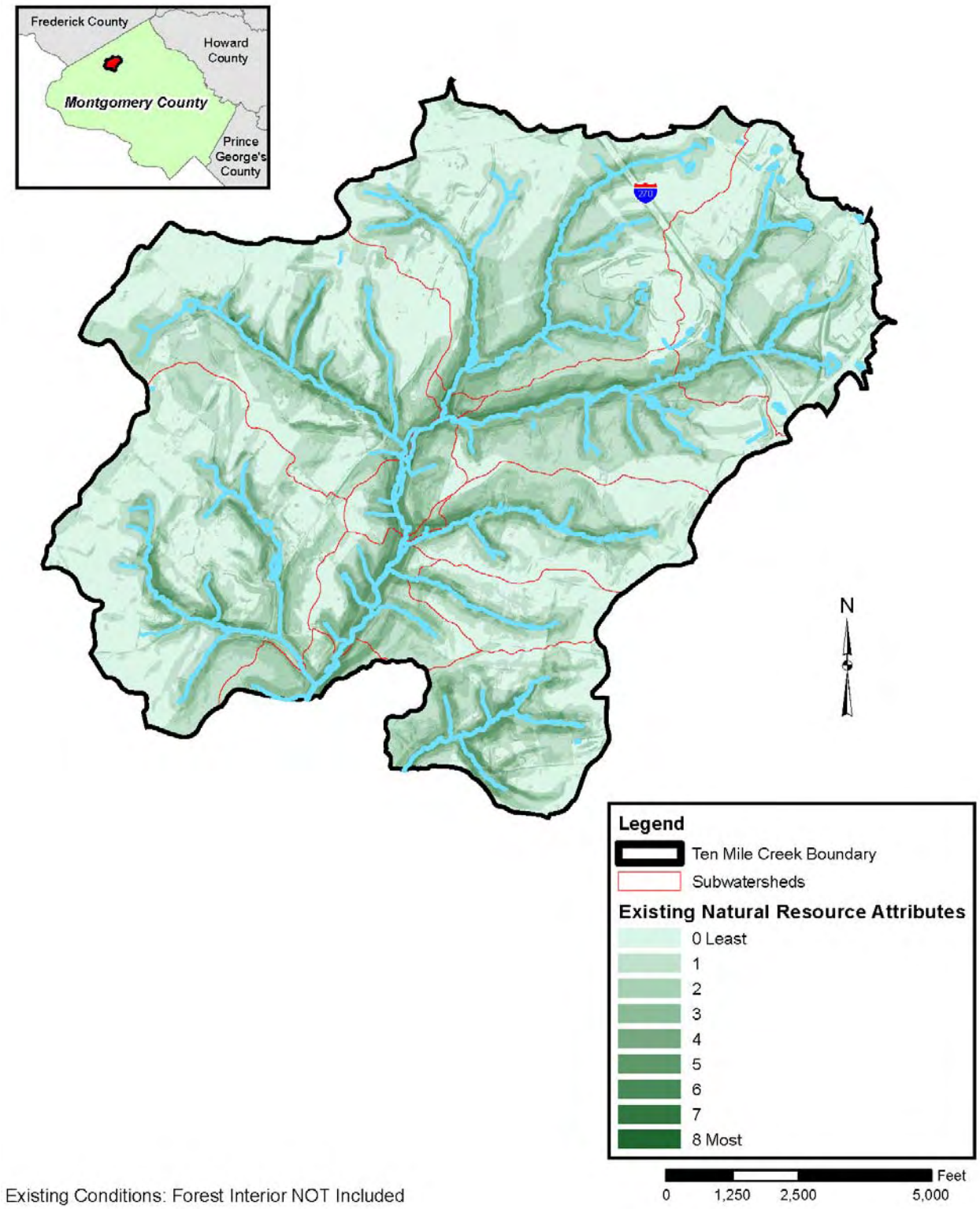


Figure 1b. Natural Resources Attribute Scores for Existing Conditions, Forest Interior Not Included

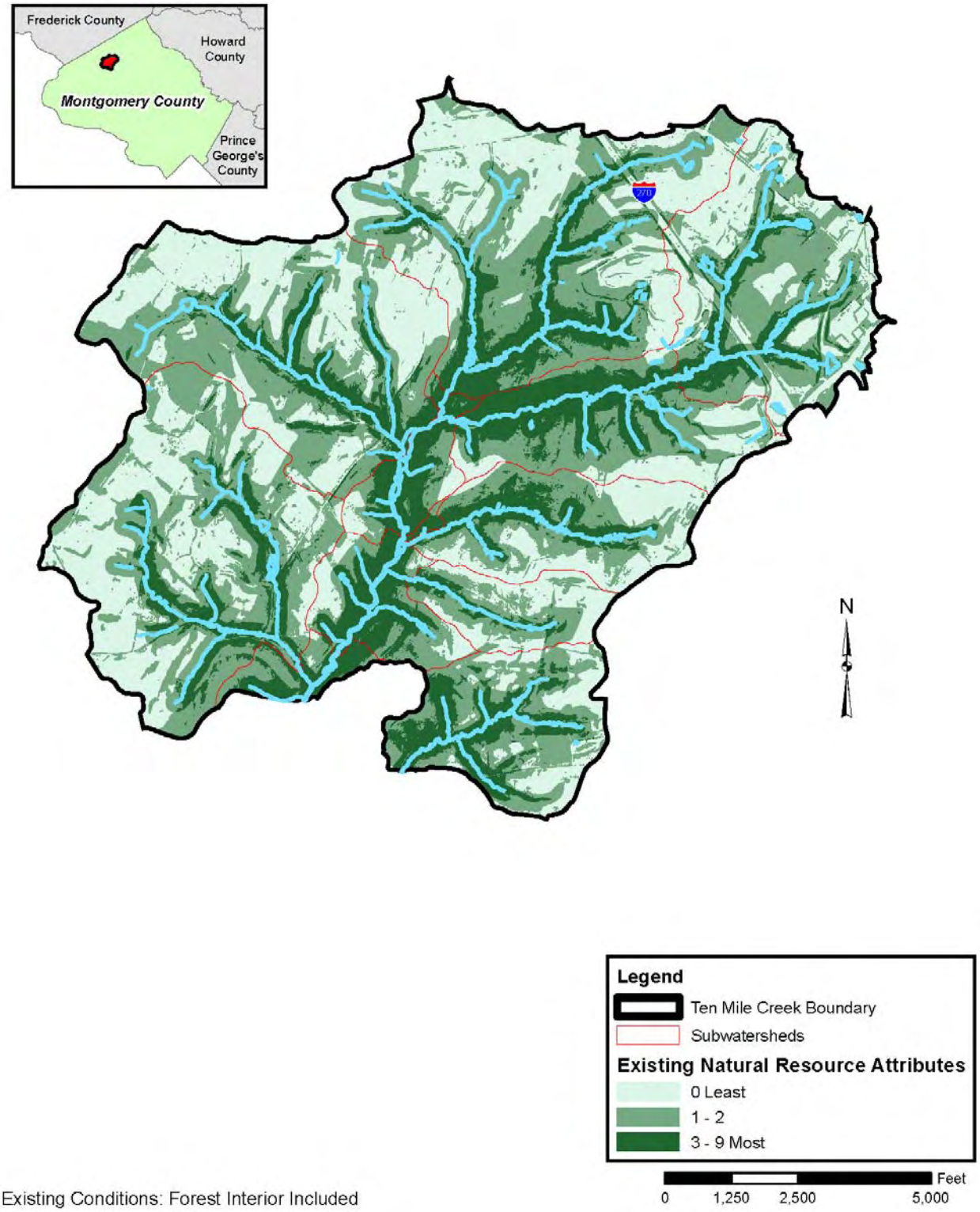


Figure 2a. Natural Resources Attribute Scores for Existing Conditions (Grouped into Three Categories), Forest Interior Included

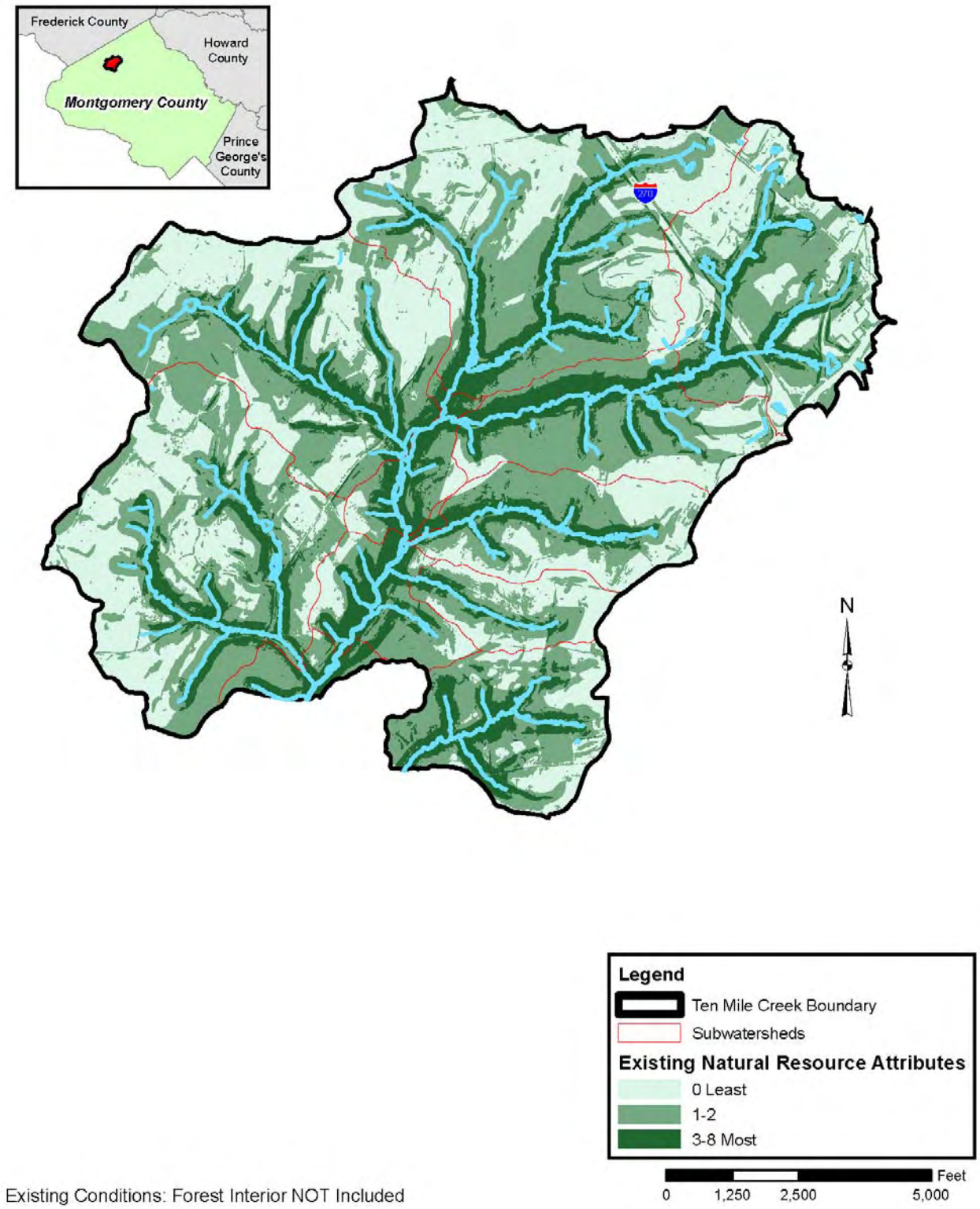


Figure 2b. Natural Resources Attribute Scores for Existing Conditions (Grouped into Three Categories), Forest Interior Not Included

Development Scenario Analysis

The Planning Department crafted four scenarios for future development within the watershed, including:

Scenario 2: 1994 Master Plan – The 1994 Clarksburg Master Plan recommendations for density and land use in Stage 4, assuming full Environmental Site Design for the developable and redevelopable properties.

Scenario 3: Reduced Footprint, Same Yield – The same as Scenario 2 with a reduced footprint for the Pulte properties. Assumes a different unit mix that would allow approximately the same number of units permitted by the 1994 Plan.

Scenario 4: Reduced Footprint Lower Yield – The same as Scenario 3 with the same unit mix as recommended in the 1994 Plan for the Pulte property, resulting in fewer potential units on Pulte.

Scenario 5: 7% Watershed Imperviousness – The same as Scenario 3 with reduced yield on Miles/Coppola, Egan, and the County properties.

The projected limits of disturbance for Scenario 2 and Scenarios 3&4 were overlaid on the existing conditions Spatial Watershed Analysis to identify the extent of potential impacts to natural resources. Scenarios 3&4 have the same projected limits of disturbance, so this analysis applies to both. The limits of disturbance for Scenario 5 are very similar to Scenario 3, so a separate analysis was not conducted as similar results can be expected. In addition, rural residential properties west of Ten Mile Creek were not included in this analysis. It is assumed that when development occurs buildings and infrastructure will be placed within existing open fields and that natural resource disturbance will be minimal.

Scenario 2: 1994 Master Plan

The Planning Department developed projected potential limits of disturbance associated with build-out of the 1994 Master Plan. The projected limits of disturbance are approximately 422 acres, or 14% of the Ten Mile Creek study area. These limits of disturbance were overlaid on the existing conditions Spatial Watershed Analysis, with and without the interior forest attribute, to identify extent of potential impacts to natural resources.

No more than seven natural resource attributes were identified at any location within the projected limits of disturbance. Figure 3 and Table 4 display the results of this analysis, with the attributes grouped into three categories. The darker red areas in the figures have the high numbers of natural resource attributes present that would be impacted by implementation of Scenario 2.

Table 4. Attribute Category (Three) Areas that will be Impacted by Scenario 2

Attribute Scores/Categories	With Forest Interior		Without Forest Interior	
	Area (acres)	% of Disturbed Area	Area (acres)	% of Disturbed Area
0	258.9	61%	258.9	61%
1 to 2	143.8	34%	148.6	35%
3 to 9	19.7	5%	14.9	4%

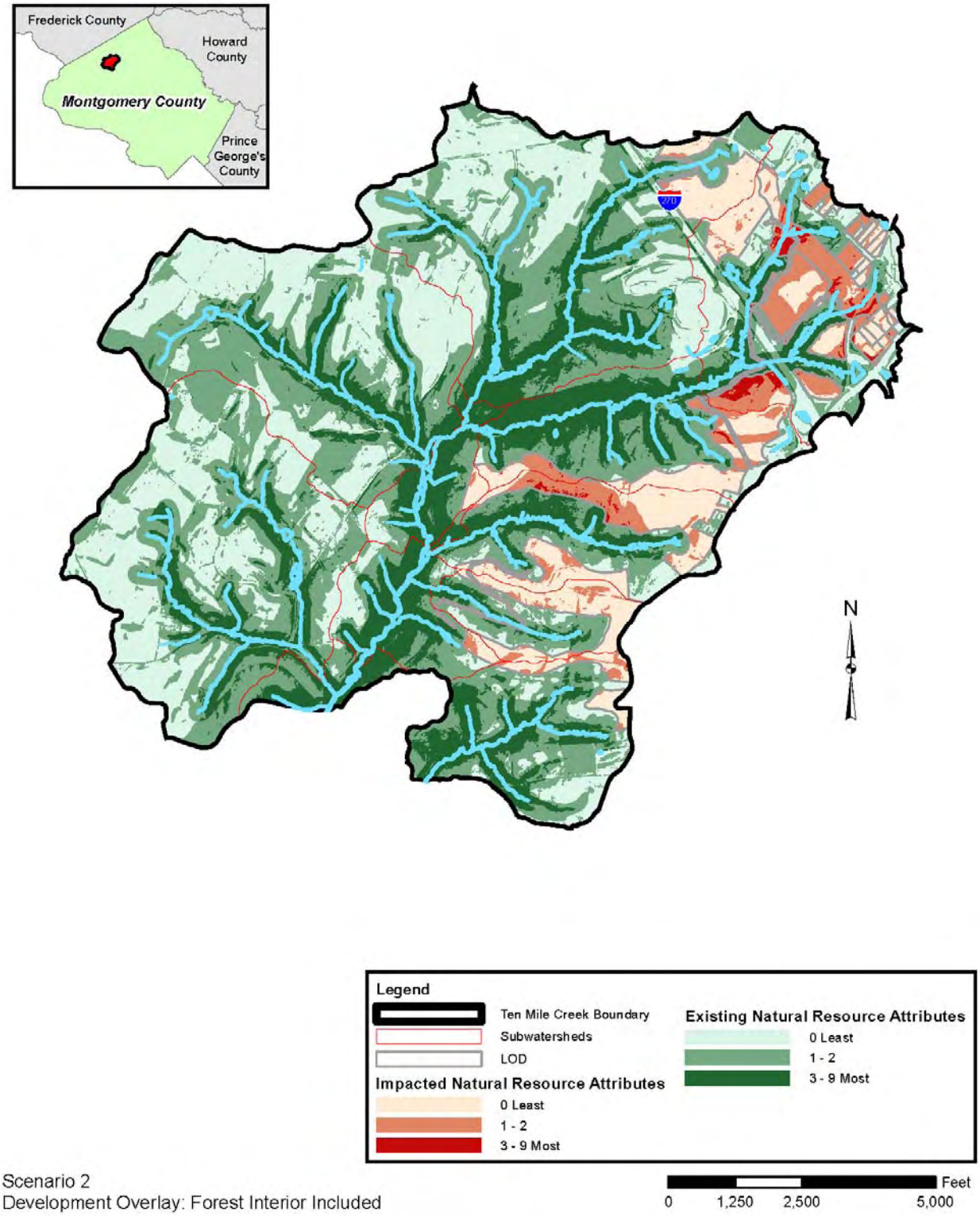


Figure 3a. Natural Resource Attribute Areas that will be Impacted by Scenario 2 (grouped into Three Categories), Forest Interior Included

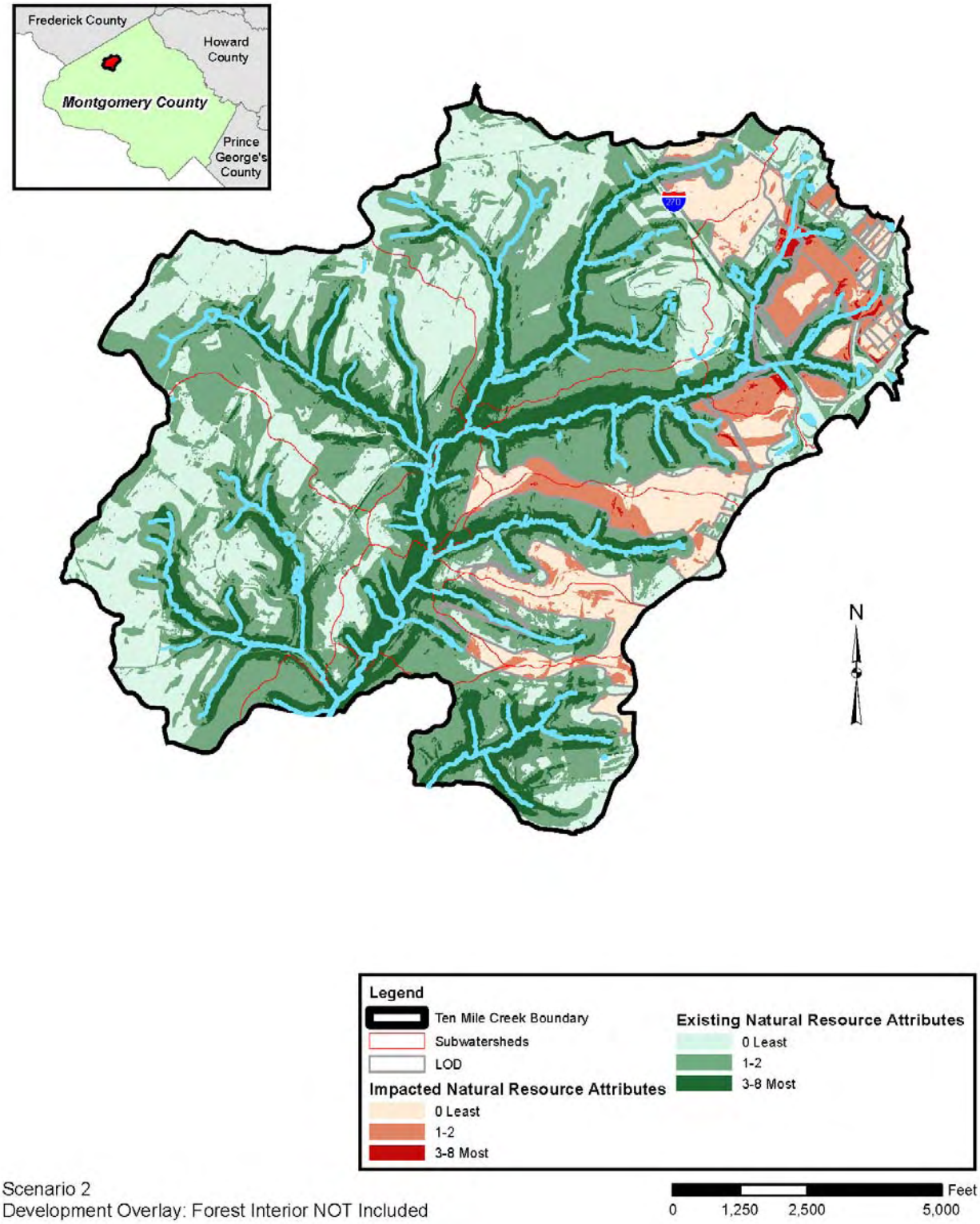


Figure 3b. Natural Resource Attribute Areas that will be Impacted by Scenario 2 (grouped into Three Categories), Forest Interior Not Included

Scenarios 3 and 4: Reduced Footprint

For Scenarios 3 and 4, the Planning Department reduced the footprint of development for selected properties. The projected limits of disturbance are approximately 307 acres, or 10% of the Ten Mile Creek study area. These limits of disturbance were overlaid on the existing conditions Spatial Watershed Analysis, with and without the interior forest attribute, to identify extent of potential impacts to natural resources.

No more than six natural resource attributes were identified at any location within the projected limits of disturbance. Figure 4 and Table 5 display the results of this analysis, with the attributes grouped into three categories. The darker red areas in the figures have the high numbers of natural resource attributes present that would be impacted by implementation of Scenarios 3 and 4.

Table 5. Attribute Category (Three) Areas that will be Impacted by Scenario 2

Attribute Scores/Categories	With Forest Interior		Without Forest Interior	
	Area (acres)	% of Disturbed Area	Area (acres)	% of Disturbed Area
0	221.3	72%	221.3	72%
1 to 2	79.1	26%	79.3	26%
3 to 9	7.0	2%	6.9	2%

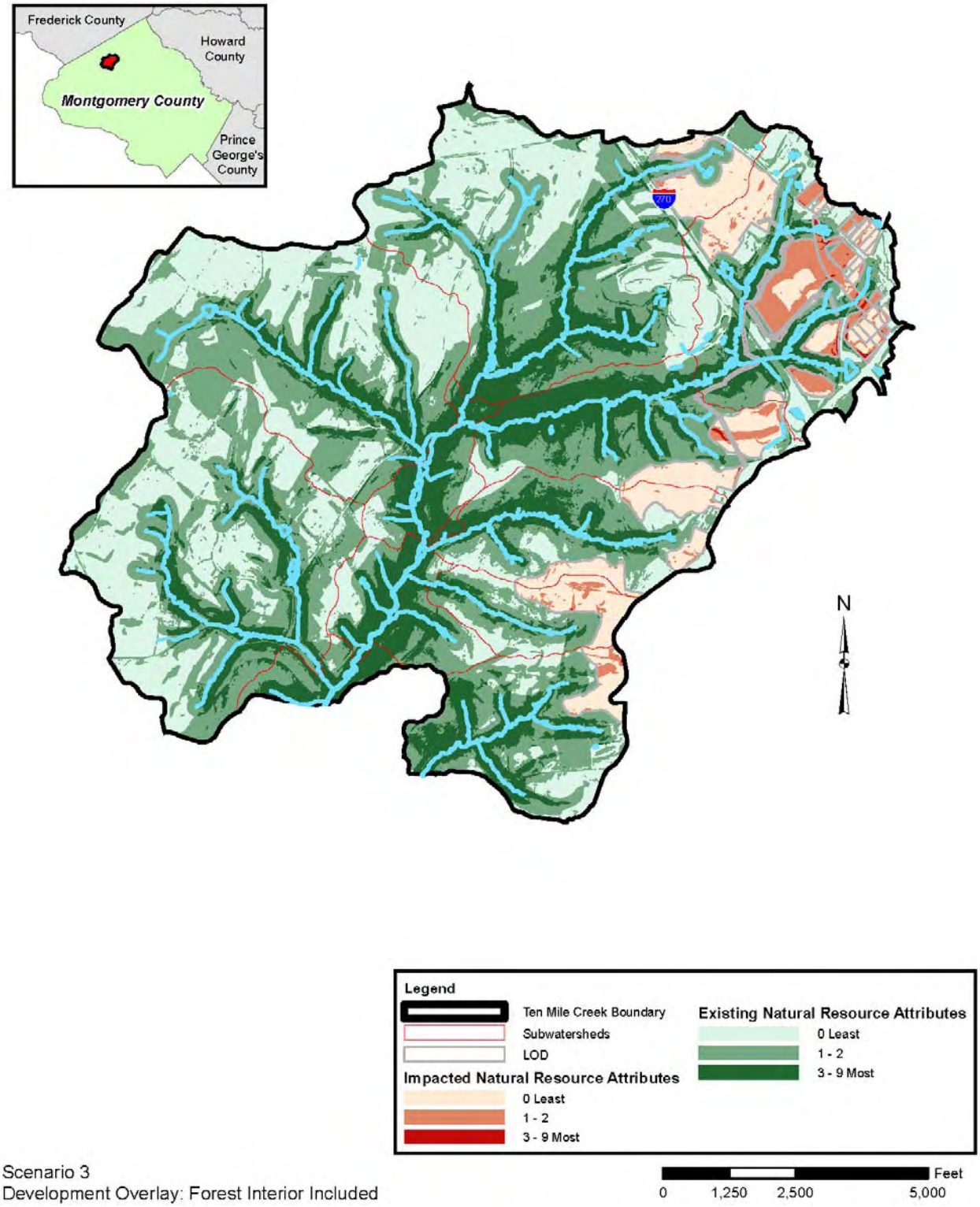


Figure 4a. Natural Resource Attribute Areas that will be Impacted by Scenarios 3 and 4 (grouped into Three Categories), Forest Interior Included

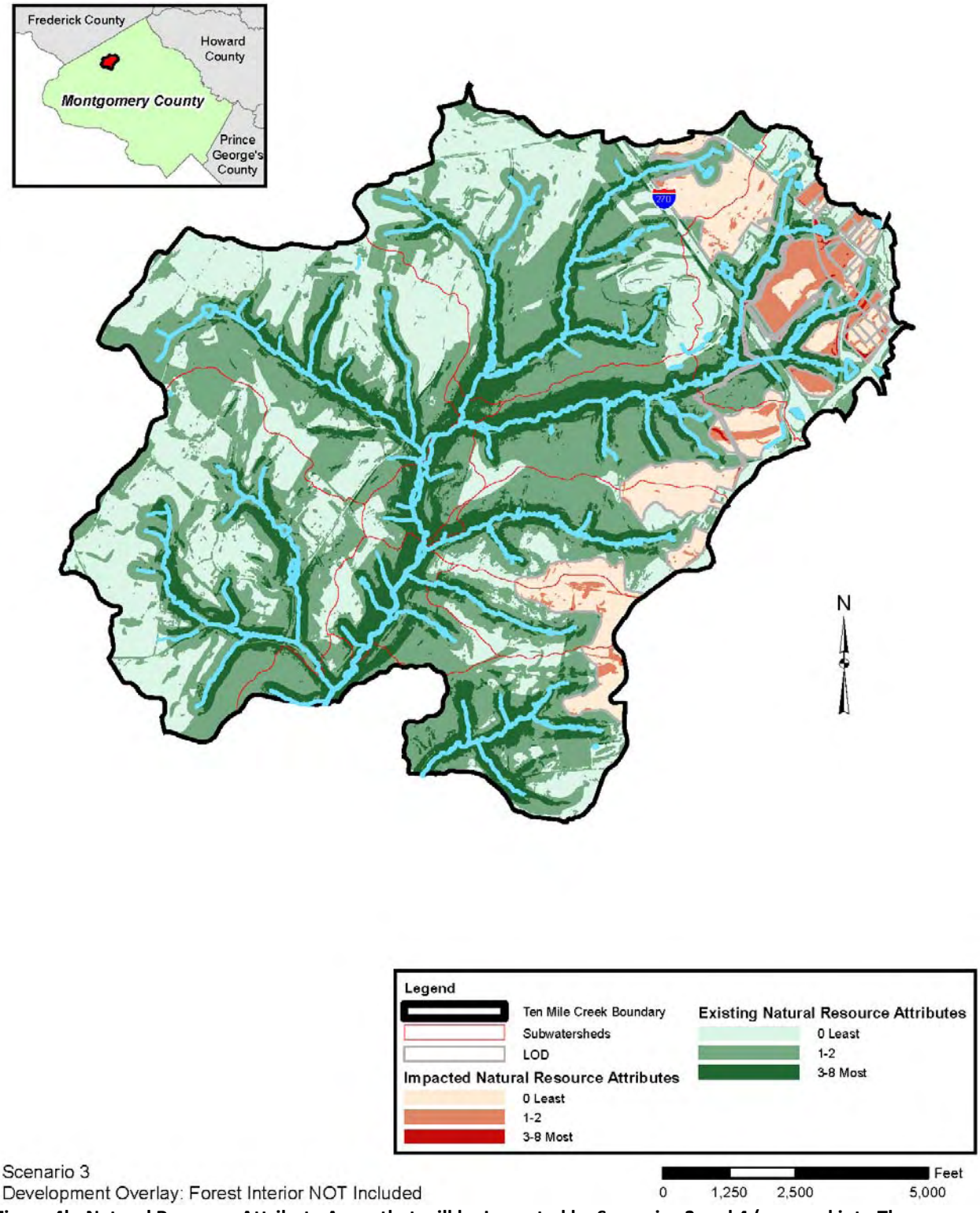


Figure 4b. Natural Resource Attribute Areas that will be Impacted by Scenarios 3 and 4 (grouped into Three Categories), Forest Interior Not Included

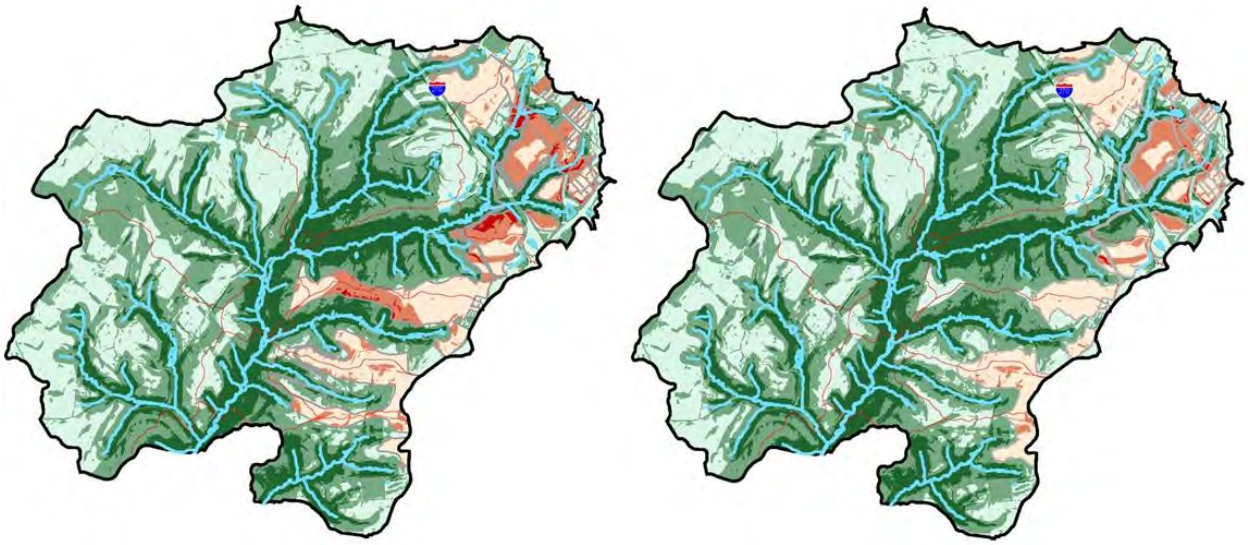
DISCUSSION

Areas of high resource value within the watershed are generally concentrated near the streams, particularly the mainstem, where wetlands, floodplains, forest, springs, seeps and the streams themselves provide critical watershed functions such as rainfall capture and runoff reduction, pollutant filtering, nutrient cycling, overbank flow attenuation and reduction, and aquatic and upland habitat.

Areas of high resource value are also associated with forest interior, largely concentrated along and east of the mainstem, west of I270, extending onto the County and Pulte properties. In response to a request for information related to rare, threatened and endangered species within the study area, the Maryland Department of Natural Resources stated that "analysis of the information provided suggests that the forested area on the project site contains Forest Interior Dwelling Bird habitat. Populations of many Forest Interior Dwelling Bird species (FIDS) are declining in Maryland and throughout the eastern United States. The conservation of FIDS habitat is strongly encouraged by the Department of Natural Resources." (MD DNR, 2013).

Natural resources throughout the study area will be directly impacted by build-out of the 1994 Master Plan (Scenario 2). A significant decrease in impacts is seen in Scenarios 3&4 (Figure 5 and 6).

- Of the 22 miles of streams in the area of the watershed studied, about a half of a mile has the potential to be impacted by build-out of the 1994 Master Plan (Scenario 2). The majority of these impacts would be to small headwater tributaries east of I270, as a result of construction of the MD355 Bypass. Construction of the 355 Bypass may also impact an acre of wetlands and nine of the watershed's 149 springs, seeps and seasonal pools (as identified by Montgomery County Department of Environmental Protection).
- Build-out of the 1994 Master Plan has the potential to impact up to 9% of the watershed's forest – about 120 acres out of 1,389 acres. The largest impacts are associated with the Pulte property, followed by the Miles Coppola; the MD355 Bypass; and the County property.
- Build-out of the 1994 Master Plan would also result in the loss of over 60 acres of interior forest, 16% of interior forest within the study area. About 18 of these acres may be directly impacted by development, namely on the County and Pulte properties. The remaining loss would be attributed to overall reduction in forest cover, reducing the size and buffer of contiguous forest.
- Approximately 57 acres on lands with a slope greater than 15% would be developed under the 1994 Master Plan, with 6 of these acres on lands with a slope greater than 25%. These include the Pulte, County, and Miles Coppola properties, as well as the MD355 Bypass.
- Scenarios 3&4 show a significant decrease in impacts areas with high natural resource value. Forest impacts are reduced from 120 acres to approximately 60 acres, and forest interior impacts are reduced from over 60 acres to approximately 14 acres. Direct stream and wetland impacts are reduced by half, largely due to the proposed realignment of the MD355 Bypass.



Scenario 2 *Scenarios 3 and 4*

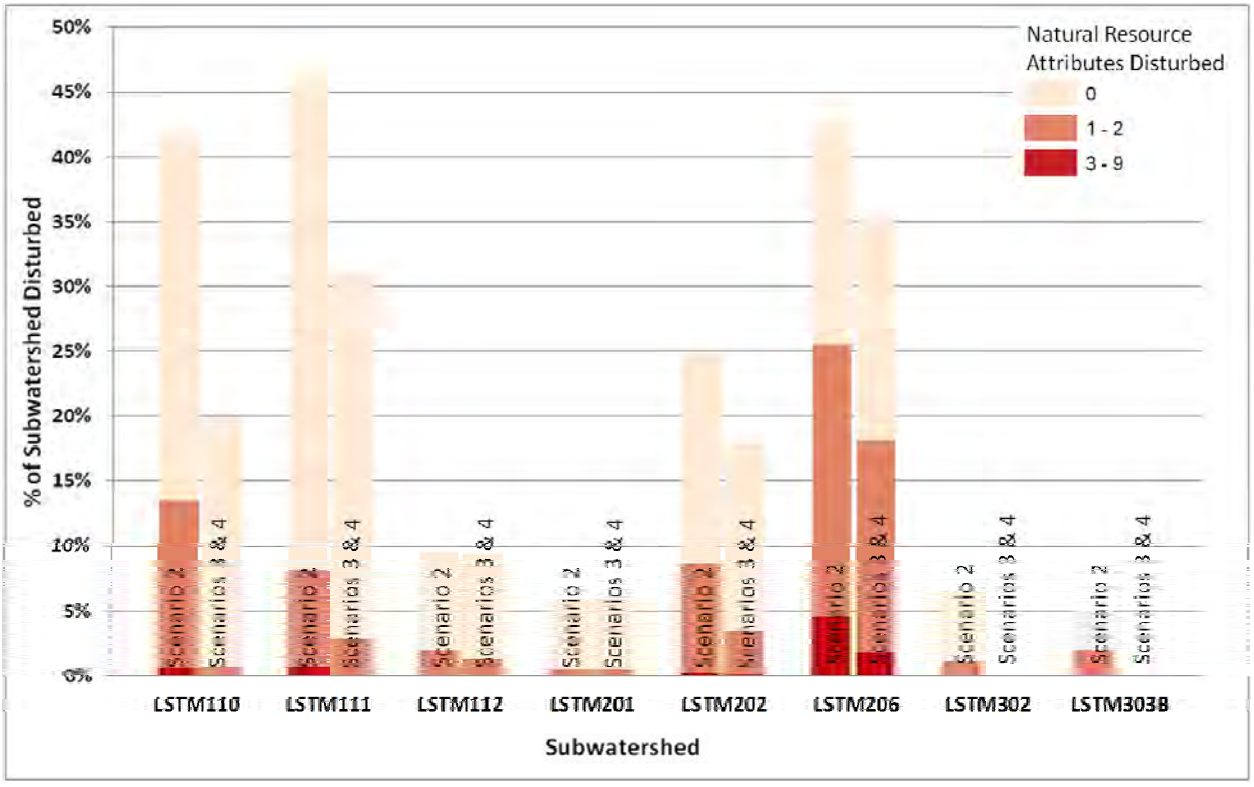
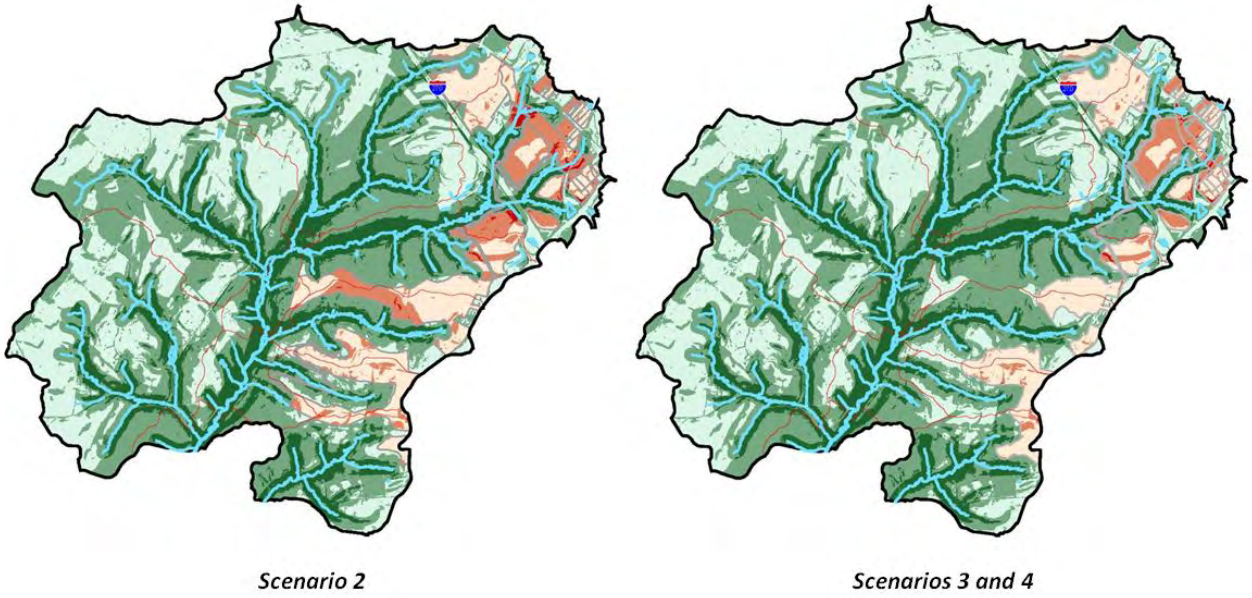


Figure 5. Potential for Disturbance of Natural Resource Attributes in Scenarios 2, 3 and 4
(Forest Interior Included)



Scenario 2 *Scenarios 3 and 4*

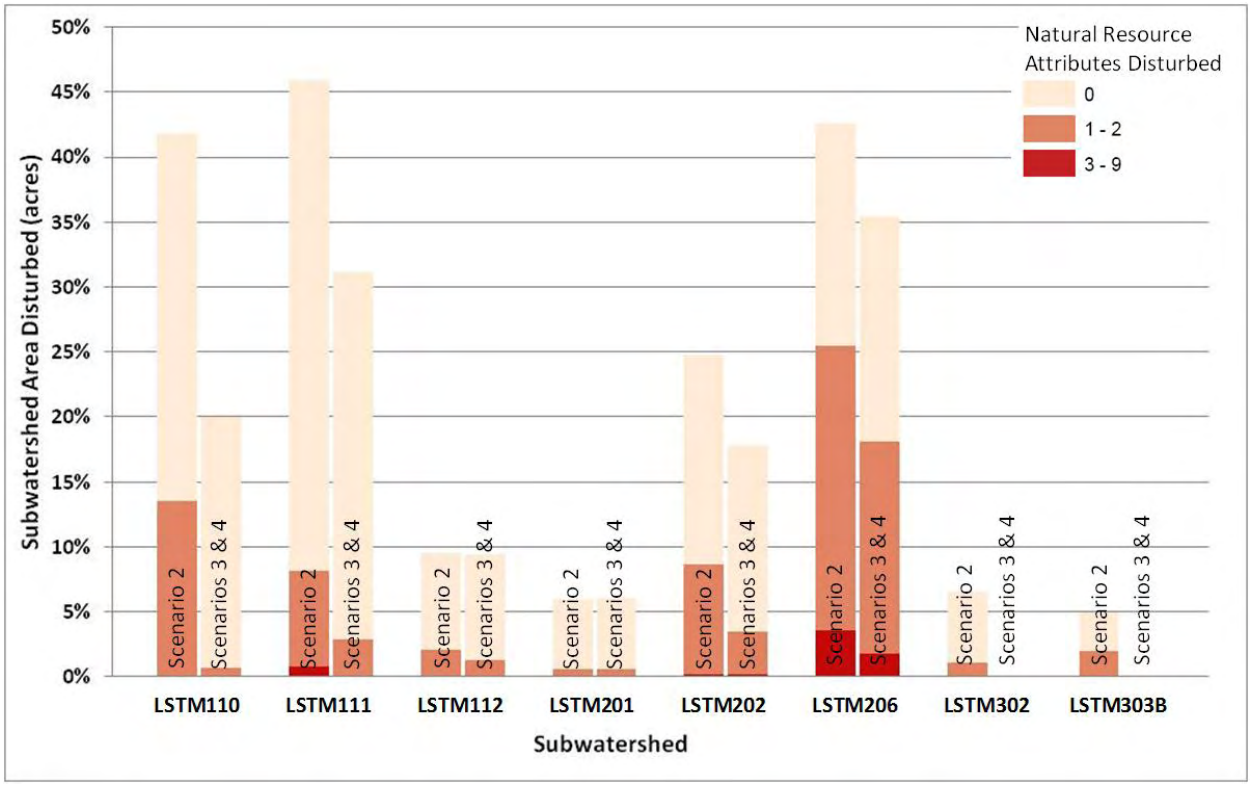


Figure 6. Potential for Disturbance of Natural Resource Attributes in Scenarios 2, 3 and 4
(Forest Interior NOT Included)

REFERENCES

Czech, B and P. R. Krausman. (1997). Distribution and Causation of Species Endangerment in the United States. Science 277 (5329): 1116-1117.

Environmental Laboratory. (1987). "Corps of Engineers wetlands delineation manual," Technical Report Y-87-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS., NTIS No. AD A176 912.

Fischer, R. A. and J. C. Fischenich. (2000). "Design Recommendations for Riparian Corridors and Vegetated Buffer Strips". EMRRP Technical Notes Collection (ERDC TN-EMRRP-SR-24), U.S. Army Engineer Research and Development Center, Vicksburg, MS. www.wes.army.mil/el/emrrp

Fischer, R. A. (2001). "Suggestions to assist Section 404 permit decisions involving upland and riparian buffer strips," WRAP Technical Notes Collection (ERDC TN-WRAP-01-06), U.S. Army Engineer Research and Development Center, Vicksburg, MS. www.wes.army.mil/el/wrap

Jones, C., McCann J., & McConville, S. (2000). A guide to the conservation of forest interior dwelling birds in the Chesapeake Bay critical area. Critical Area Commission for the Chesapeake and Atlantic Coastal Bays. Annapolis, Maryland. Retrieved at http://www.dnr.state.md.us/irc/docs/00009691.pdf

Maryland Department of Natural Resources (DNR). (2013). Environmental Review for the Ten Mile Creek Watershed Existing Conditions, Montgomery County, Maryland. Response Letter.

Montgomery County Department of Environmental Protection (DEP). (2012). Special protection area program annual report 2010. Montgomery County Department of Environmental Protection, Department of Permitting Services, and Maryland-National Capital Park and Planning Commission.

Montgomery County Department of Park and Planning. (2000). Guidelines for environmental management of development in Montgomery County. Maryland-National Capital Park and Planning Commission. Silver Spring, MD.

Schueler, T. R. and H. K. Holland. (2000). The Practice of Watershed Protection. Center for Watershed Protection. Ellicott City, MD.

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. (2013). [Soils map of Montgomery County, Maryland] Web Soil Survey - Montgomery County, Maryland. Retrieved from http://websoilsurvey.nrcs.usda.gov.

Stanko,S., Boward, D., Kilian, J., Becker, A. Ashton, M., Schenk, A., Kazyak, P. (2010). Maryland Biological Stream Survey Sampling Manual: Field Protocols. CBWP-MANTA-EA-07-01 (Publication # 12-2162007-190). Maryland Department of Natural Resources, Annapolis, MD.

Weber, T. (2001a). SWGIGapshp- Green Infrastructure Gaps with Data (v5.1). Maryland Department of Natural Resources. Annapolis, MD. http://www.dnr.state.md.us/greenways/gi/gi.html (last accessed February 22, 2013)

Weber, T. (2001b). SWGIHubCorShp - Green Infrastructure Hubs and Corridors Shapefile (v5.1). Maryland Department of Natural Resources. Annapolis, MD. http://www.dnr.state.md.us/greenways/gi/gi.html (last accessed February 22, 2013)

Weber, T. (2003). Maryland's Green Infrastructure Assessment: A Comprehensive Strategy for Land Conservation and Restoration. Maryland Department of Natural Resources. Annapolis, MD. http://www.dnr.state.md.us/greenways/gi/gi.html (last accessed February 22, 2013)

Attachment F. Pollutant Load Modeling Assumptions

MEMORANDUM

CENTER FOR WATERSHED PROTECTION
8390 Main Street, 2nd Floor
Ellicott City, MD 21043
410.461.8323
FAX 410.461.8324
www.cwp.org
www.stormwatercenter.net

Date: March 15, 2013

To: Mary Dolan and Valdis Lazdins,
Montgomery County Planning Department

From: Center for Watershed Protection

RE: Ten Mile Creek Watershed Environmental Analysis in Support of the Clarksburg Master Plan Limited Amendment

SUBJ: Pollutant Load Modeling Assumptions

Overview

Pollutant load modeling of Total Nitrogen (TN), Total Phosphorus (TN) and Total Suspended Solids (TSS) and annual runoff volume (in acre-ft) was conducted using the Watershed Treatment Model (WTM; CWP, 2010), a simple spreadsheet model developed by the Center for Watershed Protection. This memo outlines the key assumptions and modifications to the model used to simulate existing and post-developed conditions in the Ten Mile Creek watershed. The WTM use several spreadsheet tabs to summarize loads and practices, and the following tabs were used for this modeling exercise:

- Primary Sources: Summarizes pollutant loads from stormwater runoff that can be described by land characteristics alone.
- Secondary Sources: Describes other sources of pollution, such as septic system loads and channel erosion.
- Existing Management Practices: Describes both the structural, non-structural and programmatic practices in place within the watershed.
- Retrofit Worksheet: A worksheet used to enter individual stormwater management practices. This was originally intended to model stormwater retrofit practices, but is used to simulate all stormwater management practices for the modeling in Ten Mile Run.
- Loads to Groundwater: This is not a separate section of the WTM, but was calculated separately for this project.

Primary Sources

Key inputs for this tab include annual rainfall, runoff coefficients, stormwater pollutant concentrations and annual pollutant loading rates.

Annual Rainfall

Annual rainfall was assumed to be 40.4 inches per year (source: http://www.weather.com/weather/wxclimatology/monthly/USMD0093).

Soils

In the WTM, soils are aggregated on a subwatershed basis, by Hydrologic Soil Group (HSG), as determined from GIS data available from the Montgomery County Department of Planning.

Land Use Categories

Land uses provided by the Montgomery County Planning Department were grouped into broader land use classifications for some of the analyses described here. These are summarized in Table 1.

Table 1. Land Use Classification

Classification	Land Use Categories Included
Residential	Low-Density Residential Medium-Density Residential High-Density Residential
Commercial	Commercial Industrial
Transportation	Transportation
Municipal	Open Urban Land Institutional
Rural	Cropland Pasture Large-Lot Subdivision – Agriculture Large-Lot Subdivision - Forest
Forest	Deciduous Forest Evergreen Forest Wetlands – Forested Wetlands - Nonforested Mixed Forest Brush
Bare Ground	Bare Ground

Runoff Coefficients

Runoff coefficients for turf, forest, and impervious cover used WTM defaults, and it was assumed that cropland had the same runoff coefficients as turf and pasture has the same runoff coefficients as forest. The resulting runoff coefficients are presented in Table 2.

Table 2. Runoff Coefficients for Land Cover Types

Hydrologic Soil Group	Impervious	Turf	Forest	Pasture	Bare Ground	Cropland	Large Lot Subdivision - Agriculture	Large Lot Subdivision - Forest
A	.95	.15	.02	.02	.5	.15	.02	.02
B	.95	.20	.03	.03	.5	.20	.03	.03
C	.95	.22	.04	.04	.5	.22	.04	.04
D	.95	.25	.05	.05	.5	.25	.05	.05

The runoff coefficient for each land use category was determined by intersecting land cover, impervious cover and forest cover layers. In urban land use categories, all land cover that was not classified as forest or impervious cover was assumed to be turf.

Pollutant Concentrations

For urban land uses, pollutant loads are calculated by multiplying a runoff concentration by an annual runoff volume. Concentrations were taken from Pitt et al. (2004), which summarized NPDES monitoring data in the northeastern United States. Concentrations are included in Table 3.

Table 3. Urban Runoff Pollutant Concentrations (mg/l)

	TN	TP	TSS
Residential	2	0.3	59
Commercial	2.1	0.26	73
Transportation	2.3	0.3	53
Municipal	1.8	0.22	18

Annual Loading Rates

Pollutant loading from non-urban land is estimated as an annual load in pounds per acre. Loads for TN and TP were taken from the Chesapeake Bay Program Phase 5.3 Model Documemntation (US EPA, 2010; Table 4). For TSS, the edge of field loads from this documentation (also Table 5.3) were multiplied by a delivery ratio based on watershed size, also used in the Bay Model, as defined by the following equation:

$$DR = .417762 \bullet A^{-0.134958} - 0.127097$$

Where:

DR = Sediment Delivery Ratio
A = Watershed Area (square miles)

Loads from Large Lot Subdivision (both Large Lot Subdivision – Agriculture and Large Lot Subdivision – Forest), were calculated as an area-weighted average of Pasture and Forest loads, depending on the forest cover in that land use category, such that:

$$LR_{LLS} = (f)(LR_F) + (1-f)(LR_P)$$

Where:

$LR_{LLS,F,P}$ = Loading Rates from Large Lot Subdivision, Forest, and Pasture, respectively
f = Fraction of LLS land use in forest cover

Table4. Annual Pollutant Loading from Rural Land

	TN (lb/year)	TP (lb/year)	Erosion (tons/acre/year)
Cropland	23.4	1.02	4.7
Pasture	7.3	0.94	1.2
Forest	3.6	0.14	0.36
Bare Ground	29.5	9.7	24.4

Notes:
1: Cropland is an average of values for "Hay with Nutrient Management" and "Conservation Tillage with Nutrient Management"
2: Pasture is the value for "Pasture with Nutrient Management"

Secondary Sources

In the WTM, Secondary Sources include point sources or other pollutant loads that cannot be determined solely based on land use. In this phase of modeling, septic systems were the only secondary sources accounted for. Illicit discharges and SSOs may be significant sources of nutrients, but insufficient data were available to adequately model these sources at this time.

Septic Systems (On-Site Sewage Disposal Systems)

Septic systems were modeled using WTM defaults, and with the following assumptions:

1) Septic system efficiency is equivalent to conventional septic systems.

2) Depth to ground water is greater than 5 feet.

3) Septic system density is less than one system per acre

4) Septic systems are applied on clay or mixed texture soils (i.e., not sandy soils)

5) Maintenance is average

Existing Management Practices

In this model run, turf management was the only management practice modeled. The WTM estimates loads from turf based on nutrient application rates and fertilizer mixture. It was assumed that fertilizer was applied 1.1 times per year, at 150 lbs of N per acre, and that the fertilizer was a phosphorus-free product. The WTM adjusts turf runoff coefficient and loading rates based on other characteristics of urban land. In the future conditions, it is assumed that turf on all new properties is compacted and "on homes <5 years old."

Stormwater Retrofit Worksheet

Although this sheet of the WTM was originally intended for implementing individual retrofit practices, it is used, and slightly customized) in this modeling exercise as it allows for flexibility in accounting for design variations of individual practices. The following modifications were made to the default WTM spreadsheet:

Loads to the Practice

In the WTM, loads to each practice are estimated using an average concentration for urban land. For this modeling effort, the loads were instead determined using concentrations specific to the land use on which the practice is applied. For example, the load to a practice applied on residential land will be calculated using the concentrations for residential land.

In the existing (but not future) condition, the impervious cover draining to the practice was unknown. As a result, the average impervious cover for the land use that the practice treated was typically applied. There were three exceptions to this rule, including the following: 1) Dry wells applied on residential land were assumed to treat rooftop (100% impervious); 2) Practices that are note to treat "Roadway" or "Parking Lot" are assigned 100% impervious cover, regardless of the land use. 3) One large pond was designed to treat "Clarksburg Detention Facility." For this practice, the impervious cover was estimated from aerial photography at 40%.

For future conditions, the impervious cover within each land parcel is provided, and assumed to be consistent across subwatersheds.

Practice Efficiencies

To be consistent with previous work completed for Montgomery County, practice efficiencies were determined from values reported in Schueler and Lane (2012) and Hirschman et al. (2008), as follows:

Table 5. Efficiencies for Urban BMPs (%)
(Schueler and Lane, 2012 and Runoff Reduction from Hirschman et al., 2008)

	TN	TP	TSS	Runoff Reduction
Dry Water Quantity Pond	5%	10%	10%	0%
Dry Extended Detention Pond	20%	20%	60%	15% (A/B Soils only)
Wet Pond or Wetland	20%	45%	60%	0%
Filters	40%	60%	80%	0%
Infiltration Practices	80%	85%	95%	90% (A/B soils) 50% (C/D Soils)
Bioretention A/B Soils	80%	85%	95%	80%
Bioretention C/D Soils	25%	45%	55%	40%

In this iteration, Environmental Site Design (ESD) is modeled as Bioretention, applied on the entire site.

Dominant Soil Types

In the WTM, a dominant soil type is assigned to each stormwater BMP's drainage area. In the existing conditions, all stormwater BMPs were in watersheds dominated by B soils, so B soils were assigned to each practice. In the future conditions, it was assumed that soil compaction during the initial phases of development. As a result, the dominant soil type for most properties was C soils. One exception was the New Pulte (4) property which was dominated by D soils.

Capture Discount

Since practices do not capture the volume of stormwater runoff for all runoff events, enlarging or undersizing a practice affects its overall pollutant capture. The data presented in Table 5 are based on capture of the runoff from a 1" storm event, with undersized practices providing less annual pollutant removal, and larger practices providing improved removal rates. The Capture discount is multiplied by the efficiencies presented in Table 5 to determine actual pollutant removals.

$$CC = 10^{\wedge 0.277*\mathrm{Log}(P_{Capture})}$$

Where:

CC = Capture Discount

$P_{capture}$ = Rainfall event captured by the stormwater BMP (inches)

Existing Conditions

In the existing conditions, practice sizing data were unavailable, so it was assumed that practices were sized to treat the 1" storm event (i.e., 1 CC value of 1.0)

Future Conditions

In the future condition, practices are sized using tables provided in the Maryland Department of the Environment's (MDE's) Stormwater Management Design Manual , using the tables in Chapter 5. Practice sizing was based on the soil type within each property/watershed intersection (in the current condition) as well as the impervious cover forecast for the property. Resulting practice sizing is presented in Table 6.

Table 6. Sizing for Proposed Development Sites

Property/ Development Scenario	Impervious Cover	Soil Types (existing)	Target Precipitation Event (inches)
Egan Mattlyn Load	50%	B/C	1.8
Fire Station	37%	B	1.8
Hammer Hill	30%	B	1.6
MD 355 Load	100%	B/C	2.6
MD121 Interchange	30%	B/C	1.6
Miles Coppola Alone	60%	B/C	2
NewPulte_Load	33%	B/C	1.8
NewPulte_Load 4	42%	B/C	1.8

Subsurface Loads

The WTM is not a groundwater model, but does model supplemental loads to groundwater from three sources: 1) septic systems; 2) leaching urban lawns; and 3) infiltration from stormwater management practices. While the loads from rural land are assumed to include all pathways to the stream (i.e., they represent an in-stream load), loads from urban land in the base calculations only include surface runoff. The loads calculated by the WTM assume some filtration by underlying soils, so that subsurface phosphorus and sediment loads are modeled as 0 lbs/year. However, nitrogen is more mobile. It is assumed that 40% of all loads to groundwater reach the stream. This is the same assumption made for Edge of Stream loads in the Chesapeake Phase 5.3 model (US EPA, 2010).

References

Center for Watershed Protection (CWP), 2010. The Watershed Treatment Model 2010. Ellicott City, MD

Hirschman, D., K. Collins and T. Schueler, 2008. Technical Memorandum: The Runoff Reduction Method. Prepared by: Center for Watershed Protection and Chesapeake Stormwater Network. Ellicott City, MD

Maryland Department of the Environment (MDE), 2009. Maryland Stormwater Design Manual. Available at: http://www.mde.state.md.us/programs/Water/StormwaterManagementProgram/MarylandStormwaterDesignManual/Pages/programs/waterprograms/sedimentandstormwater/stormwater_design/index.aspx

Pitt, R., T. Brown and R. Morchque. 2004. National Stormwater Quality Database. Version 2.0. University of Alabama and Center for Watershed Protection. Final Report to U.S. Environmental Protection Agency.

Schueler, T. and C. Lane. 2012. Recommendations of the Expert Panel to Define Removal Rates for New State Stormwater Performance Standards. Chesapeake Stormwater Network, Ellicott City, MD

USEPA (U.S. Environmental Protection Agency). 2010. Chesapeake Bay Phase 5.3 Community Watershed Model. EPA 903S10002 - CBP/TRS-303-10. U.S. Environmental Protection Agency, Chesapeake Bay Program Office, Annapolis MD. December 2010.

Attachment G. Pollutant Load Modeling Results

MEMORANDUM

CENTER FOR WATERSHED PROTECTION
8390 Main Street, 2nd Floor
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FAX 410.461.8324
www.cwp.org
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Date: March 15, 2013

To: Mary Dolan and Valdis Lazdins,
Montgomery County Planning Department

From: Center for Watershed Protection

RE: Ten Mile Creek Watershed Environmental Analysis
in Support of the Clarksburg Master Plan Limited Amendment
SUBJ: Pollutant Load Modeling Results

Modeling Scenarios

Water quality can be impacted by land development, both during the development process, and in the post-developed condition. Annual pollutant loading was assessed using the Watershed Treatment Model (CWP, 2010- a simple spreadsheet model that calculates annual runoff volume as well as pollutant loads for Nitrogen (TN), Phosphorus (TP) and Sediment (TSS). Three scenarios were analyzed. The "base conditions" scenario represents conditions as they are before implementation of the Master Plan. The "post construction" scenario models the 1994 Master Plan with the implementation of Environmental Site Design (ESD) ESD. Finally, the "during construction" scenario is similar to the post construction scenario, but assumes that construction occurs over ten construction seasons, so that 10% of the developable land is in active construction, and additional fertilizer is applied to establish new lawns. The water quality modeling also reflects conversion of 36 septic systems to sewer. Results include annual runoff volume, as well as annual runoff loads for TN, TP and TSS.

A detailed description of the modeling assumptions are provided under separate cover (See "WTM Model Assumptions"). However, a few of these assumptions, especially those regarding ESD implementation, are useful for understanding the modeling results. Environmental Site Design (ESD) has the goal of achieving the hydrology of "Woods in Good Condition" for the one year storm event in Maryland. In the Maryland Stormwater Design Manual (The Stormwater Manual), this is goal is presumed to be achieved by assigning a "Target Rainfall" event depending on the post-construction condition and requiring that the runoff from this rainfall event be captured in an ESD practice. For this modeling exercise, it is assumed that ESD implementation includes the following:

1) Designers select a target rainfall event from look-up tables in the Maryland Stormwater Design Manual (Stormwater Manual; MDE, 2010). (This target event ranges between 1.0" and 2.6" for the sites modeled).
2) The volume captured by stormwater practices is calculated using the "Short Cut Sizing" methodology described in the Stormwater Manual, which sizes stormwater practices based solely on the impervious cover in the area draining to the practice.
3) During construction, soils are compacted so that the runoff from urban soils is slightly elevated.
4) ESD practices are represented by bioretention with an underdrain. This practice reduces the annual runoff volume by 40%.

Stream channel erosion is not modeled, since insufficient data were available to adequately model this source. It is important to note, however, that channel erosion can be a significant source of sediment in urban streams, representing up to 2/3 of the sediment load (Cronin and Langland, 2003).

Watershed-Wide Pollutant Load

Watershed-wide, pollutant loads for nutrients (Nitrogen and Phosphorus) increase during construction, and decrease to slightly above pre-developed rates in the post-developed condition (Figure 1). Annual runoff volume increases during construction and continues to have a significant increase in the post-developed condition. This result at first seems counterintuitive, since the goal of ESD generate hydrology equivalent to "woods in good condition," which should result in less annual runoff volume than the cropland currently present in much of the land to be developed. However, sizing using the Short Cut Method defined in the Stormwater Manual, combined with the impacts of soil compaction, may lead to practices sized below the necessary volume needed to achieve the goal of producing hydrology equivalent to woods in good condition. In addition, many of the practices that qualify as "ESD Practices" in the Manual do not actually achieve 100% runoff reduction, and the practice selected for this modeling exercise typically reduces runoff by 40%.

As described in the next section of this memorandum, the apparent decrease in TSS can be explained by the agricultural uses dominant in much of the watershed. This TSS calculation may under represent TSS, however, since TSS calculations do not include channel erosion, which may increase as the watershed urbanizes, both due to increased runoff volume and decrease in sediment sources to the stream channel (by converting cropland) in the watershed.

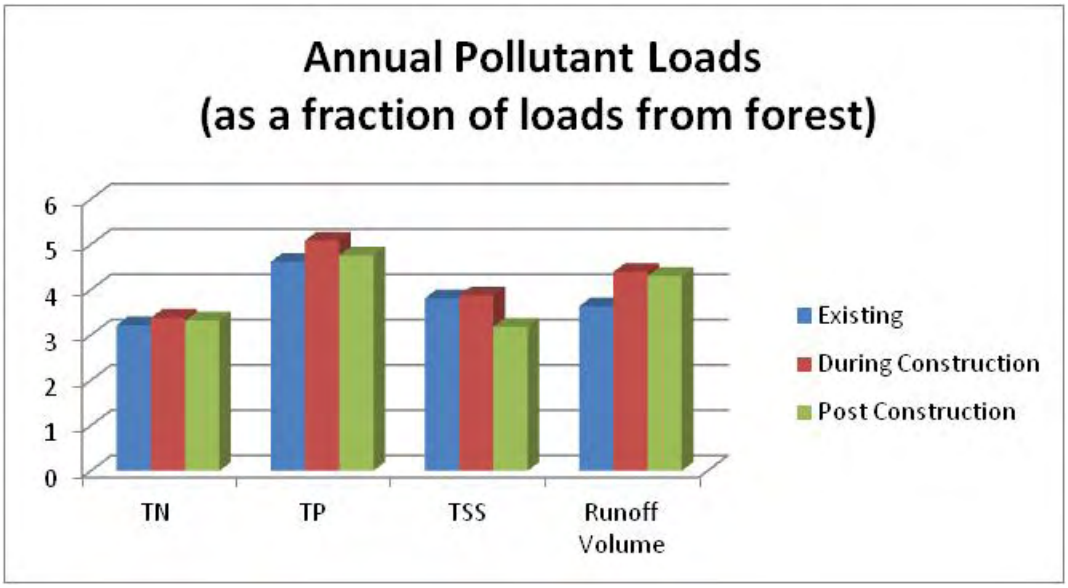

Figure 1. Comparative Pollutant Loads Throughout the Development Process

Sources of Pollutants

In the current conditions, the watershed is dominated by rural land and forest cover, with urban land comprising 15% of the total watershed area, increasing to 25% in the post-construction conditions (Figure 2). This increase in urban land is achieved be converting both rural and forested land, so that these land uses decrease by 7% and 3%, respectively.

Each of the land uses represented in Figure 2 generates pollutants and runoff at different relative rates (Figures 2-6). For example, forested land results in the lowest pollutant export of all land uses, comprising 45% of the land cover but no more than 15% of any pollutant in the existing conditions (Figures 2-6). Rural land, urban land, and active construction, on the other hand, generate relatively high pollutant loads or runoff volumes, depending on the pollutant. Rural land generates disproportionate amounts of all pollutants, as well as runoff volume, in all phases of development with one exception. In the post-developed condition, rural land generates runoff almost exactly equal to its land cover in the watershed (i.e., 33% urban land generating 34% of total runoff volume). Urban land produces disproportionate amounts of pollutants with the exception of TSS, which is dominated by rural land in all phases of development. Active construction is only present in a small fraction of the watershed (2.5%), but disproportionately contributes to runoff volume (5%), and pollutant loads of TP (13%) and TSS (18%).

In general, pollutants with the greatest increase are those where urban land is a relatively high pollutant source. For example, runoff is generated primarily by urban land, and runoff volume shows a significant increase. By contrast, TSS (excluding loads from channel erosion) actually decreases as development proceeds, and rural land is the dominant sediment source in all phases of development.

Figure 2. Land Use: Current, During Construction and Post Construction

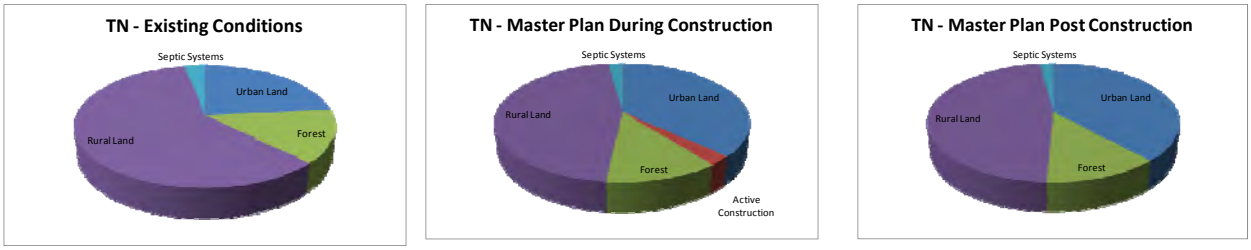

Figure 3. TN Sources: Current, During Construction and Post Construction

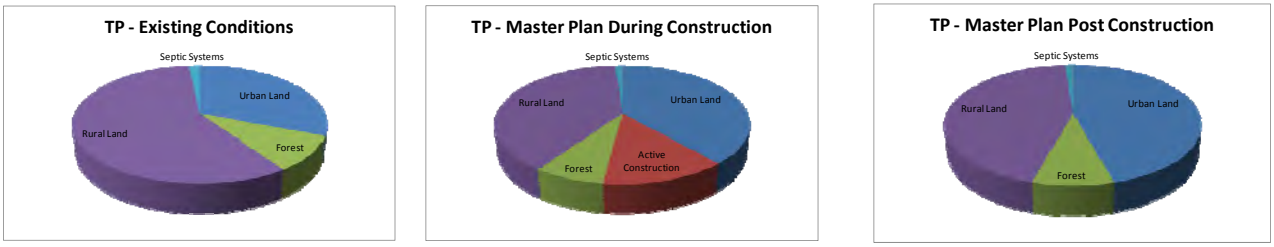

Figure 4. TP Sources: Current, During Construction and Post Construction

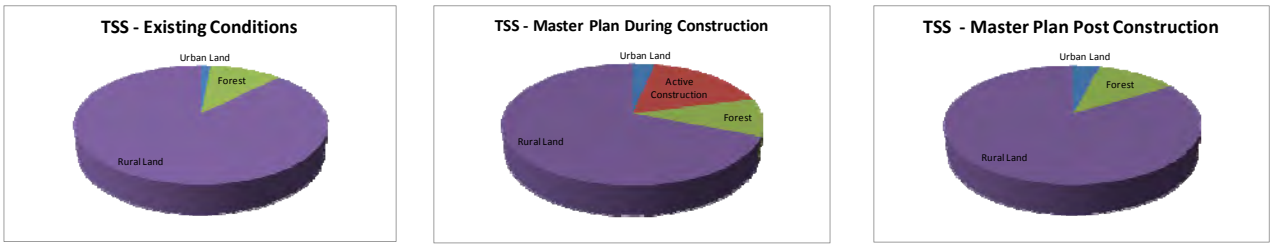

Figure 5. Sediment Sources: Current, During Construction and Post Construction

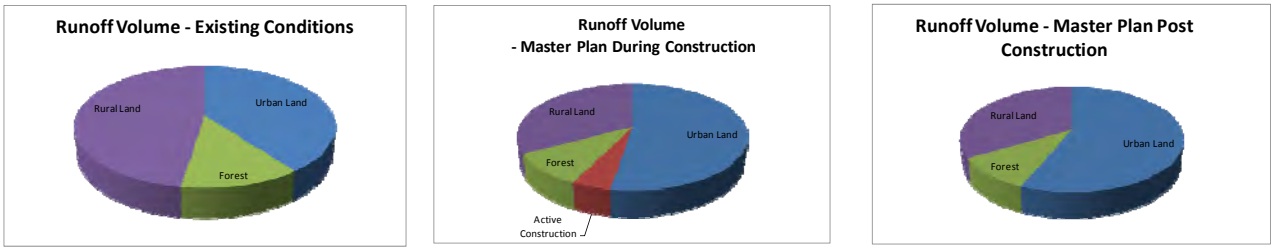

Figure 6. Sources of Runoff Volume: Current, During Construction and Post Construction

Pollutant Load by Subwatershed

Response to development is not uniform across the watershed (Tables 1-4), and is also pollutant-specific. For example, subwatershed LSTM 206 has the largest increase in TSS during construction (76%), but only a modest (7%) increase in total phosphorus. In addition, subwatersheds that are highly impacted during construction can have relatively low post-construction loads. For example, even though LSTM 206 showed a tremendous increase in sediment loads during construction, the sediment loads from this subwatershed in the post-developed condition are actually 35% lower than existing conditions.

Total Nitrogen

Total nitrogen increases moderately throughout the construction process in the watershed as a whole, with dramatically different results by subwatershed. LSTM 202 shows a significant decline in TN, while LSTM 206, 302 and 302B have increases of greater than 10%. This difference is primarily explained by the fact that land conversion in LSTM 202 is primarily from cropland to urban land, and cropland has a very high nitrogen loading rate. In contrast, land in LSTM 206, 302 and 303B is converted primarily from forest and pasture land. During construction, the loads are slightly higher than post-construction loads in all subwatersheds.

Table 1. Annual Load - Total Nitrogen (lb/year)

Subwatershed	Existing Conditions	1994 Masterplan (during construction)	Change (%)	1994 Masterplan (After Construction)	Change (%)
LSTM 110	2,406	2,786	16%	2,516	5%
LSTM 111	1,327	1,469	11%	1,322	0%
LSTM 112	2,902	2,862	-1%	2,866	-1%
LSTM 201	6,955	7,443	7%	7,301	5%
LSTM 202	2,370	1,941	-18%	1,820	-23%
LSTM 203	6,083	6,083	0%	6,083	0%
LSTM 204	7,928	7,928	0%	7,928	0%
LSTM 206	4,079	5,160	27%	5,159	26%
LSTM 302	364	436	20%	426	17%
LSTM 303B	637	732	15%	725	14%
LSTM 304	179	179	0%	179	0%
Watershed	**35,229**	**37,019**	**5%**	**36,326**	**3%**

Total Phosphorus

While the magnitude of the loads and the percent change are slightly different for phosphorus than for nitrogen, the patterns are generally the same (i.e., the subwatersheds with significant increases or decreases in nitrogen tend to have similar changes for phosphorus), with one exception. In LSTM 303B, the increase in phosphorus (3%), is much lower than the 14% increase in nitrogen in the same subwatershed. In this subwatershed, development is located primarily on pasture land which has a very low nitrogen load, but a phosphorus load similar to cropland. Loads for phosphorus are much higher during construction.

Table 2. Annual Load - Total Phosphorus (lb/year)

Subwatershed	Existing Conditions	1994 Masterplan (during construction)	Change (%)	1994 Masterplan (After Construction)	Change (%)
LSTM 110	137	220	60%	144	5%
LSTM 111	88	128	45%	87	-1%
LSTM 112	147	158	8%	147	1%
LSTM 201	351	390	11%	354	1%
LSTM 202	128	129	1%	100	-22%
LSTM 203	346	346	0%	346	0%
LSTM 204	427	427	0%	427	0%
LSTM 206	308	428	39%	368	19%
LSTM 302	16	28	75%	21	27%
LSTM 303B	137	220	60%	144	5%
LSTM 304	8	8	0%	8	0%
Watershed	**1,991**	**2,304**	**16%**	**2,038**	**2%**

Total Sediment

Sediment loads decrease uniformly after construction, except in undisturbed watersheds. This is because sediment loads from urban land are much lower than those from most pre-developed land uses, with the exception of forest. Sediment loads are much higher during construction, with the sediment load increasing, on average, about 2% during the construction period. Some subwatersheds experience a dramatic increase during construction, and at the same time have an extreme decrease after construction. For example, subwatershed LSTM 206 has a 76% increase during construction, but a 35% decrease after construction. This result occurs because sediment loads from construction are much higher than any rural land, while loads from developed land are much lower. Consequently, subwatersheds with a large area of disturbance will experience a dramatic increase during construction, followed by a much lower post-construction load. It is important to note that these modeled loads do not include channel erosion.

Table 3. Annual Load - Total Sediment (lb/year)

Subwatershed	Existing Conditions	1994 Masterplan (during construction)	Change (%)	1994 Masterplan (After Construction)	Change (%)
LSTM 110	258,706	258,850	0%	106,872	-59%
LSTM 111	198,599	170,314	-14%	76,908	-61%
LSTM 112	327,212	286,048	-13%	264,780	-19%
LSTM 201	545,924	580,117	6%	522,271	-4%
LSTM 202	154,454	139,261	-10%	78,496	-49%
LSTM 203	570,708	570,708	0%	570,708	0%
LSTM 204	700,426	700,426	0%	700,426	0%
LSTM 206	109,852	193,819	76%	71,488	-35%
LSTM 302	39,981	42,664	7%	23,788	-40%
LSTM 303B	70,061	78,948	13%	66,209	-5%
LSTM 304	15,820	15,820	0%	15,820	0%
Watershed	**2,991,740**	**3,036,972**	**2%**	**2,497,765**	**-17%**

Annual Runoff Volume

Annual runoff volume increases in every subwatershed except those that are not disturbed (LSTM 203, LSTM 204 and LSTM 304). Subwatersheds with the greatest increase were almost the inverse of results for sediment loading, with the greatest increases in LSTM 110 and 111, which would have the highest fraction of land disturbed for land development. Runoff increases are slightly higher during the construction phase, since bare ground has a high runoff coefficient, but no controls that reduce runoff volume.

Table 4. Annual Runoff Volume (acre-ft/year)

Subwatershed	Existing Conditions	1994 Masterplan (during construction)	Change (%)	1994 Masterplan (After Construction)	Change (%)
LSTM 110	63	107	69%	101	59%
LSTM 111	31	51	67%	48	55%
LSTM 112	77	86	12%	84	9%
LSTM 201	212	252	19%	250	18%
LSTM 202	72	90	25%	86	19%
LSTM 203	161	161	0%	161	0%
LSTM 204	226	226	0%	226	0%
LSTM 206	230	319	39%	311	35%
LSTM 302	11	16	46%	15	40%
LSTM 303B	17	22	31%	21	28%
LSTM 304	7	7	0%	7	0%
Watershed	**1,106**	**1,337**	**21%**	**1,310**	**18%**

Summary

Water quality modeling results for implementing Stage 4 of 1994 Master Plan Land Use with Full ESD indicate that there would be a slight increase in nutrient loads both during and following construction, a significant increase in flow volumes. Sediment loads, excluding stream bank erosion, would increase slightly during the construction phase, and then decrease in the post-developed condition. The potential for the increase in annual runoff volume is the most significant result, as it could potentially lead to greater channel erosion or directly impact in-stream biota.

Some techniques for decreasing these impacts include the following:

1) Size stormwater practices to capture runoff from both impervious and pervious surfaces.
2) Design the site to minimize disturbance, preserve or add forest cover, and reduce impervious cover.
3) Decrease disturbance, and selectively disturb the least permeable soils. Use these areas to promote infiltration.
4) Decompact disturbed soils to reduce runoff generated by urban pervious surfaces.

References

Center for Watershed Protection (CWP), 2010. The Watershed Treatment Model 2010. Ellicott City, MD

Langland, M.J., and Cronin, T.M., eds., 2003, A summary report of sediment processes in Chesapeake Bay and watershed: U.S. Geological Survey Water-Resources Investigations Report 03–4123, 109 pp.

Maryland Department of the Environment (MDE), 2009. Maryland Stormwater Design Manual. Available at: http://www.mde.state.md.us/programs/Water/StormwaterManagementProgram/MarylandStormwaterDesignManual/Pages/programs/waterprograms/sedimentandstormwater/stormwater_design/index.aspx

Attachment H. Hydrology and Hydraulics Analysis – Computations and Model Output for Existing Conditions and Four Development Scenarios

Memorandum

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Prepared for:	Montgomery County Planning Department
Project Title:	**Ten Mile Creek Watershed Environmental Analysis for the Clarksburg Master Plan Limited Amendment**
Subject:	Hydrology and Hydraulics Analysis – Computations and Model Output for Existing Conditions and Four Development Scenarios
Date:	June 12, 2013
To:	Mary Dolan and Valdis Lazdins, Montgomery County Planning Department
From:	Biohabitats and Brown and Caldwell, a Joint Venture

Section 1: Introduction

One of the chief means by which development can impact a stream is by hydrologic alteration. In the absence of stormwater controls, an increase in impervious cover can lead to higher peak streamflows and current velocities. This in turn can lead to increased erosion and sedimentation both on the land surface and within the stream system, and subsequent impacts to biota. One of the major goals of environmental site design (ESD) is to maintain natural hydrology and prevent adverse hydrologic and hydraulic (H&H) impacts. This technical memorandum presents the methods and preliminary results of a planning-level modeling analysis to evaluate the potential H&H effects of the Clarksburg Master Plan on Ten Mile Creek prepared as part of an environmental analysis being conducted for the Maryland-National Capital Park and Planning Commission (M-NCPPC) Montgomery County Planning Department by Biohabitats and Brown and Caldwell, a Joint Venture, with support from the Center for Watershed Protection. The work was authorized under Change Order 2 to Purchase Order No. PQ008435 with notice to proceed (NTP) issued May 14, 2013, and the analysis was completed in collaboration with Montgomery County Department of Environmental Protection (DEP) and Montgomery County Department of Permitting Services (DPS).

The sections below provide descriptions of the computations and detailed output for analyses conducted for the Existing Conditions and four development scenarios requested by the Planning Department in May 2013. This work was in addition to prior analyses conducted in March 2013 of Existing Conditions and development proposed under the 1994 Master Plan[1].

For the May 2013 analyses, the Planning Department crafted four scenarios for future development within the watershed. Five watershed scenarios were analyzed, including:

Scenario 1: Existing Conditions – The baseline for these analyses is existing conditions within the watershed. This includes current land use, land cover and watershed infrastructure.

Scenario 2: 1994 Plan – The 1994 Clarksburg Master Plan recommendations for density and land use in Stage 4, assuming full Environmental Site Design for the developable and redevelopable properties.

Scenario 3: Reduced Footprint, Same Yield – The same as Scenario 1 with a reduced footprint for the Pulte properties. Assumes a different unit mix that would allow approximately the same number of units permitted by the 1994 Plan.

Scenario 4: Reduced Footprint Lower Yield – The same as Scenario 2 with the same unit mix as recommended in the 1994 Plan for the Pulte property, resulting in fewer potential units on Pulte.

Scenario 5: 7% Watershed Imperviousness – The same as Scenario 3 with reduced yield on Miles/Coppola, Egan, and the County properties.

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[1] Prior work was documented in Technical Memorandum 1: *Preliminary Results of the Hydrology and Hydraulics Analysis*, dated April 2, 2013; Amendment A to Technical Memorandum 1: *Revised Environmental Site Design Modeling Scenario*, dated April 3, 2013; and an additional documentation in Memorandum: *Hydrology and Hydraulics Analysis – Computations and Model Output for Existing Conditions and 1994 Master Plan Model Scenarios,* dated April 11, 2013.

Section 2 describes the methodology used to model these development scenarios, Section 3 discusses results and findings of the H&H analysis, and model output data are tabulated in Appendix A. Additional supporting documents are provided in Appendices B through D.

Section 2: Methods

The primary tool used for the analysis was XP-SWMM 2012, a commercial modeling package developed by XP Solutions. XP-SWMM is a dynamic rainfall-runoff model that was originally developed as a graphical user interface to the USEPA Stormwater Water Management Model (EPA SWMM). For this project, the model is being used to predict H&H impacts to Ten Mile Creek that would result from the completion of the Clarksburg Master Plan implemented with full ESD in accordance with State and County regulations.

2.1 Model Set-Up and Base Conditions Scenario

XP-SWMM offers several options for the simulation of rainfall-runoff. For this project, the SWMM Runoff Non-Linear Reservoir method was selected because it provides the most flexibility for simulating ESD practices. The model was set up to simulate a 1-year, 24-hour storm (2.6 inches) and a 2-year, 24-hour storm (3.2 inches) and assuming an SCS Type II distribution. The 1-yr and 2-yr storm events were chosen to analyze the effects of development on the existing stream condition due to the ability of these storm events to influence the shape and form of natural channels. The model domain consists of the Ten Mile Creek watershed upstream of Little Seneca Lake. The watershed was conceptually divided into 16 runoff nodes that represent areas draining to Ten Mile Creek. The runoff nodes are listed in ascending order starting from the most downstream node. The main Ten Mile Creek itself was represented in the model as 30 hydraulic links, parameterized as natural channels using cross-sectional survey data provided by the County. Links are labeled according to their upstream node and have the prefix 'LN', for example link LN102 conveys flows from node 102 to node 101. A link node diagram of the study area is provided in Appendix A.

The model set up described above is similar to the structure used in the prior analyses, which were documented in the April 2013 memoranda mentioned above. However, several refinements were made prior to evaluating the May 2013 scenarios. These included:

- Creation of new subcatchment areas representing drainage to conventional BMPs to model existing stormwater BMPs explicitly. This was a change from prior model runs which had modeled existing stormwater BMPs implicitly by increasing the subcatchment width to represent increased time of concentrations and peak discharge lags associated with existing stormwater management facilities.
- Addition of 5 runoff nodes and 13 hydraulic links to incorporate the additional catchments (as compared to 11 nodes and 17 links used in the prior analyses).
- Adjustments to the model structure to prevent water loss from the system during flooding. These included adjustments of model node cross-sections and allowance of ponding at all model nodes.

BMPs providing stormwater management within the Ten Mile Creek study area were identified through review of Montgomery County GIS data, and are listed below. The existing BMPs modeled in the revised May 2013 existing conditions scenario are listed in Table 1.

Table 1 – Existing BMPs Included in Model

Asset Number	Structure Type	Property Name	Drainage Area	Data Source	Sub - Watershed
11512	PDWTED	Gateway 270 Corporate Park	34.5	DEP BMP Database	206
N/A	PDWTED	SHA MD121/I-270 Southbound	7.6	MDE Storm Print	206
13700	SF	High Point Farm (MD355)	14.6	DEP BMP Database	201
UNK	SF[2]	Clarksburg Detention Facility	35	Montgomery Co DEP	201

GIS analysis was conducted to determine the acres of impervious surfaces draining to each type of BMP. The existing Wet Pond BMP (Asset 11512) was modeled by limiting the discharge of the Channel Protection Volume (CPv) to ensure a 24-hour detention in accordance with the requirements of the Maryland Stormwater Design Manual. Asset 13700 at High Point Farm and the existing BMPs at the Detention Center were modeled as surface sand filters using cross section information from as-built records.

Pre-treatment, water quality and structures treating less than five acres were excluded due to assumed negligible hydrologic impact. The excluded practices are listed in Table 2.

Table 2 – Existing BMPs Excluded from the Model

Asset Number	Structure Type	Property Name	Drainage Area	Data Source	Sub - Watershed
Basin3	PDWTED	Stringtown Road Extension & Gateway Commons	12.9	Montgomery Co DEP[3]	206
10387	INF	Garden of Remembrance Cemetery	3.9	DEP BMP Database*	201
11212	PDQNED	Little Bennett Regional Park	3.7	DEP BMP Database	201
12412	SF	Little Bennett Regional Park	3.2	DEP BMP Database*	206
UNK	BR	Woodcrest Phase 5	1.1	DEP BMP Database*	206
10337	IT	Clarksburg Nursery	6.1	DEP BMP Database*	206
14407	BR	Clarksburg Ridge HOA	0.9	DEP BMP Database*	206
14406	SF	Clarksburg Ridge HOA	0.6	DEP BMP Database*	206
12742	UG	Clarksburg Elementary School	3.8	DEP BMP Database	206
10701	INFU	Clarksburg Elementary School	0.3	DEP BMP Database*	206
UNK	DW	Huffman Property Single Family Residence	0.09	DEP BMP Database*	204
UNK	DW	Branch Hill Single Family Residence	0.03	DEP BMP Database*	204

*Water quality BMP

[2] Per as-built data, Detention Center SWM provided by sand filters and a dry pond.

[3]Montgomery County Department of Environmental Protection (DEP) (2012). Per 2010 Special Protection area program annual report, sediment control structure not yet converted to a SWM facility, considered part of 11512 drainage area.

The approach described above was used to create a revised "base conditions" model scenario to represent the Ten Mile Creek watershed under existing conditions, prior to development described in the Master Plan and the other development scenarios provided by the Planning Department.

To characterize the runoff characteristics of each subwatershed, each runoff node was assigned acreages of pervious and impervious land based on available GIS data. Infiltration on pervious land covers was modeled using the SCS Curve Number method. Composite curve numbers were calculated for each runoff nodes based on land use and hydrologic soil group (HSG). The methods for developing the composite curve numbers are described in Appendix C.

2.2 Development Scenarios

To represent the development scenarios, the base conditions model was altered in two manners. First, the runoff nodes were parameterized to represent the land use and land cover conditions proposed in the development scenarios provided by the Planning Department. This step required GIS-based analysis and additional calculations to quantify how the proposed development (including a new utility easement and highway interchange) would change the existing land cover and alter the existing composite curve numbers. To account for construction impacts on soil, it was assumed that the hydrologic soil groups (HSGs) of disturbed areas would be reduced by one category (e.g., B soils became C soils; C soils became D soils). It was further assumed that development would be in compliance with County topsoiling requirements; therefore curve numbers were adjusted by taking an average of the curve numbers obtained from the existing HSGs and the reduced HSGs described above. Additional changes to land use and land cover conditions were made outside the Planning Department's development limits of disturbance (LODs) that occurred within the Special Protection Area (SPA). These changes reflect the assumption that existing pasture and cropland between the limits of disturbance and the stream would be replanted as forest. However, due to the time required to generate forest growth, the pasture and cropland polygons were modeled using a runoff curve number representing meadow in good condition. After GIS analysis of the land use changes associated with each of the development scenarios, composite curve numbers were calculated for each model subcatchment area. Additional description of the runoff curve numbers used for the development scenarios is provided in Appendix C.

Secondly, the base scenario model was altered to conceptually direct runoff from new development to treatment practices. For the purposes of this screening-level analysis, with the exception of the proposed I-270 widening discussed below, all development was assumed to be treated using micro-bioretention as a representative ESD practice. The required area and storage volume of micro-bioretention was calculated based on the new impervious surface of each subwatershed, using the procedures of the Maryland Stormwater Design Manual and guidelines provided by Montgomery County DEP. Each micro-bioretention filter was modeled with 9-inches of storage above the filter media, with a decaying infiltration rate to model the available storage within the soil media as if it were initially dry with a constant infiltration rate. The Horton method was utilized in XP-SWMM to represent both the decaying infiltration of the ponded area and the constant infiltration from the soil media. A maximum infiltration rate of 2 in/hour and a minimum (asymptotic) infiltration rate of 0.25 in/hour with a decaying

rate of 0.0015/sec were utilized in the model to represent the decaying infiltration rate. A constant infiltration rate of 0.05[4] inch per hour was used to represent the infiltration from the soil media.

The available storage within the soil media was computed by assuming that the soil media cross section would be 3-ft deep with a 40% void ratio. This depth of storage was combined with the assumed 3-inch thick stone reservoir, also with a 40% void ratio, to arrive at the total storage available within the conceptualized micro-bioretention cross section. The micro-bioretention filters were also assumed to have underdrains that would be placed above the level of the stone reservoir and discharge to surface water.

Although design standards allow larger micro-bioretention storage volumes than those used for in the H&H modeling analyses, constructed practices cannot be assumed to function at maximum design performance at all locations throughout the development, or at all times through a range of storm events. Therefore, the parameters selected for modeling represent a more moderate level of performance which allows for a margin of safety appropriate for this planning-level analysis.

In addition to the conceptual ESD practices, the development scenario model structure included a new subcatchment to represent the drainage from the new impervious surface proposed as part of I-270 widening, which was modeled with conventional stormwater management to control the required volumes. These model parameters were developed for the May model scenarios in conjunction with the Planning Department, Montgomery County Department of Environmental Protection (DEP) and Montgomery County Department of Permitting Services (DPS) based on feedback received after presentation of the earlier model results documented in the April 2013 memoranda mentioned above.

For each development scenario, each of the subwatersheds within the Ten Mile Creek Study Area was represented in the model by five individual subcatchments. As described in more detail in Appendix C, GIS files provided by the Planning Department were utilized to determine the composite runoff curve number for each of the subcatchments based on land use and hydrologic soil groups (HSG). Subcatchments #1 and #3 were the primary subcatchments utilizing curve numbers for the model analysis to represent the infiltration capacity of the soils. Within each subwatershed, subcatchment #1 was used to represent all the land outside the proposed development area as defined by the LOD provided by the Planning Department. A composite curve number was computed for subcatchment #1 based on the existing land use and underlying soil types. Subcatchments #2 and #3 were used to represent the impervious and pervious portions of the proposed development, respectively. Subcatchment #2 was used to combine all of the impervious areas of the proposed development, and was assigned a curve number of 98. A composite curve number was computed for subcatchment #3 based on the proposed pervious land uses and underlying soil types. Summaries of the curve numbers used for the model runs are provided in Appendix C.

[4] Changed from the (0.025"/hr rate specified in the Statement of Work SOW during the MNCPPC weekly check-in call on 5/6/13.

The XP-SWMM Runoff Non-Linear Reservoir method was used to simulate the runoff from subcatchments #2 and #3 and route the runoff through the modeled ESD practices, which were represented in the model as subcatchments #4 and #5. Subcatchment #4 represented the available storage for ponding above the soil media for the conceptualized micro-bioretention cross section, and subcatchment #5 represented the available storage in the soil media and conceptualized stone reservoir at the base. The required areas and storage volumes of micro-bioretention practices were calculated based on the new impervious surface areas of each subwatershed, using the procedures outlined in Chapter 5 of the Maryland Stormwater Design Manual (including the target rainfalls values listed in Table 5.3) and the micro-bioretention guidelines provided by Montgomery County DPS. The analysis assumed that the rainfall targets will be met and Channel Protection Volume (CPv) requirements will be satisfied, therefore negating the need for any additional stormwater management practices for the development areas routed to ESD practices.

The required areas of ESD practices for each development were then calculated using Montgomery County's micro-bioretention guidelines, and the ESD areas for all developments proposed within the subwatershed were summed and entered into the model. The ESD calculations are provided in Appendix D.

Due to the limited amount of space within the I-270 Right-of-Way, the increase in impervious area associated with the proposed I-270 widening was assumed to be treated with a conventional stormwater treatment practice in the model. A wet pond was represented in the model as a storage node with its discharge limited to the required Channel Protection storage volume in accordance with Appendix D.11.1 of the Maryland Stormwater Design Manual.

Section 3: H&H Model Results and Findings

The model provided estimates of relative changes in total streamflow volume, peak streamflow and streamflow velocity predicted to occur as a result of differences between existing land cover compared to each development scenario. Results are tabulated in Appendix A. Major findings include:

- For all development scenarios, the modeling results indicate that the development proposed for the Ten Mile Creek study area will impact hydrology in all of the modeled subwatersheds to a varying degree, with the exception of LSTM204, which was not predicted to be impacted. Streamflow changes shown in the modeling results will occur in some tributaries directly as a result of land cover changes within the subwatershed, or in some downstream locations indirectly as a result of flow changes from upstream development.

- The subwatersheds predicted to be most impacted from the 1994 Master Plan development modeled in Scenario 2 include LSTM110, LSTM111 and LSTM206, with increased streamflow volumes and peak flows also noted at downstream points LSTM202, LSTM302, LSTM303B and the study outlet point at LSTM304.

- The subwatersheds which showed most improvement from the reduced footprints modeled in Scenario 3 (compared to Scenario 2) were LSTM110 and LSTM111. Improvements were also seen at downstream points LSTM303B and the study area outlet at LSTM304.

- In most subwatersheds, the differences between the development proposed under Scenario 3 versus Scenario 4 were too small to result in any significant model response. However, additional improvements were seen as a result of the reduced imperviousness modeled in Scenario 5, with the greatest benefits predicted in LSTM110, LSTM111 and LSTM206. Improvements were also seen in LSTM201 and at the downstream modeling points at LSTM202, LSTM203, LSTM302, LSTM303B and the study outlet point at LSTM304.

Conclusions and Recommendations

The H&H model was used as one of several planning-level tools in the environmental analysis of the Ten Mile Creek Watershed conducted in support of the Clarksburg Master Plan Limited Amendment. The purpose of the analysis was to compare the results of different scenarios within each modeled subwatershed, and not for precise predictions of future health of Ten Mile Creek. There are no models that can determine the impacts of development with proposed Environmental Site Design (ESD) practices on the biological and ecosystem health of a receiving stream, and the model used for this analysis was not calibrated to the downstream gauge so does not produce absolute value of the modeled parameters. Rather, the model was used in this study to estimate relative discharge to the model nodes to as one means of predicting the potential watershed impacts resulting from changes between existing conditions and the modeled development scenarios.

The model responses represented the total change occurring in each subwatershed as a result of each development scenario, including new impervious acres, reductions in existing forest cover and other existing land use acreage, post-development runoff curve numbers, and the total area of ESD practices required by the Maryland Stormwater Design Manual to manage runoff from the total acres of new development. The H&H analysis was conducted at a scale that necessitated relatively large subcatchment areas, and the configuration of new development within the Planning Department's LODs was not spatially represented in the model, nor were the ESD structures, which in practice will be required to be distributed throughout the development per Montgomery County and Maryland design requirements. A more detailed assessment conducted at a smaller subcatchment scale to reflect proposed development configuration and site-specific ESD techniques may be better able to simulate the extent of stream response to proposed developments, however, the results of the planning scale analysis indicate that ESD will not fully mitigate the impacts of development on the hydrology in the Ten Mile Creek watershed.

Given the level of development proposed and the strong correlation between the extent of development and model responses, increases in stormwater runoff volume and peak flow can be expected in all development scenarios despite the application of ESD practices (Center for Watershed Protection, 2013). Literature review of case studies and monitoring to document the effectiveness of ESD and similar low impact development (LID) strategies are limited and don't appear to exist at a

watershed scale of analysis. Where case studies do exist at a subdivision scale, there is no conclusive evidence that ESD fully protects stream health.

So although ESD may be able to mitigate the impacts of development to some degree, the findings of the analysis indicate that additional development within the Ten Mile Creek watershed will have a negative impact on stream hydrology. In order to minimize impacts to Ten Mile Creek, it is recommended that disturbance of natural resources throughout the Ten Mile Creek study area be minimized, especially forest cover in the headwater areas, and that existing conditions in the high quality headwater subwatersheds of LSTM110 and LSTM111 be preserved. If development occurs in these subwatersheds, the limits of disturbance should be minimized, such as the LODs represented in Scenarios 3, 4 and 5.

In addition, within any developed areas, it is recommended that site planning techniques be employed as the first measure of Environmental Site Design to preserve and protect natural resources; conserve natural drainage patterns; minimize impervious areas; cluster development; and limit soil disturbance, mass grading and compaction. Required volumes should be controlled with ESD treatment practices selected to achieve the greatest watershed benefits based on evaluation of site-specific and subwatershed-specific considerations.

Appendix A –

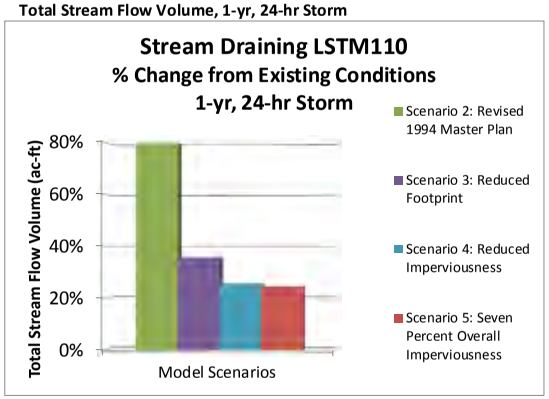
Model Results

LSTM110			Existing Conditions	Scenario 2: Revised 1994 Master Plan			Scenario 3: Reduced Footprint			Scenario 4: Reduced Imperviousness			Scenario 5: Seven Percent Overall Imperviousness		
Model Results	Storm Event:	Model Parameter:	Existing Conditions	Developed Conditions	Net Impact (Change)	% Change	Developed Conditions	Net Impact (Change)	% Change	Developed Conditions	Net Impact (Change)	% Change	Developed Conditions	Net Impact (Change)	% Change
	1-yr, 24-hr Storm	Total Stream Flow Volume (ac-ft)	5.5	**9.9**	4.4	80%	**7.5**	2.0	36%	**6.9**	1.4	25%	**6.8**	1.3	24%
		Peak Stream Flow (cfs)	12.2	**54.7**	42.6	350%	**47.2**	35.1	289%	**41.8**	29.7	244%	**40.4**	28.2	232%
		Stream Flow Velocity (fps)	1.8	**2.8**	1.1	62%	**2.9**	1.1	63%	**2.8**	1.0	57%	**2.7**	1.0	56%
	2-yr, 24-hr Storm	Total Stream Flow Volume (ac-ft)	10.1	**15.7**	5.7	56%	**12.4**	2.3	23%	**11.6**	1.6	15%	**11.6**	1.5	15%
		Peak Stream Flow (cfs)	15.5	**95.2**	79.8	516%	**80.5**	65.0	420%	**72.9**	57.4	371%	**70.8**	55.3	357%
		Stream Flow Velocity (fps)	1.9	**3.4**	1.5	78%	**3.2**	1.3	67%	**3.0**	1.2	61%	**3.0**	1.1	60%

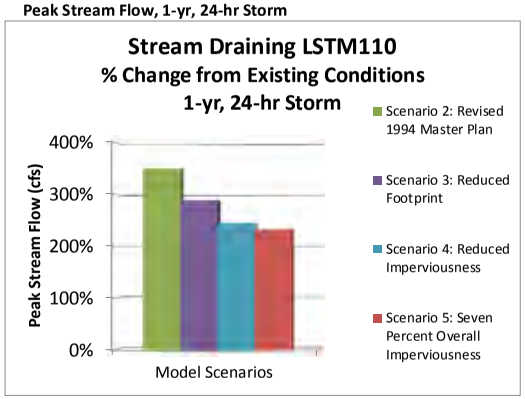
drains to link 71

Change compared to Existing Conditions

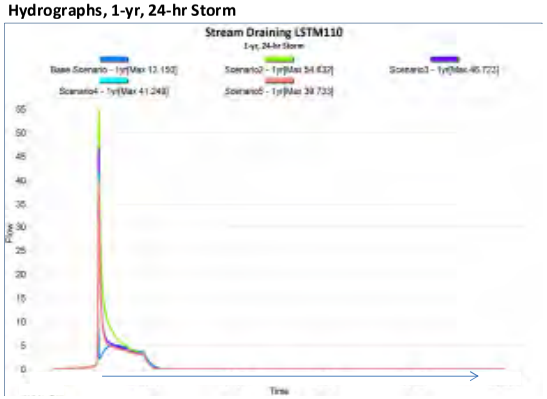
Total Stream Flow Volume, 1-yr, 24-hr Storm



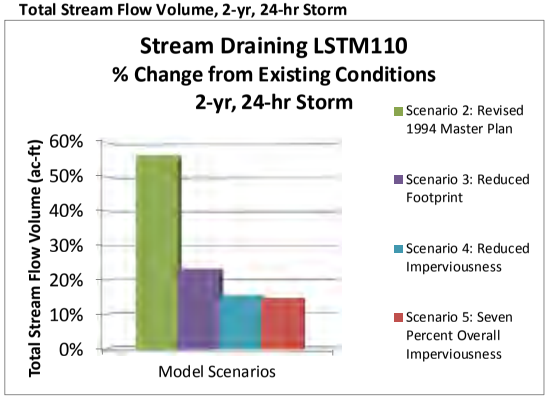
Peak Stream Flow, 1-yr, 24-hr Storm



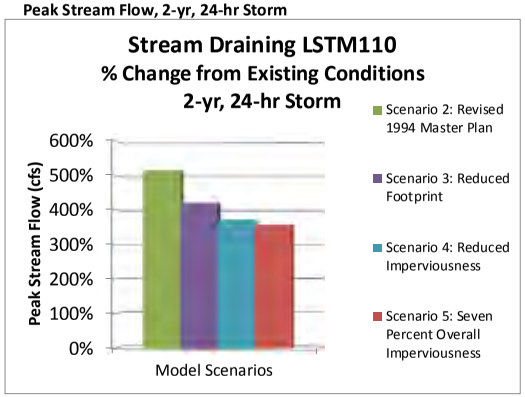
Hydrographs, 1-yr, 24-hr Storm



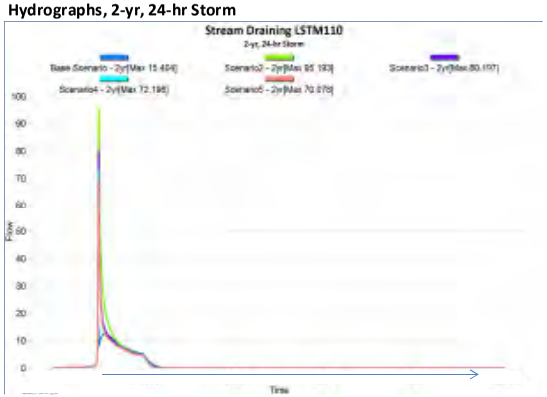
Total Stream Flow Volume, 2-yr, 24-hr Storm



Peak Stream Flow, 2-yr, 24-hr Storm



Hydrographs, 2-yr, 24-hr Storm

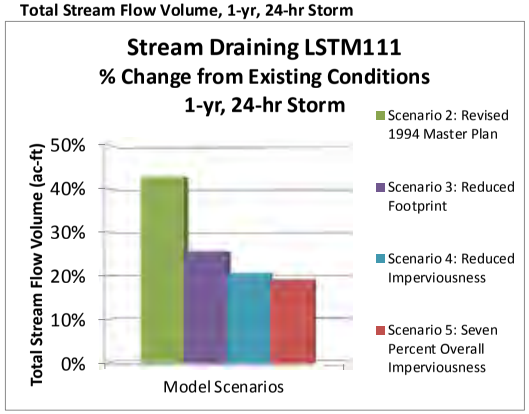


LSTM111			Existing Conditions	Scenario 2: Revised 1994 Master Plan			Scenario 3: Reduced Footprint			Scenario 4: Reduced Imperviousness			Scenario 5: Seven Percent Overall Imperviousness		
Model Results	Storm Event:	Model Parameter:	Existing Conditions	Developed Conditions	Net Impact (Change)	% Change	Developed Conditions	Net Impact (Change)	% Change	Developed Conditions	Net Impact (Change)	% Change	Developed Conditions	Net Impact (Change)	% Change
	1-yr, 24-hr Storm	Total Stream Flow Volume (ac-ft)	3.472	**5.0**	1.5	43%	**4.4**	0.9	26%	**4.2**	0.7	21%	**4.1**	0.7	19%
		Peak Stream Flow (cfs)	3.9360	**33.1**	29.2	741%	**33.0**	29.1	739%	**29.3**	25.3	644%	**27.8**	23.8	605%
		Stream Flow Velocity (fps)	0.7	**1.8**	1.1	151%	**1.8**	1.1	155%	**1.7**	1.0	141%	**1.7**	1.0	137%
	2-yr, 24-hr Storm	Total Stream Flow Volume (ac-ft)	6.0	**7.9**	1.8	30%	**7.0**	1.0	17%	**6.8**	0.8	13%	**6.8**	0.7	12%
		Peak Stream Flow (cfs)	9.5	**56.9**	47.4	497%	**55.8**	46.2	485%	**49.7**	40.2	421%	**47.7**	38.2	400%
		Stream Flow Velocity (fps)	0.9	**2.1**	1.3	145%	**2.1**	1.3	145%	**2.0**	1.2	132%	**2.0**	1.1	130%

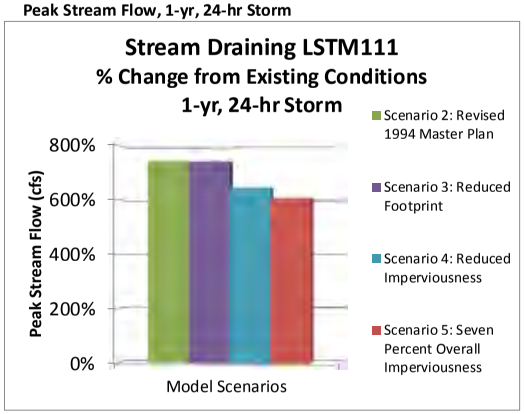
drains to link 61

Change compared to Existing Conditions

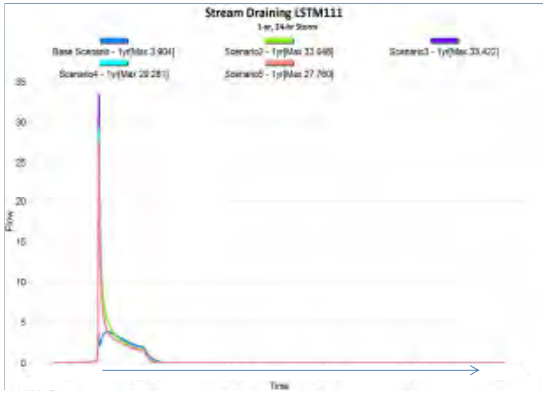
Total Stream Flow Volume, 1-yr, 24-hr Storm



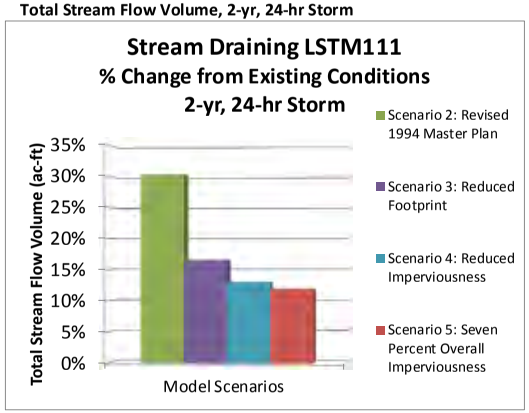
Peak Stream Flow, 1-yr, 24-hr Storm



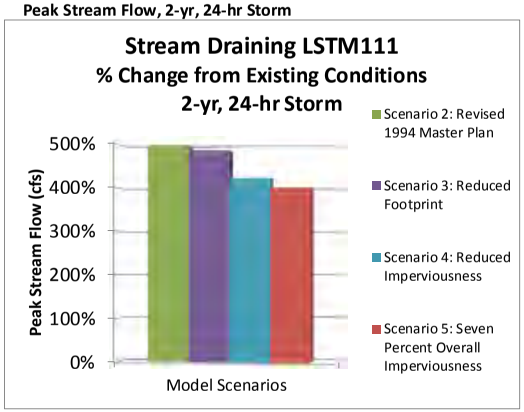
Hydrographs, 1-yr, 24-hr Storm



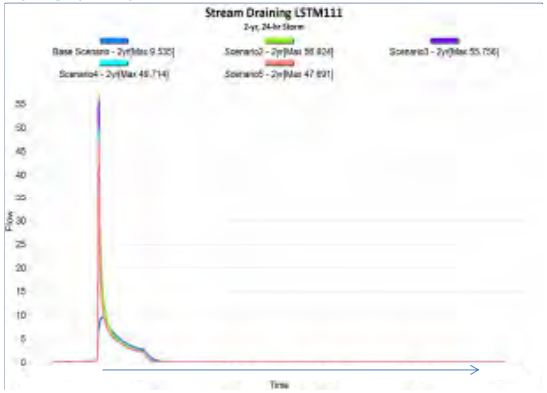
Total Stream Flow Volume, 2-yr, 24-hr Storm



Peak Stream Flow, 2-yr, 24-hr Storm



Hydrographs, 2-yr, 24-hr Storm

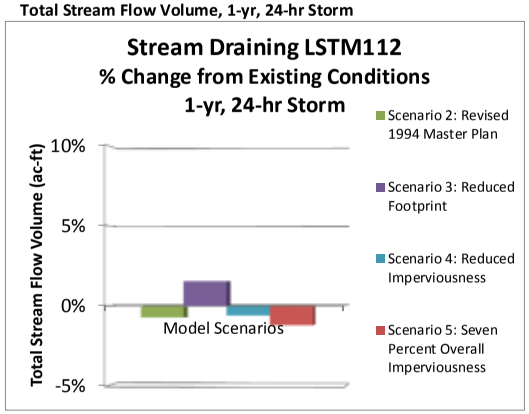


LSTM112			Existing Conditions	Scenario 2: Revised 1994 Master Plan			Scenario 3: Reduced Footprint			Scenario 4: Reduced Imperviousness			Scenario 5: Seven Percent Overall Imperviousness		
Model Results	Storm Event:	Model Parameter:	Existing Conditions	Developed Conditions	Net Impact (Change)	% Change	Developed Conditions	Net Impact (Change)	% Change	Developed Conditions	Net Impact (Change)	% Change	Developed Conditions	Net Impact (Change)	% Change
	1-yr, 24-hr Storm	Total Stream Flow Volume (ac-ft)	5.7	**5.7**	0.0	-1%	**5.8**	0.1	2%	**5.7**	0.0	-1%	**5.7**	-0.1	-1%
		Peak Stream Flow (cfs)	17.3	**32.9**	15.5	90%	**34.4**	17.1	98%	**32.7**	15.4	89%	**32.1**	14.8	85%
		Stream Flow Velocity (fps)	1.9	**2.2**	0.3	14%	**2.2**	0.3	14%	**2.1**	0.2	12%	**2.1**	0.2	11%
	2-yr, 24-hr Storm	Total Stream Flow Volume (ac-ft)	10.5	**10.3**	-0.2	-2%	**10.5**	0.0	0%	**10.3**	-0.2	-2%	**10.2**	-0.3	-3%
		Peak Stream Flow (cfs)	21.8	**53.0**	31.2	143%	**57.4**	35.6	163%	**53.4**	31.6	145%	**52.2**	30.4	139%
		Stream Flow Velocity (fps)	2.1	**2.1**	0.1	3%	**2.1**	0.1	3%	**2.2**	0.1	5%	**2.2**	0.2	7%

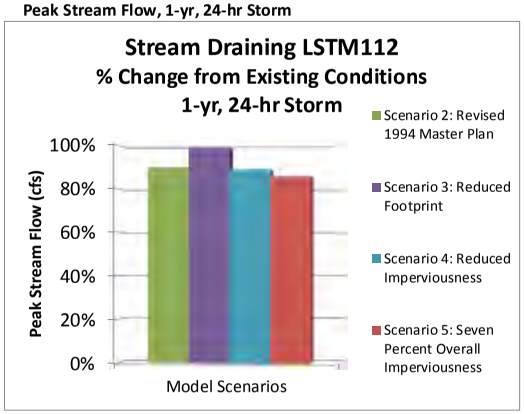
drains to link 21

Change compared to Existing Conditions

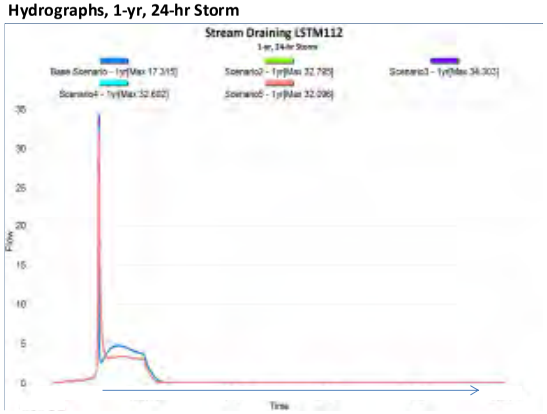
Total Stream Flow Volume, 1-yr, 24-hr Storm



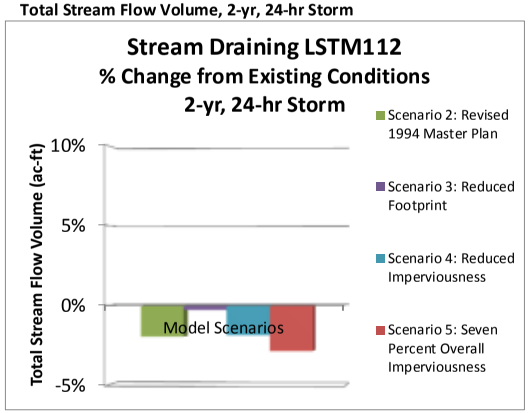
Peak Stream Flow, 1-yr, 24-hr Storm



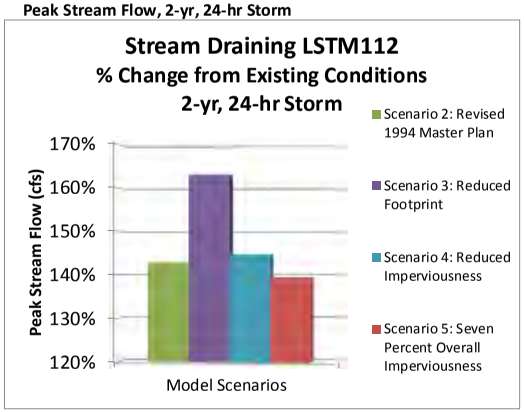
Hydrographs, 1-yr, 24-hr Storm



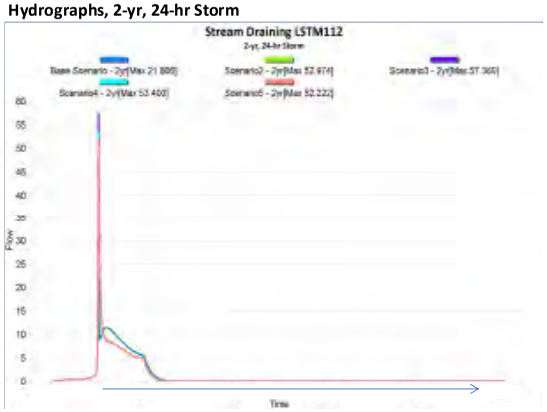
Total Stream Flow Volume, 2-yr, 24-hr Storm



Peak Stream Flow, 2-yr, 24-hr Storm



Hydrographs, 2-yr, 24-hr Storm

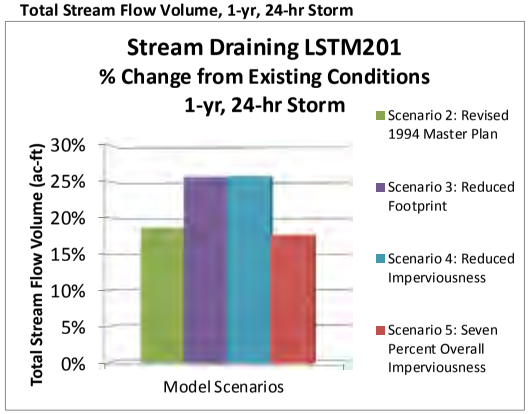


LSTM201			Existing Conditions	Scenario 2: Revised 1994 Master Plan			Scenario 3: Reduced Footprint			Scenario 4: Reduced Imperviousness			Scenario 5: Seven Percent Overall Imperviousness		
Model Results	Storm Event:	Model Parameter:	Existing Conditions	Developed Conditions	Net Impact (Change)	% Change	Developed Conditions	Net Impact (Change)	% Change	Developed Conditions	Net Impact (Change)	% Change	Developed Conditions	Net Impact (Change)	% Change
	1-yr, 24-hr Storm	Total Stream Flow Volume (ac-ft)	17.2	**20.5**	3.2	19%	**21.7**	4.4	26%	**21.7**	4.4	26%	**20.3**	3.0	18%
		Peak Stream Flow (cfs)	53.5	**68.7**	15.2	28%	**69.3**	15.8	30%	**69.4**	16.0	30%	**57.1**	3.6	7%
		Stream Flow Velocity (fps)	1.7	**1.8**	0.2	10%	**1.8**	0.2	10%	**1.8**	0.2	10%	**1.7**	0.0	1%
	2-yr, 24-hr Storm	Total Stream Flow Volume (ac-ft)	30.7	**34.9**	4.3	14%	**36.7**	6.1	20%	**36.7**	6.1	20%	**35.0**	4.3	14%
		Peak Stream Flow (cfs)	66.9	**116.9**	50.0	75%	**118.9**	52.0	78%	**119.1**	52.2	78%	**95.1**	28.2	42%
		Stream Flow Velocity (fps)	1.8	**2.3**	0.5	25%	**2.3**	0.5	26%	**2.3**	0.5	26%	**2.1**	0.2	13%

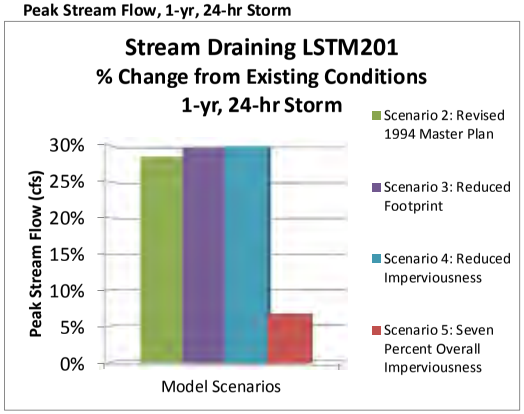
drains to link 110

Change compared to Existing Conditions

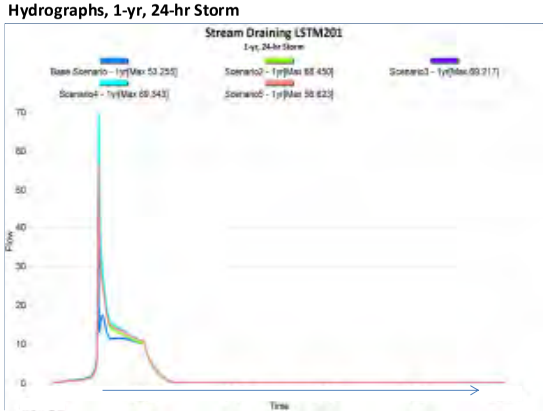
Total Stream Flow Volume, 1-yr, 24-hr Storm



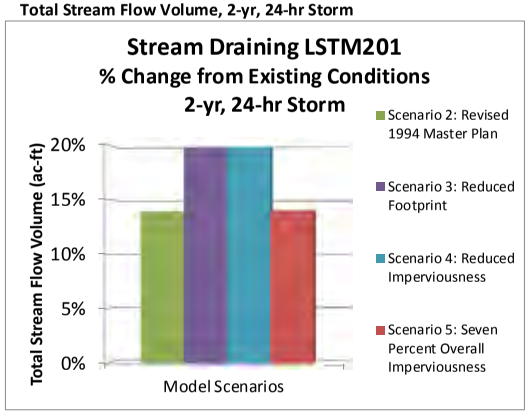
Peak Stream Flow, 1-yr, 24-hr Storm



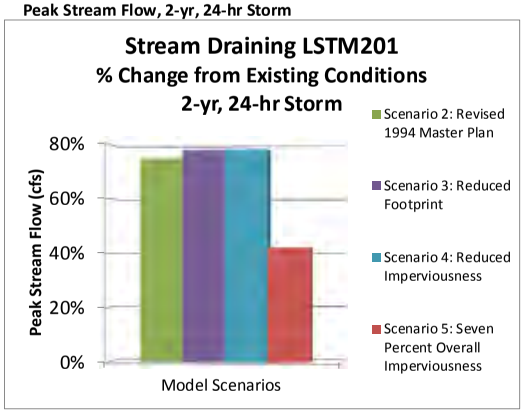
Hydrographs, 1-yr, 24-hr Storm



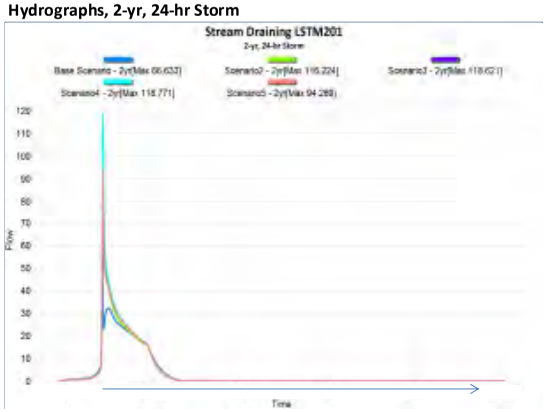
Total Stream Flow Volume, 2-yr, 24-hr Storm



Peak Stream Flow, 2-yr, 24-hr Storm



Hydrographs, 2-yr, 24-hr Storm

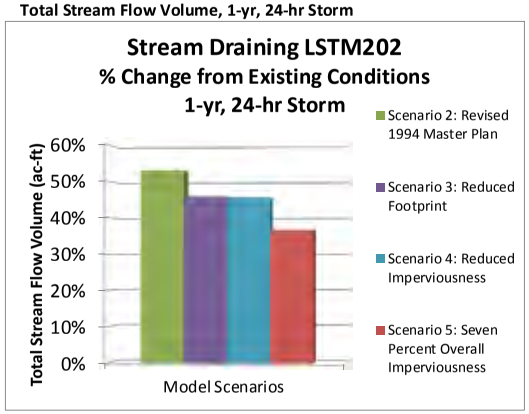


LSTM202			Existing Conditions	Scenario 2: Revised 1994 Master Plan			Scenario 3: Reduced Footprint			Scenario 4: Reduced Imperviousness			Scenario 5: Seven Percent Overall Imperviousness		
Model Results	Storm Event:	Model Parameter:	Existing Conditions	Developed Conditions	Net Impact (Change)	% Change	Developed Conditions	Net Impact (Change)	% Change	Developed Conditions	Net Impact (Change)	% Change	Developed Conditions	Net Impact (Change)	% Change
	1-yr, 24-hr Storm	Total Stream Flow Volume (ac-ft)	24.6	**37.6**	13.0	53%	**35.8**	11.3	46%	**35.8**	11.2	46%	**33.6**	9.0	37%
		Peak Stream Flow (cfs)	98.3	**137.9**	39.6	40%	**141.8**	43.5	44%	**140.4**	42.1	43%	**122.4**	24.1	25%
		Stream Flow Velocity (fps)	2.5	**2.7**	0.2	8%	**2.8**	0.2	9%	**2.7**	0.2	9%	**2.7**	0.2	8%
	2-yr, 24-hr Storm	Total Stream Flow Volume (ac-ft)	39.2	**56.2**	17.0	43%	**53.7**	14.4	37%	**53.6**	14.4	37%	**50.7**	11.5	29%
		Peak Stream Flow (cfs)	127.0	**229.5**	102.5	81%	**227.3**	100.3	79%	**225.6**	98.6	78%	**195.1**	68.0	54%
		Stream Flow Velocity (fps)	2.7	**3.2**	0.5	16%	**3.2**	0.4	16%	**3.2**	0.4	15%	**3.0**	0.3	10%

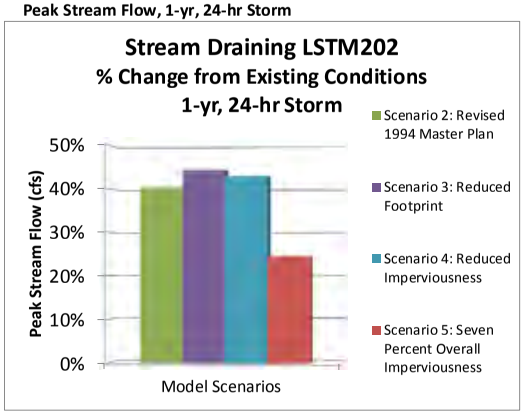
drains to link 101

Change compared to Existing Conditions

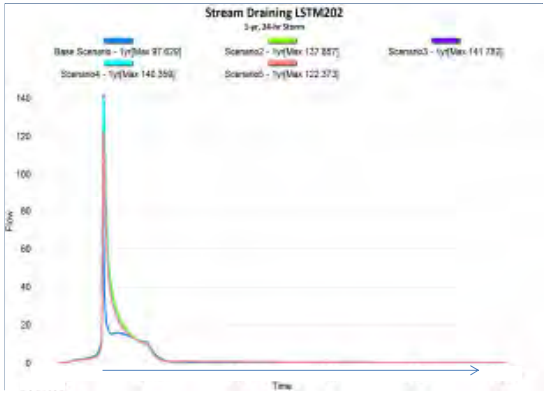
Total Stream Flow Volume, 1-yr, 24-hr Storm



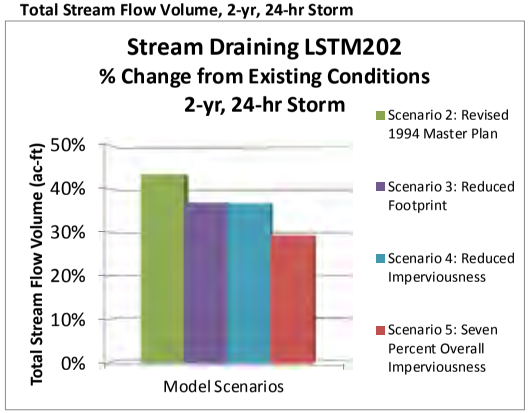
Peak Stream Flow, 1-yr, 24-hr Storm



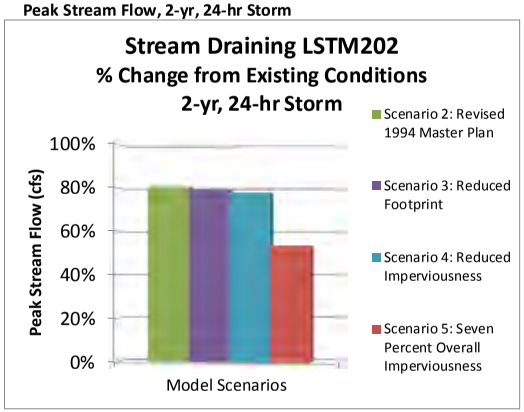
Hydrographs, 1-yr, 24-hr Storm



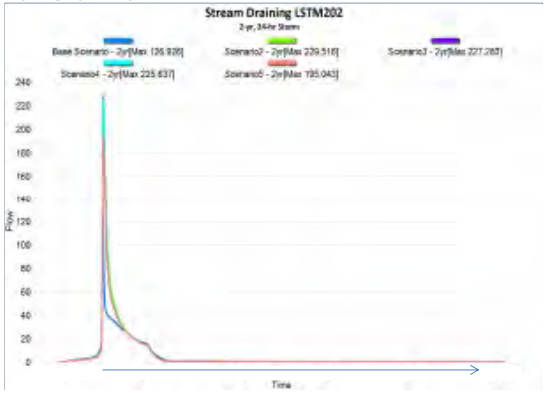
Total Stream Flow Volume, 2-yr, 24-hr Storm



Peak Stream Flow, 2-yr, 24-hr Storm



Hydrographs, 2-yr, 24-hr Storm

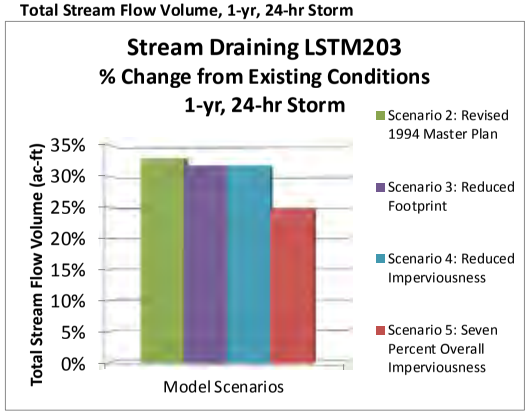


LSTM203			Existing Conditions	Scenario 2: Revised 1994 Master Plan			Scenario 3: Reduced Footprint			Scenario 4: Reduced Imperviousness			Scenario 5: Seven Percent Overall Imperviousness		
Model Results	Storm Event:	Model Parameter:	Existing Conditions	Developed Conditions	Net Impact (Change)	% Change	Developed Conditions	Net Impact (Change)	% Change	Developed Conditions	Net Impact (Change)	% Change	Developed Conditions	Net Impact (Change)	% Change
	1-yr, 24-hr Storm	Total Stream Flow Volume (ac-ft)	53.7	**71.3**	17.7	33%	**70.7**	17.0	32%	**70.6**	17.0	32%	**67.0**	13.3	25%
		Peak Stream Flow (cfs)	115.7	**196.9**	81.2	70%	**196.5**	80.8	70%	**196.1**	80.4	69%	**161.6**	45.9	40%
		Stream Flow Velocity (fps)	2.1	**2.5**	0.4	20%	**2.5**	0.5	22%	**2.5**	0.4	21%	**2.3**	0.3	13%
	2-yr, 24-hr Storm	Total Stream Flow Volume (ac-ft)	92.2	**115.5**	23.3	25%	**114.7**	22.5	24%	**114.6**	22.4	24%	**109.8**	17.6	19%
		Peak Stream Flow (cfs)	167.1	**323.8**	156.7	94%	**326.1**	159.0	95%	**324.5**	157.4	94%	**272.6**	105.5	63%
		Stream Flow Velocity (fps)	2.4	**2.9**	0.5	23%	**2.9**	0.5	23%	**2.9**	0.5	23%	**2.8**	0.4	19%

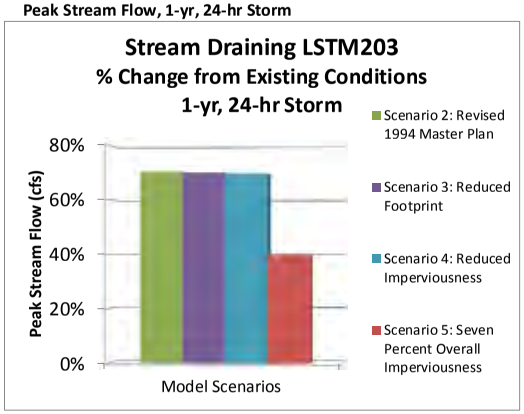
drains to link 90

Change compared to Existing Conditions

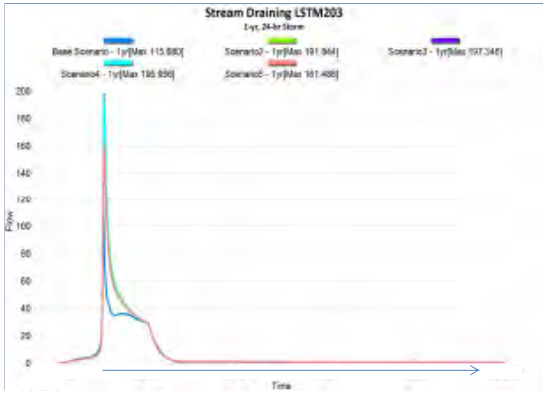
Total Stream Flow Volume, 1-yr, 24-hr Storm



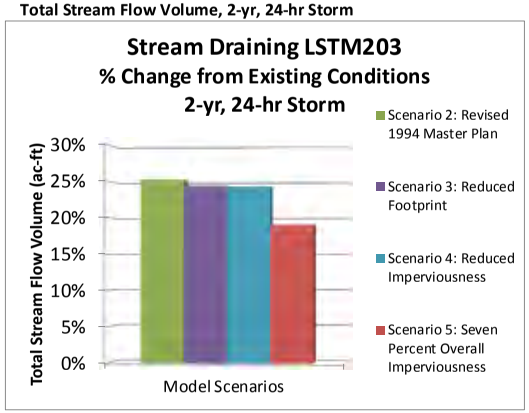
Peak Stream Flow, 1-yr, 24-hr Storm



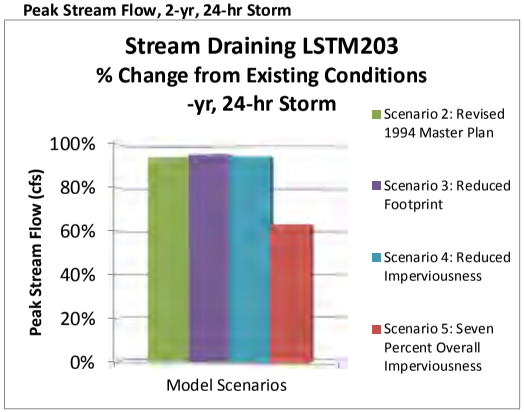
Hydrographs, 1-yr, 24-hr Storm



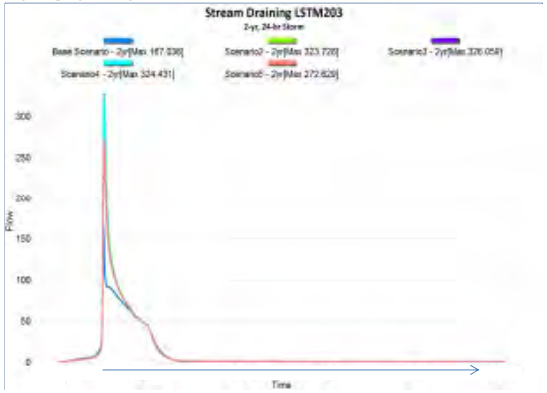
Total Stream Flow Volume, 2-yr, 24-hr Storm



Peak Stream Flow, 2-yr, 24-hr Storm



Hydrographs, 2-yr, 24-hr Storm

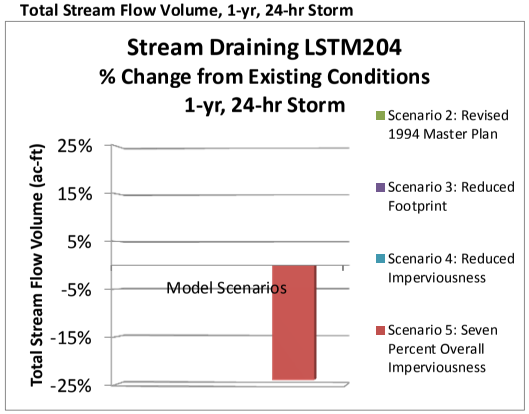


LSTM204			Existing Conditions	Scenario 2: Revised 1994 Master Plan			Scenario 3: Reduced Footprint			Scenario 4: Reduced Imperviousness			Scenario 5: Seven Percent Overall Imperviousness		
Model Results	Storm Event:	Model Parameter:	Existing Conditions	Developed Conditions	Net Impact (Change)	% Change	Developed Conditions	Net Impact (Change)	% Change	Developed Conditions	Net Impact (Change)	% Change	Developed Conditions	Net Impact (Change)	% Change
	1-yr, 24-hr Storm	Total Stream Flow Volume (ac-ft)	15.9	15.9	0.0	0%	**15.9**	0.0	0%	**15.9**	0.0	0%	**12.1**	-3.8	-24%
		Peak Stream Flow (cfs)	47.4	**47.7**	0.3	1%	**47.5**	0.2	0%	**47.5**	0.1	0%	**46.4**	-0.9	-2%
		Stream Flow Velocity (fps)	2.6	**2.7**	0.0	2%	**2.6**	0.0	0%	**2.6**	0.0	0%	**2.6**	0.0	-1%
	2-yr, 24-hr Storm	Total Stream Flow Volume (ac-ft)	28.6	**28.6**	0.0	0%	**28.6**	0.0	0%	**28.6**	0.0	0%	**23.0**	-5.6	-20%
		Peak Stream Flow (cfs)	60.3	**61.5**	1.2	2%	**61.6**	1.3	2%	**61.5**	1.2	2%	**58.4**	-1.9	-3%
		Stream Flow Velocity (fps)	2.7	**2.5**	-0.2	-6%	**2.5**	-0.2	-6%	**2.5**	-0.1	-5%	**2.5**	-0.2	-6%

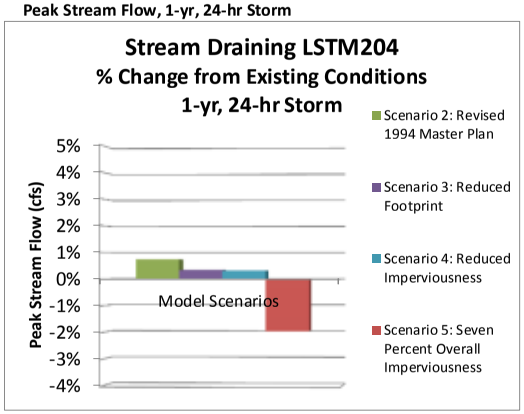
drains to link 041

Change compared to Existing Conditions

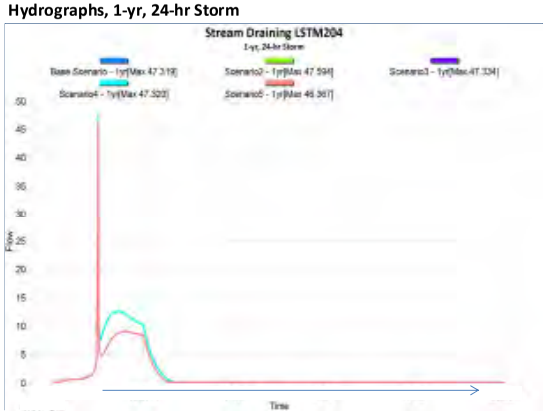
Total Stream Flow Volume, 1-yr, 24-hr Storm



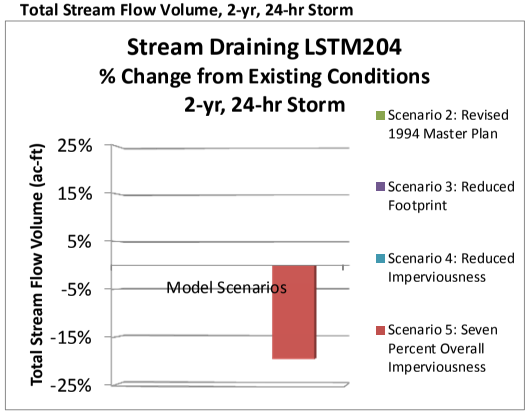
Peak Stream Flow, 1-yr, 24-hr Storm



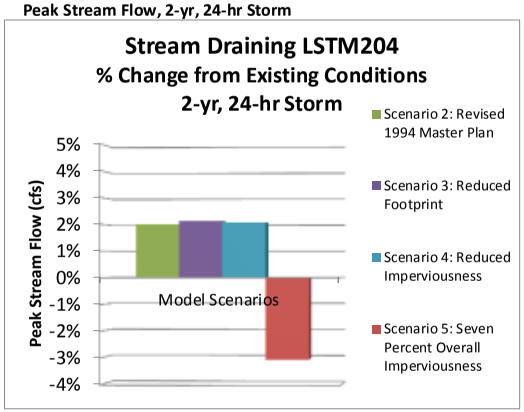
Hydrographs, 1-yr, 24-hr Storm



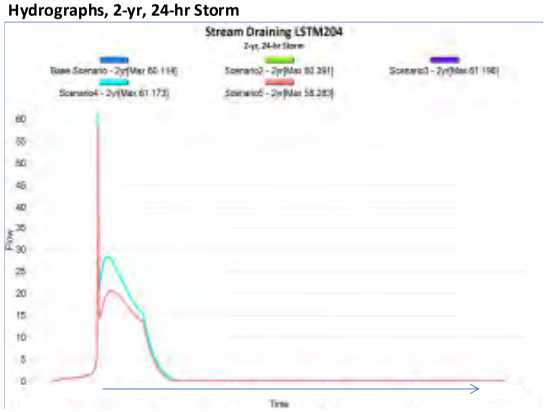
Total Stream Flow Volume, 2-yr, 24-hr Storm



Peak Stream Flow, 2-yr, 24-hr Storm



Hydrographs, 2-yr, 24-hr Storm

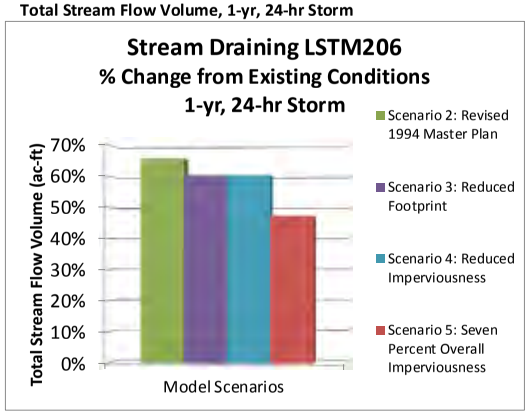


LSTM206			Existing Conditions	Scenario 2: Revised 1994 Master Plan			Scenario 3: Reduced Footprint			Scenario 4: Reduced Imperviousness			Scenario 5: Seven Percent Overall Imperviousness		
Model Results	Storm Event:	Model Parameter:	Existing Conditions	Developed Conditions	Net Impact (Change)	% Change	Developed Conditions	Net Impact (Change)	% Change	Developed Conditions	Net Impact (Change)	% Change	Developed Conditions	Net Impact (Change)	% Change
	1-yr, 24-hr Storm	Total Stream Flow Volume (ac-ft)	16.5	**27.3**	10.8	66%	**26.4**	9.9	60%	**26.4**	9.9	60%	**24.3**	7.8	47%
		Peak Stream Flow (cfs)	87.2	**98.4**	11.2	13%	**99.9**	12.7	15%	**99.9**	12.8	15%	**82.6**	-4.6	-5%
		Stream Flow Velocity (fps)	2.5	**2.6**	0.1	3%	**2.6**	0.1	4%	**2.6**	0.1	4%	**2.5**	0.0	-2%
	2-yr, 24-hr Storm	Total Stream Flow Volume (ac-ft)	25.2	**39.5**	14.3	57%	**38.2**	13.0	52%	**38.2**	13.1	52%	**35.5**	10.3	41%
		Peak Stream Flow (cfs)	108.0	**161.1**	53.1	49%	**160.9**	52.9	49%	**161.0**	53.0	49%	**130.0**	22.0	20%
		Stream Flow Velocity (fps)	2.7	**2.8**	0.1	4%	**2.8**	0.1	4%	**2.8**	0.1	4%	**2.7**	0.0	-1%

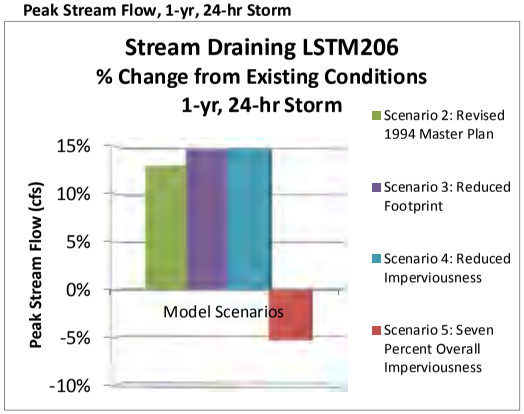
drains to link 102

Change compared to Existing Conditions

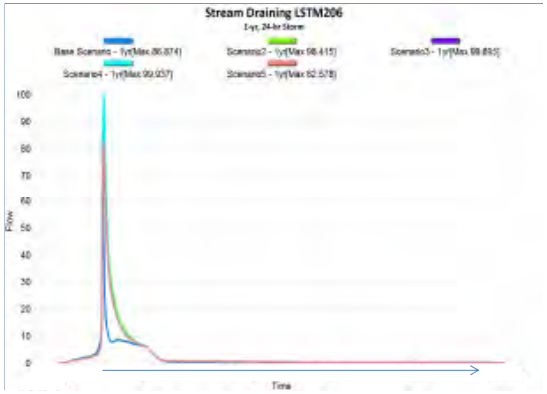
Total Stream Flow Volume, 1-yr, 24-hr Storm



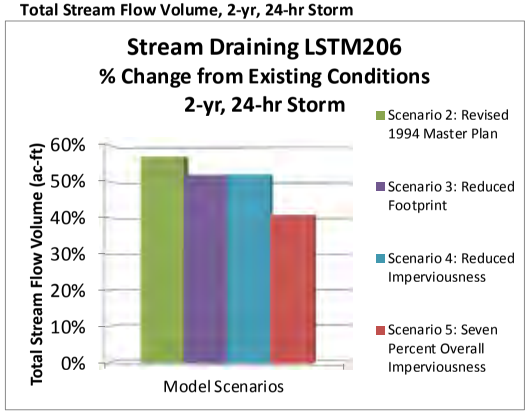
Peak Stream Flow, 1-yr, 24-hr Storm



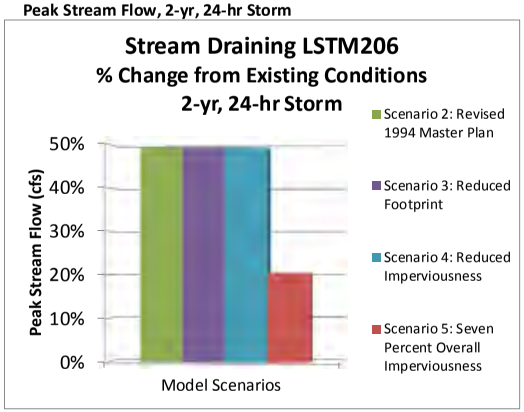
Hydrographs, 1-yr, 24-hr Storm



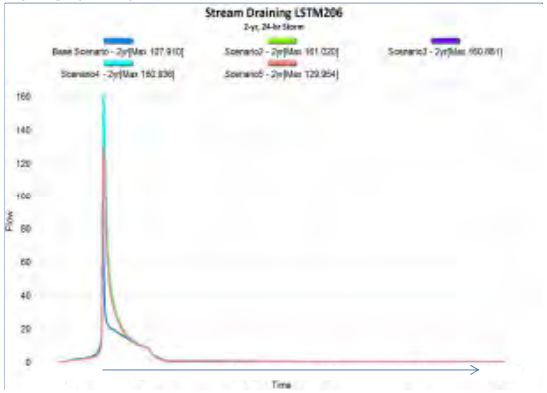
Total Stream Flow Volume, 2-yr, 24-hr Storm



Peak Stream Flow, 2-yr, 24-hr Storm



Hydrographs, 2-yr, 24-hr Storm

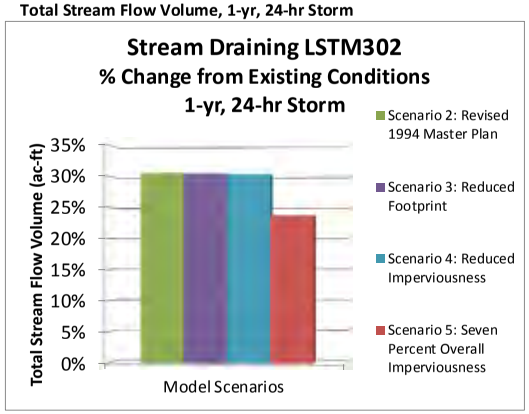


LSTM302			Existing Conditions	Scenario 2: Revised 1994 Master Plan			Scenario 3: Reduced Footprint			Scenario 4: Reduced Imperviousness			Scenario 5: Seven Percent Overall Imperviousness		
Model Results	Storm Event:	Model Parameter:	Existing Conditions	Developed Conditions	Net Impact (Change)	% Change	Developed Conditions	Net Impact (Change)	% Change	Developed Conditions	Net Impact (Change)	% Change	Developed Conditions	Net Impact (Change)	% Change
	1-yr, 24-hr Storm	Total Stream Flow Volume (ac-ft)	56.3	**73.5**	17.2	30%	**73.5**	17.1	30%	**73.4**	17.1	30%	**69.7**	13.3	24%
		Peak Stream Flow (cfs)	112.5	**190.3**	77.8	69%	**195.7**	83.1	74%	**194.5**	81.9	73%	**160.7**	48.1	43%
		Stream Flow Velocity (fps)	1.5	**1.8**	0.3	21%	**1.8**	0.3	23%	**1.8**	0.3	22%	**1.7**	0.2	14%
	2-yr, 24-hr Storm	Total Stream Flow Volume (ac-ft)	96.9	**119.5**	22.5	23%	**119.5**	22.6	23%	**119.5**	22.5	23%	**114.6**	17.7	18%
		Peak Stream Flow (cfs)	167.2	**322.5**	155.3	93%	**326.7**	159.5	95%	**325.3**	158.1	95%	**274.4**	107.2	64%
		Stream Flow Velocity (fps)	1.7	**2.1**	0.4	21%	**2.1**	0.4	22%	**2.1**	0.4	22%	**2.0**	0.3	18%

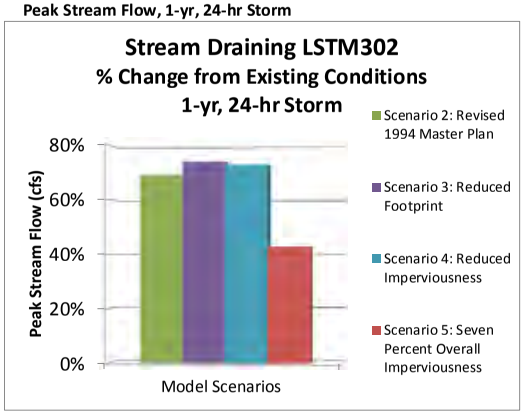
drains to link 80

Change compared to Existing Conditions

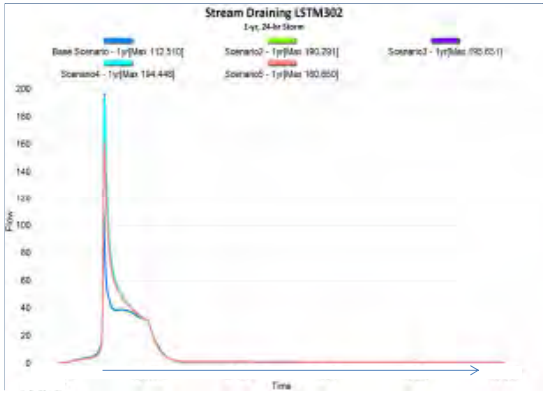
Total Stream Flow Volume, 1-yr, 24-hr Storm



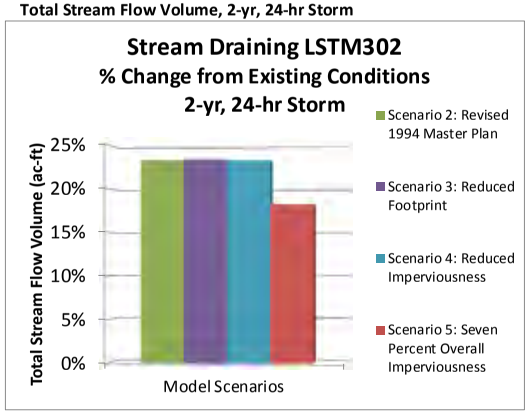
Peak Stream Flow, 1-yr, 24-hr Storm



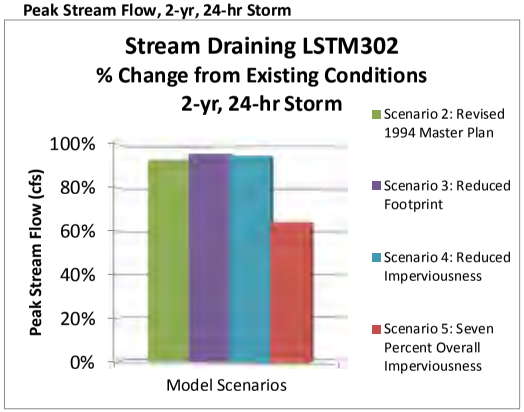
Hydrographs, 1-yr, 24-hr Storm



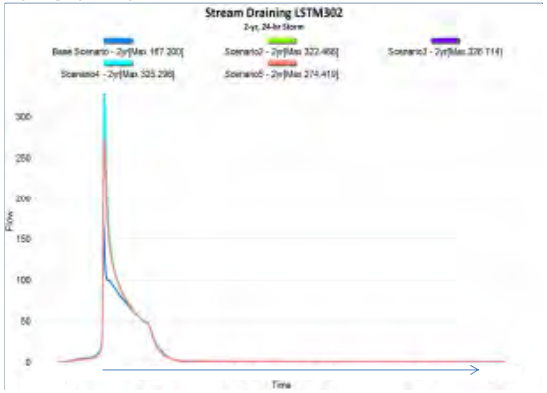
Total Stream Flow Volume, 2-yr, 24-hr Storm



Peak Stream Flow, 2-yr, 24-hr Storm



Hydrographs, 2-yr, 24-hr Storm

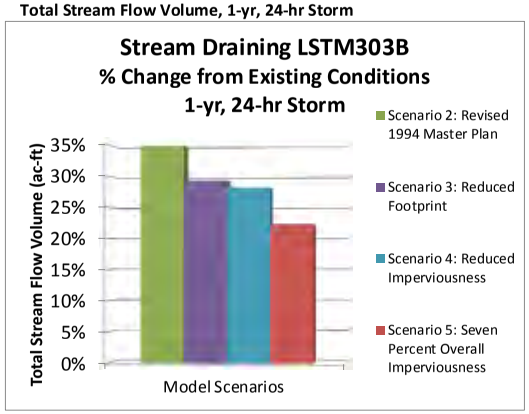


LSTM303B			Existing Conditions	Scenario 2: Revised 1994 Master Plan			Scenario 3: Reduced Footprint			Scenario 4: Reduced Imperviousness			Scenario 5: Seven Percent Overall Imperviousness		
Model Results	Storm Event:	Model Parameter:	Existing Conditions	Developed Conditions	Net Impact (Change)	% Change	Developed Conditions	Net Impact (Change)	% Change	Developed Conditions	Net Impact (Change)	% Change	Developed Conditions	Net Impact (Change)	% Change
	1-yr, 24-hr Storm	Total Stream Flow Volume (ac-ft)	68.1	**91.9**	23.8	35%	**88.1**	19.9	29%	**87.3**	19.2	28%	**83.3**	15.2	22%
		Peak Stream Flow (cfs)	107.5	**231.6**	124.1	115%	**222.2**	114.7	107%	**216.8**	109.3	102%	**183.7**	76.2	71%
		Stream Flow Velocity (fps)	2.0	**2.4**	0.4	18%	**2.4**	0.3	17%	**2.3**	0.3	15%	**2.3**	0.3	14%
	2-yr, 24-hr Storm	Total Stream Flow Volume (ac-ft)	118.4	**149.2**	30.8	26%	**144.2**	25.8	22%	**143.1**	24.7	21%	**138.0**	19.6	17%
		Peak Stream Flow (cfs)	176.2	**402.7**	226.5	129%	**381.8**	205.6	117%	**376.6**	200.4	114%	**328.9**	152.6	87%
		Stream Flow Velocity (fps)	2.3	**2.9**	0.6	27%	**2.9**	0.6	25%	**2.9**	0.6	24%	**2.7**	0.4	18%

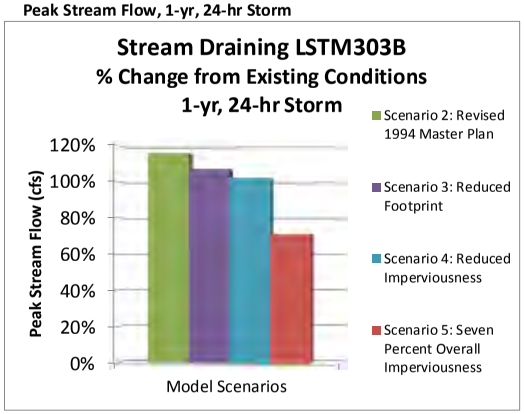
drains to link 50

Change compared to Existing Conditions

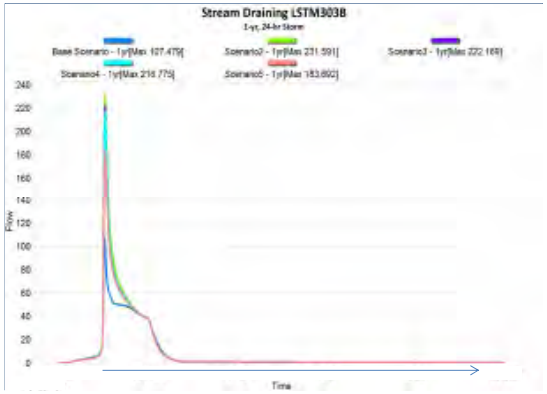
Total Stream Flow Volume, 1-yr, 24-hr Storm



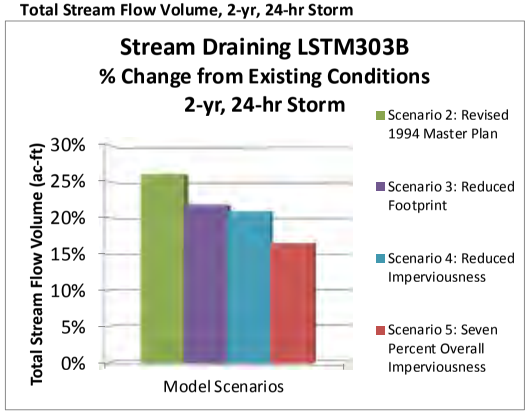
Peak Stream Flow, 1-yr, 24-hr Storm



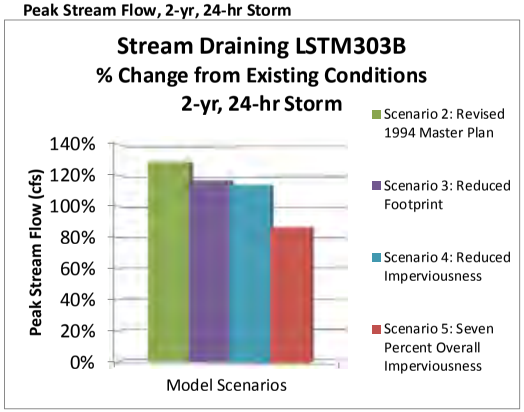
Hydrographs, 1-yr, 24-hr Storm



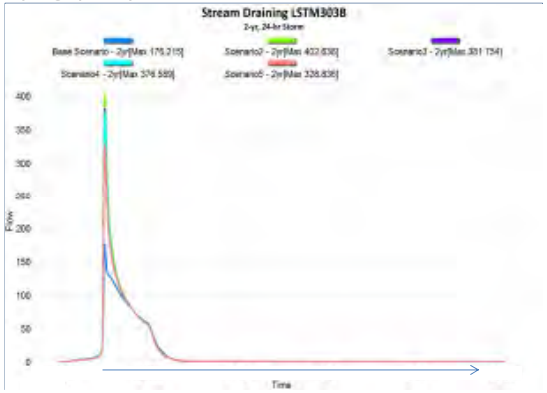
Total Stream Flow Volume, 2-yr, 24-hr Storm



Peak Stream Flow, 2-yr, 24-hr Storm



Hydrographs, 2-yr, 24-hr Storm

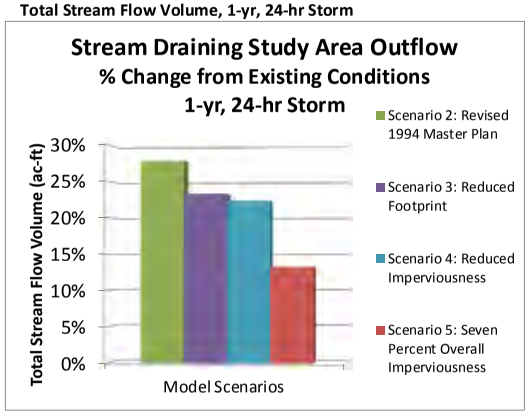


STUDY AREA OUTFLOW			Existing Conditions	Scenario 2: Revised 1994 Master Plan			Scenario 3: Reduced Footprint			Scenario 4: Reduced Imperviousness			Scenario 5: Seven Percent Overall Imperviousness		
	Storm Event:	Model Parameter:	Existing Conditions	Developed Conditions	Net Impact (Change)	% Change	Developed Conditions	Net Impact (Change)	% Change	Developed Conditions	Net Impact (Change)	% Change	Developed Conditions	Net Impact (Change)	% Change
Model Results	1-yr, 24-hr Storm	Total Stream Flow Volume (ac-ft)	85.6	**109.4**	23.8	28%	**105.5**	19.9	23%	**104.7**	19.1	22%	**96.9**	11.3	13%
		Peak Stream Flow (cfs)	109.4	**229.6**	120.2	110%	**219.0**	109.7	100%	**214.0**	104.6	96%	**182.6**	73.3	67%
		Stream Flow Velocity (fps)	2.2	**2.6**	0.4	20%	**2.6**	0.4	18%	**2.6**	0.4	18%	**2.6**	0.4	17%
	2-yr, 24-hr Storm	Total Stream Flow Volume (ac-ft)	149.9	**180.7**	30.8	21%	**175.5**	25.7	17%	**174.5**	24.6	16%	**163.7**	13.9	9%
		Peak Stream Flow (cfs)	194.2	**423.0**	228.8	118%	**398.8**	204.6	105%	**393.2**	199.0	102%	**335.4**	141.2	73%
		Stream Flow Velocity (fps)	2.6	**3.2**	0.6	25%	**3.2**	0.6	21%	**3.1**	0.5	20%	**2.9**	0.3	13%

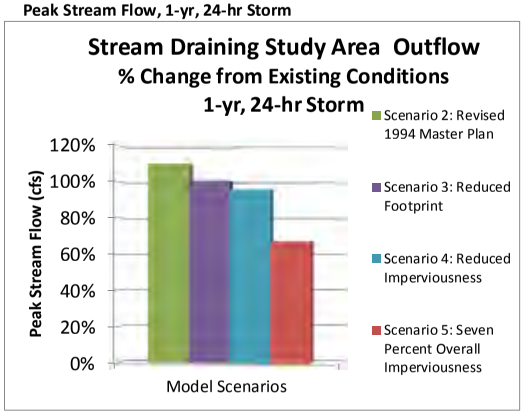
drains to link 30

Change compared to Existing Conditions

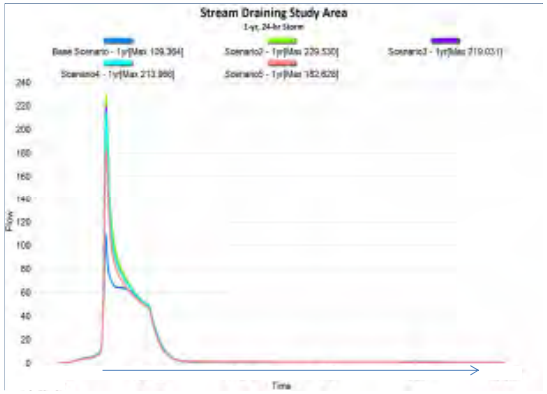
Total Stream Flow Volume, 1-yr, 24-hr Storm



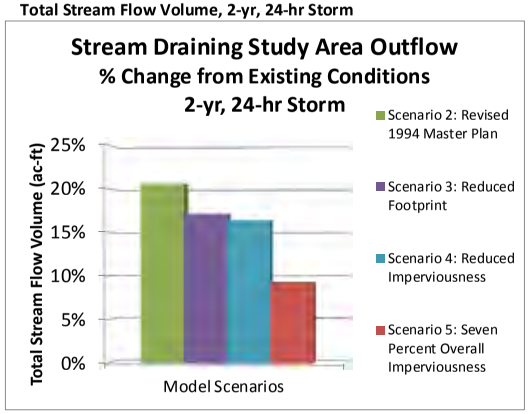
Peak Stream Flow, 1-yr, 24-hr Storm



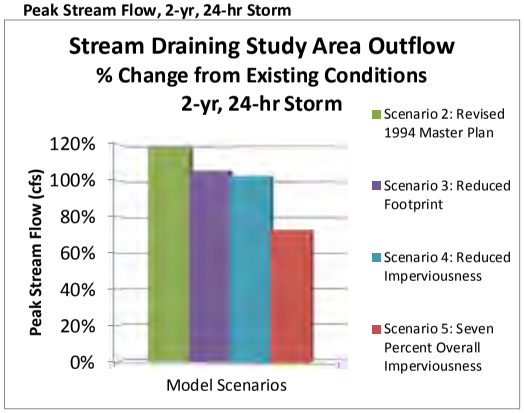
Hydrographs, 1-yr, 24-hr Storm



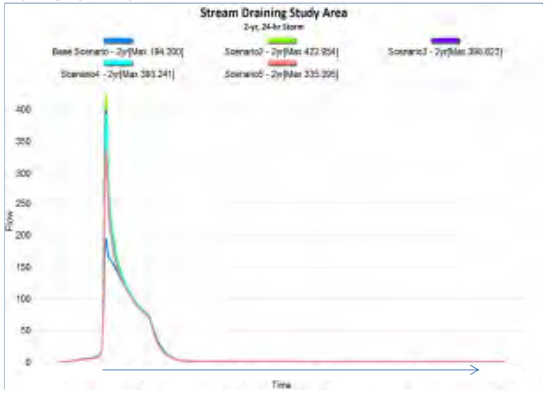
Total Stream Flow Volume, 2-yr, 24-hr Storm



Peak Stream Flow, 2-yr, 24-hr Storm

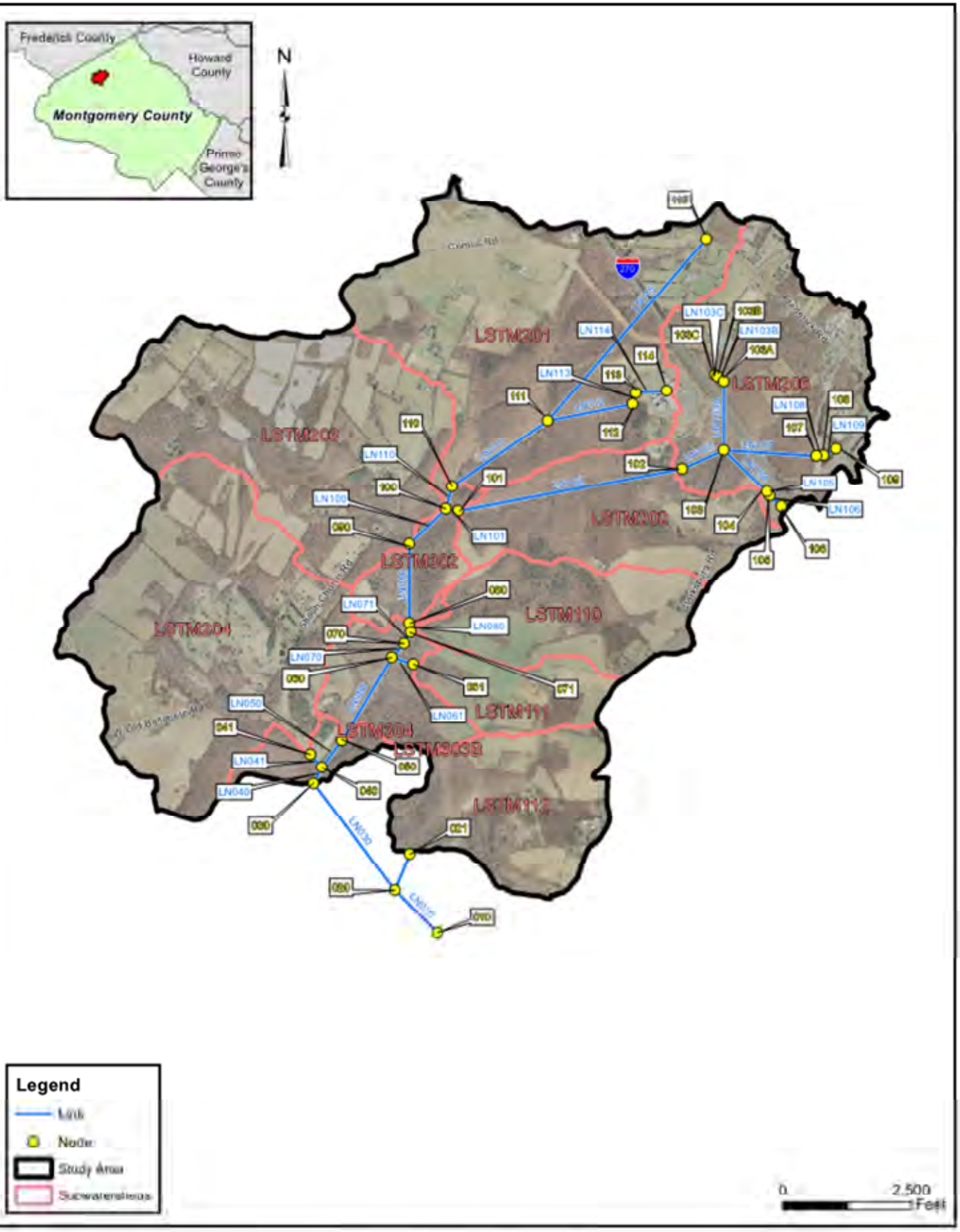


Hydrographs, 2-yr, 24-hr Storm



Appendix B –

Link Node Diagram



Ten Mile Creek

Clarksburg Master Plan Limited Amendment

SWMM Model Features

Appendix C –

Calculation of Runoff Curve Numbers

The XP-SWMM hydrologic model uses a standard Curve Number method as part of its calculation of runoff during storm events. Curve numbers correspond to runoff characteristics of different hydrologic soil groups and land cover types, with higher curve numbers corresponding to soil groups and land cover types that are less permeable and contribute more stormwater runoff. The process of generating composite curve numbers for each of the modeled subcatchments is described below.

Curve numbers were be established from the United States Department of Agriculture's "Urban Hydrology for Small Watersheds, TR-55", tables 2-2a, 2-2b, and 2-2c. Land uses in the Ten Mile Creek study area were used to assign a representative TR-55 cover description then an associated curve number based on soil infiltration characteristics. The study area land use descriptions, representative TR-55 cover descriptions and curve numbers utilized in the model scenario are provided in Table C-1.

Table C-1: Runoff Curve Numbers

Land Cover Type		Curve Numbers for Hydrologic Soil Group			
Study Area Land Use	**Representative TR-55 Cover Description**	**A**	**B**	**C**	**D**
Impervious	Impervious	98	98	98	98
Wetlands	Impervious	98	98	98	98
Water	Impervious	98	98	98	98
Cropland	Small Grain, Good	63	75	83	87
Bare Ground	Fallow, Bare Soil	77	86	91	94
Large Lot Subdivision (ag)	Pasture, Grassland, Good Condition	39	61	74	80
Pasture	Pasture, Grassland, Good Condition	39	61	74	80
Large Lot Subdivision (forest)	Woods, Good	30	55	70	77
Forest	Woods, Good	30	55	70	77
Low Density Residential	Residential Districts, 2 acres	46	65	77	82
Medium Density Residential	Residential Districts, 1/2 acre	54	70	80	85
High Density Residential	Residential Districts 1/8 acre	77	85	90	92
Transportation Right of Way	Open Space, Good Condition	39	61	74	80
Utility Right of Way	Open Space, Good Condition	39	61	74	80
Institutional	Open Space, Fair Condition	49	69	79	84
Industrial	Industrial	81	88	91	93
Commercial	Commercial and Business	89	92	94	95
Land conversions outside SPA LODs[3]	Meadow	30	58	71	78
Land conversions inside Rural Parcel LODs[4]	Open Space, Good Condition	39	61	74	80

1. Representative TR-55 Cover Description and Curve Numbers synthesized from tables: 2-2a, 2-2b, and 2-2c from USDA NRCS "Urban Hydrology for Small Watersheds TR-55".
2. A hydrologic condition of "good" assumed for all appropriate cover descriptions
3. Conversions of unforested land to Meadow were processed between the stream and LODs in the SPA, as described in Section 2.
4. Conversions to of undeveloped and unforested land to Open Space were processed for development in the rural parcels.

For the base (existing conditions) model scenario, the overall runoff characteristics to each model node were characterized by calculating acreages for each combination of existing land use and HSG category based on unions of the GIS land cover, land use and hydrologic soil group (HSG) data provided for the study. Each of the resulting land use/HSG combinations was then assigned a TR-55 curve number from Table C-1, then the data polygons were combined through weighted averages to produce one composite curve number representing overall runoff characteristics for each subcatchment area. Data sources used for the analyses were provided by the Planning Department.

During development, heavy equipment used to grade land for construction compacts soils within the Limits of Disturbance (LOD), which increases the runoff from these areas along with the associated curve number. One method of modeling to account for the soil compaction that occurs during development is to assume that a soil moves from its original hydrologic soil group to the next less permeable soil group as a result of compaction.

In addition to state ESD requirements, Montgomery County requires a toposoiling or decompaction procedure for soils in grassed and landscaped (pervious) areas with the LOD. This procedure involves tillage to a depth from 8 to 10 inches, with 4 inches of topsoil added. A more rigorous procedure that involves a deeper tillage of 2 feet with organic material mixed in to amend the soil typically is sufficient to bring the soil approximately back to its original curve number. Because the County's requirements involve tillage to almost half the depth of the more rigorous procedure, and includes topsoil, a moderate assumption for the effect of the County's soil decompaction method is a final curve number halfway between the original soil curve number and the compacted soil curve number. This assumption was used to represent the County's soil decompaction requirements in the XP-SWMM hydrologic model.

For the May 2013 development scenarios, as described in Section 2, in each subwatershed, subcatchment #1 was used to represent all the land outside the proposed development area as defined by the LODs provided by the Planning Department. After separating out the areas within the development LODs, the composite curve number within subcatchment #1 was recalculated based on the remaining acreages of existing land use and underlying soil type combinations, using the same land use categories and associated TR-55 curve numbers as were used to calculate the CNs for the base (existing conditions) model scenario. Subcatchments #2 and #3 were used to represent the impervious and pervious portions of the new development, respectively. Subcatchment #2 was used to combine all of the impervious areas of the proposed development, and assigned a curve number of 98. A composite curve number was computed for subcatchment #3 based on the proposed pervious land uses after the conversion process described above, and the underlying soil types. The TR-55 curve numbers for existing soil HSG and the next less permeable HSG were averaged to represent each post-development pervious land use polygon. For example, a polygon converted to High Density Residential in a B soil HSG would be assigned a curve number of 87.5, or the average between the B soil CN of 85 and the C soil CN of 90.

The data used to generate the composite curve numbers for the development scenarios included the TR-55 curve numbers listed in Table C-1, along with existing land use data, the shapefiles representing proposed development parcels, and numerous other data files provided by the Planning Department. Table C-2 provides a summary of CNs calculated for each model scenario.

Table C-2: Composite Curve Numbers used for Model Scenarios									
	Scenario 1	Scenario 2		Scenario 3		Scenario 4		Scenario 5	
LSTM	Existing Conditons	SC1 - Undeveloped	SC3 - Developed Pervious	SC1 - Undeveloped	SC3 - Developed Pervious	SC1 - Undeveloped	SC3 - Developed Pervious	SC1 - Undeveloped	SC3 - Developed Pervious
110	66	65	72	62	77	62	77	62	77
111	69	64	75	63	78	63	78	63	78
112	65	61	77	61	78	61	78	61	78
201	66	66	71	66	71	66	71	60	69
202	69	66	78	64	84	64	84	64	86
203	66	66	79	66	79	66	79	66	79
204	68	68	76	68	76	68	76	68	76
206	65	67	69	65	72	65	72	65	72
302	69	64	73	70	68	70	68	70	68
303B	65	65	70	64	76	64	76	64	76
304	67	67	NA	67	NA	67	NA	67	NA
SC = Subcatchment		Scenarios 2-5 also included subcatchment 2 to represent all post-development impervious area, with a curve number of 98.							

Appendix D –

Environmental Site Design Calculations

Sub Basin 110 (1 yr 24 hr Storm)														
Sub-Basin	Development	HSG	Area (Acres)	Area (ft2)	RCN	RCN*	Impervious (%)	Rv	Pe (in)	Qe (in)	ESDv (ft3)	Af (Mont Co) sf	Total Af (acres)Mont. Co	Af (Acres)
110	Pulte Residential	B	85.43	3721209.64	55	55	33.02	0.34718	1.8	0.62	197736.68	101403.43	2.33	3.74
110	Pulte Residential	C	1.74	75796.38	70				1.6					
Sub Basin 111 (1 yr 24 hr Storm)														
Sub-Basin	Development	HSG	Area (Acres)	Area (ft2)	RCN	RCN*	Impervious (%)	Rv	Pe (in)	Qe (in)	ESDv (ft3)	Af (Mont Co) sf	Total Af (acres)Mont. Co	Af (Acres)
111	Pulte Residential	B	42.76	1862633.22	55	55	33.02	0.34718	1.8	0.62	99376.13	50962.12	1.17	1.88
111	Pulte Residential	C	1.05	45620.54	70				1.6					
Sub Basin 112 (1 yr 24 hr Storm)														
Sub-Basin	Development	HSG	Area (Acres)	Area (ft2)	RCN	RCN*	Impervious (%)	Rv	Pe (in)	Qe (in)	ESDv (ft3)	Af (Mont Co) sf	Total Af (acres)Mont. Co	Af (Acres)
112	Pulte Residential	B	21.73	946588.72	55	55	33.02	0.34718	1.8	0.62	49295.50	25279.74	0.58	0.93
Sub Basin 201 (1 yr 24 hr Storm)														
Sub-Basin	Development	HSG	Area (Acres)	Area (ft2)	RCN	RCN*	Impervious (%)	Rv	Pe (in)	Qe (in)	ESDv (ft3)	Af (Mont Co) sf	Total Af (acres)Mont. Co	Af (Acres)
201	Egan/Mattlyn	B	35.04	1526330.654	55	55	50.15	0.50135	1.8	0.90	114798.84	58871.20	2.24	2.17
201	Egan/Mattlyn	C	0.00	198.9206325	70	55			1.8					
201	Developable Private Rural	B	20.35	886381.9597	55	56	43.00	0.437	1.8	0.79	60130.77	30836.29		1.14
201	Developable Private Rural	C	0.71	30944.87133	70	60			1.8					
201	I-270 Median	B	1.59	69112.15949	55	57	100.00	0.95	2.6	2.47	15312.54	7852.59		0.29
201	I-270 Median	D	0.12	5280.754543	77	77			2					
Sub Basin 202 (1 yr 24 hr Storm)														
Sub-Basin	Development	HSG	Area (Acres)	Area (ft2)	RCN	RCN*	Impervious (%)	Rv	Pe (in)	Qe (in)	ESDv (ft3)	Af (Mont Co) sf	Total Af (acres)Mont. Co	Af (Acres)
202	MD 121	B	1.60	69683.28	55	55	100.00	0.95	2.6	2.47	14343.14	7355.46	1.94	0.27
202	Pulte Residential	B	31.96	1392109.30	55	55	33.02	0.34718	1.8	0.62	72978.93	37425.09		1.38
202	Pulte Residential	C	0.21	9256.57	70				1.6					
202	Pulte County Site	B	10.88	473781.66	55	65	41.56	0.42404	1.8	0.76	77399.12	39691.85		1.46
202	Pulte County Site	C	12.59	548274.12	70				1.8					
202	Pulte County Site	D	4.47	194796.67	77				1.6					
Sub Basin 203 (1 yr 24 hr Storm)														
Sub-Basin	Development	HSG	Area (Acres)	Area (ft2)	RCN	RCN*	Impervious (%)	Rv	Pe (in)	Qe (in)	ESDv (ft3)	Af (Mont Co) sf	Total Af (acres)Mont. Co	Af (Acres)
203	Developable Private Rural	B	2.334415982	101687.16	55	#REF!	43.00	0.437	1.8	0.79	6665.59	3418.25	0.08	0.13
Sub Basin 204 (1 yr 24 hr Storm)														
Sub-Basin	Development	HSG	Area (Acres)	Area (ft2)	RCN	RCN*	Impervious (%)	Rv	Pe (in)	Qe (in)	ESDv (ft3)	Af (Mont Co) sf	Total Af (acres)Mont. Co	Af (Acres)
204	Developable Private Rural	B	1.494632774	65106.20	55	#REF!	43.00	0.437	1.8	0.79	4267.71	2188.57	0.05	0.08
Sub Basin 206 (1 yr 24 hr Storm)														
Sub-Basin	Development	HSG	Area (Acres)	Area (ft2)	RCN	RCN*	Impervious (%)	Rv	Pe (in)	Qe (in)	ESDv (ft3)	Af (Mont Co) sf	Total Af (acres)Mont. Co	Af (Acres)
206	Developable Private Rural	B	0.12	5343.57	55	55	43.00	0.437	1.8	0.79	350.27	179.63	5.87	0.01
206	Egan/Mattlyn	B	21.77	948405.34	55	55	50.15	0.50135	1.8	0.90	71322.45	36575.62		1.35
206	Fire Station	B	4.08	177846.53	55	55	37.00	0.383	1.8	0.69	10217.28	5239.63		0.19
206	Hammer Hill	B	1.34	58560.40	55	55	30.00	0.32	1.6	0.51	2498.58	1281.32		0.05
206	Historic Area Commercial	B	0.73	31706.23	55	55	80.00	0.77	2.2	1.69	4475.86	2295.31		0.08
206	Historic Property Vacant	B	4.38	190970.95	55	55	15.40	0.1886	1	0.19	3001.43	1539.19		0.06
206	Historic Property Vacant	D	0.08	3345.58	77									
206	MD 121	B	3.67	159854.42	55	56	100.00	0.95	2.6	2.47	32903.37	16873.52		0.62
206	MD 121	C	0.39	16896.48	70				2.2					
206	MD 121	D	0.01	501.97	77				2					
206	MD 355	B	28.61	1246204.78	55	60	30.40	0.3236	1.6	0.52	53769.58	27574.14		1.02
206	MD 355	C	2.87	125117.89	70				1.6					
206	MD 355	D	6.93	302056.71	77				1.2					
206	Miles Coppola	B	37.04	1613561.64	55	57	60.03	0.59027	2	1.18	181963.06	93314.39		3.44
206	Miles Coppola	C	4.75	207086.40	70				2					
206	Miles Coppola	D	0.67	28977.35	77				1.8					
206	Pulte County	B	5.64	245654.62	55	65	41.56	0.42404	1.8	0.76	49290.62	25277.24		0.93
206	Pulte County	C	12.15	529282.01	70				1.8					
206	I-270 Median	B	1.63	71154.70	55	57	100.00	0.95	2.6	2.47	16709.76	8569.11		0.32
206	I-270 Median	C	0.08	3524.98	70				2.2					
206	I-270 Median	D	0.15	6501.34	77				2					
206	Historic District Residential	B	5.88	256177.22	55	55	15.40	0.1886	1	0.19	4026.25	2064.74		
206	Towne Center Redev	B	17.55	764429.49	55	55	53.69	0.53321	2	1.07	67933.57	34837.73		
Sub Basin 302 (1 yr 24 hr Storm)														
Sub-Basin	Development	HSG	Area (Acres)	Area (ft2)	RCN	RCN*	Impervious (%)	Rv	Pe (in)	Qe (in)	ESDv (ft3)	Af (Mont Co) sf	Total Af (acres)Mont. Co	Af (Acres)
302	Pulte Residential	B	5.08	221215.36	55	55	33.02	0.34718	1.8	0.62	11520.23	5907.81	0.14	0.22
302	Developable Private Rural	B	2.72	118680.56	55	55	43.00	0.437	1.8	0.79	7782.11	3990.83		0.15
302	Developable Private Rural	C	0.00	39.71	70									
Sub Basin 303B (1 yr 24 hr Storm)														
Sub-Basin	Development	HSG	Area (Acres)	Area (ft2)	RCN	RCN*	Impervious (%)	Rv	Pe (in)	Qe (in)	ESDv (ft3)	Af (Mont Co) sf	Total Af (acres)Mont. Co	Af (Acres)
303b	Developable Private Rural	B	3.18	138628.24	55	55	43.00	0.437	1.8	0.79	9120.25	4677.05	0.11	0.17
303b	Developable Private Rural	C	0.01	506.07	70									
303b	Pulte Residential	B	5.22	227379.34	55	55	33.02	0.34718	1.8	0.62	11953.26	6129.88		0.23
303b	Pulte Residential	C	0.05	2151.24	70				1.6					

sin 110 (1 yr 24 hr Storm)														
Sub-Basin	Development	HSG	Area (Acres)	Area (ft2)	RCN	RCN*	Impervious (%)	Rv	Pe (in)	Qe (in)	ESDv (ft3)	Af (Mont Co) sf	Total Af (acres)Mont. Co	Af (Acres)
110	Pulte Residential	B	42.25	1840346.81	55	55	40.00	0.41	1.8	0.74	113190.21	58046.26	1.33	2.14
110	Pulte Residential	C	0.00	144.44	70				1.8					
sin 111 (1 yr 24 hr Storm)														
Sub-Basin	Development	HSG	Area (Acres)	Area (ft2)	RCN	RCN*	Impervious (%)	Rv	Pe (in)	Qe (in)	ESDv (ft3)	Af (Mont Co) sf	Total Af (acres)Mont. Co	Af (Acres)
111	Pulte Residential	B	31.09	1354277.32	55	56	40.00	0.41	1.8	0.74	86354.70	44284.46	1.02	1.63
111	Pulte Residential	C	1.14	49864.11	70				1.8					
sin 112 (1 yr 24 hr Storm)														
Sub-Basin	Development	HSG	Area (Acres)	Area (ft2)	RCN	RCN*	Impervious (%)	Rv	Pe (in)	Qe (in)	ESDv (ft3)	Af (Mont Co) sf	Total Af (acres)Mont. Co	Af (Acres)
112	Pulte Residential	B	21.56	939368.15	55	55	40.00	0.41	1.8	0.74	57771.14	29626.23	0.68	1.09
sin 201 (1 yr 24 hr Storm)														
Sub-Basin	Development	HSG	Area (Acres)	Area (ft2)	RCN	RCN*	Impervious (%)	Rv	Pe (in)	Qe (in)	ESDv (ft3)	Af (Mont Co) sf	Total Af (acres)Mont. Co	Af (Acres)
201	Egan/Mattlyn	B	35.62	1551720.55	55	55	50.15	0.50135	1.8	0.90	116823.55	59909.51	2.26	2.21
201	Egan/Mattlyn	C	0.04	1732.45	70	55			1.8					
201	Developable Private Rural	B	20.35	886381.96	55	56	43.00	0.437	1.8	0.79	60130.77	30836.29		1.14
201	Developable Private Rural	C	0.71	30944.87	70	60			1.8					
201	I-270 Median	B	1.59	69112.46	55	57	100.00	0.95	2.6	2.47	15312.61	7852.62		0.29
201	I-270 Median	D	0.12	5280.80	77	77			2					
sin 202 (1 yr 24 hr Storm)														
Sub-Basin	Development	HSG	Area (Acres)	Area (ft2)	RCN	RCN*	Impervious (%)	Rv	Pe (in)	Qe (in)	ESDv (ft3)	Af (Mont Co) sf	Total Af (acres)Mont. Co	Af (Acres)
202	MD 121	B	1.60	69683.18	55	55	100.00	0.95	2.6	2.47	14343.12	7355.45	1.52	0.27
202	Pulte Residential	B	18.87	822155.07	55	55	40.00	0.41	1.8	0.74	50706.65	26003.41		0.96
202	Pulte Residential	C	0.05	2343.38	70				1.8					
202	Pulte County Site	B	4.14	180370.12	55	69	41.56	0.42404	1.8	0.76	64188.57	32917.22		1.21
202	Pulte County Site	C	14.63	637345.77	70				1.8					
202	Pulte County Site	D	4.39	191443.21	77				1.6					
sin 203 (1 yr 24 hr Storm)														
Sub-Basin	Development	HSG	Area (Acres)	Area (ft2)	RCN	RCN*	Impervious (%)	Rv	Pe (in)	Qe (in)	ESDv (ft3)	Af (Mont Co) sf	Total Af (acres)Mont. Co	Af (Acres)
203	Developable Private Rural	B	2.334415982	101687.16	55	55	43.00	0.437	1.8	0.79	6665.59	3418.25	0.08	0.13
203	Developable Private Rural	C	0	0.00	70		43.00		1.8					
sin 204 (1 yr 24 hr Storm)														
Sub-Basin	Development	HSG	Area (Acres)	Area (ft2)	RCN	RCN*	Impervious (%)	Rv	Pe (in)	Qe (in)	ESDv (ft3)	Af (Mont Co) sf	Total Af (acres)Mont. Co	Af (Acres)
204	Developable Private Rural	B	1.494632774	65106.20	55	55	43.00	0.437	1.8	0.79	4267.71	2188.57	0.05	0.08
204	Developable Private Rural	C	0	0.00	70				1.8					
sin 206 (1 yr 24 hr Storm)														
Sub-Basin	Development	HSG	Area (Acres)	Area (ft2)	RCN	RCN*	Impervious (%)	Rv	Pe (in)	Qe (in)	ESDv (ft3)	Af (Mont Co) sf	Total Af (acres)Mont. Co	Af (Acres)
206	Developable Private Rural	B	0.12	5343.57	55	55	43.00	0.437	1.8	0.79	350.27	179.63	5.52	0.01
206	Egan/Mattlyn	B	28.45	1239168.42	55	55	50.15	0.50135	1.8	0.90	93188.56	47789.01		1.76
206	Fire Station	B	4.08	177622.25	55	55	37.00	0.383	1.8	0.69	10204.40	5233.02		0.19
206	Hammer Hill	B	1.34	58560.43	55	55	30.00	0.32	1.6	0.51	2498.58	1281.32		0.05
206	Historic Area Commercial	B	0.73	31706.37	55	55	80.00	0.77	2.2	1.69	4475.88	2295.32		0.08
206	Historic Property Vacant	B	4.76	207264.60	55	55	15.40	0.1886	1	0.19	3257.51	1670.52		0.06
206	Historic Property Vacant	D	0.08	3354.65	77									
206	MD 121	B	3.67	159854.33	55	56	100.00	0.95	2.6	2.47	32903.35	16873.51		0.62
206	MD 121	C	0.39	16896.54	70				2.2					
206	MD 121	D	0.01	501.98	77				2					
206	MD 355	B	10.09	439324.87	55	59	30.40	0.3236	1.6	0.52	18955.40	9720.72		0.36
206	MD 355	C	0.97	42132.27	70				1.6					
206	MD 355	D	1.36	59175.37	77				1.2					
206	Miles Coppola	B	43.14	1879059.79	55	57	60.03	0.59027	2	1.18	209427.94	107398.94		3.96
206	Miles Coppola	C	4.97	216646.86	70				2					
206	Miles Coppola	D	0.76	33094.84	77				1.8					
206	Pulte County	B	1.48	64485.40	55	55	41.56	0.42404	1.8	0.76	4165.05	2135.92		0.08
206	Pulte County	C	0.02	996.68	70				1.8					
206	I-270 Median	B	1.63	71154.37	55	57	100.00	0.95	2.6	2.47	16709.69	8569.07		0.32
206	I-270 Median	C	0.08	3525.04	70				2.2					
206	I-270 Median	D	0.15	6501.28	77				2					
206	Historic District Residential	B	5.88	256177.17	55	55	15.40	0.1886	1	0.19	4026.25	2064.74		
206	Towne Center Redev	B	17.68	770193.16	55	55	53.69	0.53321	2	1.07	68445.78	35100.40		
sin 302 (1 yr 24 hr Storm)														
Sub-Basin	Development	HSG	Area (Acres)	Area (ft2)	RCN	RCN*	Impervious (%)	Rv	Pe (in)	Qe (in)	ESDv (ft3)	Af (Mont Co) sf	Total Af (acres)Mont. Co	Af (Acres)
302	Developable Private Rural	B	2.72	118680.56	55	55	43.00	0.437	1.8	0.79	7782.11	3990.83	0.09	0.15
302	Developable Private Rural	C	0.00	39.71	70									
in 303B (1 yr 24 hr Storm)														
Sub-Basin	Development	HSG	Area (Acres)	Area (ft2)	RCN	RCN*	Impervious (%)	Rv	Pe (in)	Qe (in)	ESDv (ft3)	Af (Mont Co) sf	Total Af (acres)Mont. Co	Af (Acres)
303b	Developable Private Rural	B	3.18	138628.24	55	55	43.00	0.437	1.8	0.79	9120.25	4677.05	0.11	0.17
303b	Developable Private Rural	C	0.01	506.07	70									
sin 304 (1 yr 24 hr Storm)														
Sub-Basin	Development	HSG	Area (Acres)	Area (ft2)	RCN	RCN*	Impervious (%)	Rv	Pe (in)	Qe (in)	ESDv (ft3)	Af (Mont Co) sf	Total Af (acres)Mont. Co	Af (Acres)
304	Developable Private Rural	B	0.00	0.00	55	NA	43.00	0.437	1.8	0.79	0.00	0.00	0.00	0.00
304	Developable Private Rural	C	0.00	0.00	70				1.8					

in 110 (1 yr 24 hr Storm)														
Sub-Basin	Development	HSG	Area (Acres)	Area (ft2)	RCN	RCN*	Impervious (%)	Rv	Pe (in)	Qe (in)	ESDv (ft3)	Af (Mont Co) sf	Total Af (acres)Mont. Co	Af (Acres)
110	Pulte Residential	B	42.25	1840346.81	55	55	33.02	0.35	1.8	0.62	95847.26	49152.44	1.13	1.81
110	Pulte Residential	C	0.00	144.44	70				1.8					
in 111 (1 yr 24 hr Storm)														
Sub-Basin	Development	HSG	Area (Acres)	Area (ft2)	RCN	RCN*	Impervious (%)	Rv	Pe (in)	Qe (in)	ESDv (ft3)	Af (Mont Co) sf	Total Af (acres)Mont. Co	Af (Acres)
111	Pulte Residential	B	31.09	1354277.32	55	56	33.02	0.35	1.8	0.62	73123.47	37499.22	0.86	1.38
111	Pulte Residential	C	1.14	49864.11	70				1.6					
in 112 (1 yr 24 hr Storm)														
Sub-Basin	Development	HSG	Area (Acres)	Area (ft2)	RCN	RCN*	Impervious (%)	Rv	Pe (in)	Qe (in)	ESDv (ft3)	Af (Mont Co) sf	Total Af (acres)Mont. Co	Af (Acres)
112	Pulte Residential	B	21.56	939368.15	55	55	33.02	0.35	1.8	0.62	48919.48	25086.91	0.58	0.92
in 201 (1 yr 24 hr Storm)														
Sub-Basin	Development	HSG	Area (Acres)	Area (ft2)	RCN	RCN*	Impervious (%)	Rv	Pe (in)	Qe (in)	ESDv (ft3)	Af (Mont Co) sf	Total Af (acres)Mont. Co	Af (Acres)
201	Egan/Mattlyn	B	35.62	1551720.552	55	55	50.15	0.50	1.8	0.90	116823.55	59909.51	2.26	2.21
201	Egan/Mattlyn	C	0.04	1732.449268	70	55			1.8					
201	Developable Private Rural	B	20.35	886381.9597	55	56	43.00	0.44	1.8	0.79	60130.77	30836.29		1.14
201	Developable Private Rural	C	0.71	30944.87133	70	60			1.8					
201	I-270 Median	B	1.59	69112.46001	55	57	100.00	0.95	2.6	2.47	15312.61	7852.62		0.29
201	I-270 Median	D	0.12	5280.800442	77	77			2					
in 202 (1 yr 24 hr Storm)														
Sub-Basin	Development	HSG	Area (Acres)	Area (ft2)	RCN	RCN*	Impervious (%)	Rv	Pe (in)	Qe (in)	ESDv (ft3)	Af (Mont Co) sf	Total Af (acres)Mont. Co	Af (Acres)
202	MD 121	B	1.60	69683.18	55	55	100.00	0.95	2.6	2.47	14343.12	7355.45	1.43	0.27
202	Pulte Residential	B	18.87	822155.07	55	55	33.02	0.35	1.8	0.62	42937.41	22019.18		0.81
202	Pulte Residential	C	0.05	2343.38	70				1.6					
202	Pulte County Site	B	4.14	180370.12	55	69	41.56	0.42	1.8	0.76	64188.57	32917.22		1.21
202	Pulte County Site	C	14.63	637345.77	70				1.8					
202	Pulte County Site	D	4.39	191443.21	77				1.6					
in 203 (1 yr 24 hr Storm)														
Sub-Basin	Development	HSG	Area (Acres)	Area (ft2)	RCN	RCN*	Impervious (%)	Rv	Pe (in)	Qe (in)	ESDv (ft3)	Af (Mont Co) sf	Total Af (acres)Mont. Co	Af (Acres)
203	Developable Private Rural	B	2.334415982	101687.16	55	55	43.00	0.44	1.8	0.79	6665.59	3418.25	0.08	0.13
203	Developable Private Rural	C	0	0.00	70		43.00		1.8					
in 204 (1 yr 24 hr Storm)														
Sub-Basin	Development	HSG	Area (Acres)	Area (ft2)	RCN	RCN*	Impervious (%)	Rv	Pe (in)	Qe (in)	ESDv (ft3)	Af (Mont Co) sf	Total Af (acres)Mont. Co	Af (Acres)
204	Developable Private Rural	B	1.494632774	65106.20	55	55	43.00	0.44	1.8	0.79	4267.71	2188.57	0.05	0.08
204	Developable Private Rural	C	0	0.00	70				1.8					
in 206 (1 yr 24 hr Storm)														
Sub-Basin	Development	HSG	Area (Acres)	Area (ft2)	RCN	RCN*	Impervious (%)	Rv	Pe (in)	Qe (in)	ESDv (ft3)	Af (Mont Co) sf	Total Af (acres)Mont. Co	Af (Acres)
206	Developable Private Rural	B	0.12	5343.57	55	55	43.00	0.44	1.8	0.79	350.27	179.63	5.52	0.01
206	Egan/Mattlyn	B	28.45	1239168.42	55	55	50.15	0.50	1.8	0.90	93188.56	47789.01		1.76
206	Fire Station	B	4.08	177622.25	55	55	37.00	0.38	1.8	0.69	10204.40	5233.02		0.19
206	Hammer Hill	B	1.34	58560.43	55	55	30.00	0.32	1.6	0.51	2498.58	1281.32		0.05
206	Historic Area Commercial	B	0.73	31706.37	55	55	80.00	0.77	2.2	1.69	4475.88	2295.32		0.08
206	Historic Property Vacant	B	4.76	207264.60	55	55	15.40	0.19	1	0.19	3257.51	1670.52		0.06
206	Historic Property Vacant	D	0.08	3354.65	77									
206	MD 121	B	3.67	159854.33	55	56	100.00	0.95	2.6	2.47	32903.35	16873.51		0.62
206	MD 121	C	0.39	16896.54	70				2.2					
206	MD 121	D	0.01	501.98	77				2					
206	MD 355	B	10.09	439324.87	55	59	30.40	0.32	1.6	0.52	18955.40	9720.72		0.36
206	MD 355	C	0.97	42132.27	70				1.6					
206	MD 355	D	1.36	59175.37	77				1.2					
206	Miles Coppola	B	43.14	1879059.79	55	57	60.03	0.59	2	1.18	209427.94	107398.94		3.96
206	Miles Coppola	C	4.97	216646.86	70				2					
206	Miles Coppola	D	0.76	33094.84	77				1.8					
206	Pulte County	B	1.48	64485.40	55	55	41.56	0.42	1.8	0.76	4165.05	2135.92		0.08
206	Pulte County	C	0.02	996.68	70				1.8					
206	I-270 Median	B	1.63	71154.37	55	57	100.00	0.95	2.6	2.47	16709.69	8569.07		0.32
206	I-270 Median	C	0.08	3525.04	70				2.2					
206	I-270 Median	D	0.15	6501.28	77				2					
206	Historic District Residential	B	5.88	256177.17	55	55	15.40	0.19	1	0.19	4026.25	2064.74		
206	Towne Center Redev	B	17.68	770193.16	55	55	53.69	0.53	2	1.07	68445.78	35100.40		
in 302 (1 yr 24 hr Storm)														
Sub-Basin	Development	HSG	Area (Acres)	Area (ft2)	RCN	RCN*	Impervious (%)	Rv	Pe (in)	Qe (in)	ESDv (ft3)	Af (Mont Co) sf	Total Af (acres)Mont. Co	Af (Acres)
302	Developable Private Rural	B	2.72	118680.56	55	55	43.00	0.44	1.8	0.79	7782.11	3990.83	0.09	0.15
302	Developable Private Rural	C	0.00	39.71	70									
n 303B (1 yr 24 hr Storm)														
Sub-Basin	Development	HSG	Area (Acres)	Area (ft2)	RCN	RCN*	Impervious (%)	Rv	Pe (in)	Qe (in)	ESDv (ft3)	Af (Mont Co) sf	Total Af (acres)Mont. Co	Af (Acres)
303b	Developable Private Rural	B	3.18	138628.24	55	55	43.00	0.44	1.8	0.79	9120.25	4677.05	0.11	0.17
303b	Developable Private Rural	C	0.01	506.07	70									
in 304 (1 yr 24 hr Storm)														
Sub-Basin	Development	HSG	Area (Acres)	Area (ft2)	RCN	RCN*	Impervious (%)	Rv	Pe (in)	Qe (in)	ESDv (ft3)	Af (Mont Co) sf	Total Af (acres)Mont. Co	Af (Acres)
304	Developable Private Rural	B	0.00	0.00	55	#DIV/0!	43.00	0.44	1.8	0.79	0.00	0.00	0.00	0.00
304	Developable Private Rural	C	0.00	0.00	70				1.8					

110 (1 yr 24 hr Storm)														
Sub-Basin	Development	HSG	Area (Acres)	Area (ft2)	RCN	RCN*	Impervious (%)	Rv	Pe (in)	Qe (in)	ESDv (ft3)	Af (Mont Co) sf	Total Af (acres)Mont. Co	Af (Acres)
110	Pulte Residential	B	42.25	1840347	55	55	31.00	0.33	1.8	0.59	90828.24	46578.5861	1.069297202	1.72
110	Pulte Residential	C	0.00	144	70				1.8					
111 (1 yr 24 hr Storm)														
Sub-Basin	Development	HSG	Area (Acres)	Area (ft2)	RCN	RCN*	Impervious (%)	Rv	Pe (in)	Qe (in)	ESDv (ft3)	Af (Mont Co) sf	Total Af (acres)Mont. Co	Af (Acres)
111	Pulte Residential	B	31.09	1354277	55	56	31.00	0.33	1.8	0.59	69294.38	35535.57914	0.815784645	1.31
111	Pulte Residential	C	1.14	49864	70				1.6					
112 (1 yr 24 hr Storm)														
Sub-Basin	Development	HSG	Area (Acres)	Area (ft2)	RCN	RCN*	Impervious (%)	Rv	Pe (in)	Qe (in)	ESDv (ft3)	Af (Mont Co) sf	Total Af (acres)Mont. Co	Af (Acres)
112	Pulte Residential	B	21.56	939368	55	55	31.00	0.33	1.8	0.59	46357.82	23773.2402	0.545758499	0.88
201 (1 yr 24 hr Storm)														
Sub-Basin	Development	HSG	Area (Acres)	Area (ft2)	RCN	RCN*	Impervious (%)	Rv	Pe (in)	Qe (in)	ESDv (ft3)	Af (Mont Co) sf	Total Af (acres)Mont. Co	Af (Acres)
201	Egan/Mattlyn	B	35.62	1551721	55	55	32.60	0.34	1.8	0.62	80018.36	41035.0585	1.54915207	1.51
201	Egan/Mattlyn	C	0.04	1732	70	55			1.8					
201	Developable Private Rural	B	12.50	544496	55	56	42.11	0.43	1.8	0.77	36257.10	18593.38375		0.69
201	Developable Private Rural	C	0.44	19009	70	58			1.8					
201	I-270 Median	B	1.59	69112	55	57	100.00	0.95	2.6	2.47	15312.61	7852.621936		0.29
201	I-270 Median	D	0.12	5281	77	77			2					
202 (1 yr 24 hr Storm)														
Sub-Basin	Development	HSG	Area (Acres)	Area (ft2)	RCN	RCN*	Impervious (%)	Rv	Pe (in)	Qe (in)	ESDv (ft3)	Af (Mont Co) sf	Total Af (acres)Mont. Co	Af (Acres)
202	MD 121	B	1.60	69683	55	55	100.00	0.95	2.6	2.47	14343.12	7355.446956	0.73698304	0.27
202	Pulte Residential	B	18.87	822155	55	55	31.00	0.33	1.8	0.59	40689.00	20866.15311		0.77
202	Pulte Residential	C	0.05	2343	70				1.6					
202	Pulte County Site	B	4.14	180370	55	69	0.00	0.05	1.8	0.09	7568.69	3881.381144		0.14
202	Pulte County Site	C	14.63	637346	70				1.8					
202	Pulte County Site	D	4.39	191443	77				1.6					
203 (1 yr 24 hr Storm)														
Sub-Basin	Development	HSG	Area (Acres)	Area (ft2)	RCN	RCN*	Impervious (%)	Rv	Pe (in)	Qe (in)	ESDv (ft3)	Af (Mont Co) sf	Total Af (acres)Mont. Co	Af (Acres)
203	Dev Private Rural	B	1.434009171	62465	55	55	42.11	0.43	1.8	0.77	4019.16	2061.106607	0.047316497	0.08
203	Dev Private Rural	C		0	70				1.8					
204 (1 yr 24 hr Storm)														
Sub-Basin	Development	HSG	Area (Acres)	Area (ft2)	RCN	RCN*	Impervious (%)	Rv	Pe (in)	Qe (in)	ESDv (ft3)	Af (Mont Co) sf	Total Af (acres)Mont. Co	Af (Acres)
204	Developable Private Rural	B	0.918138464	39994	55	55	42.11	0.43	1.8	0.77	2573.31	1319.64376	0.030294852	0.05
204	Developable Private Rural	C		0	70				1.8					
206 (1 yr 24 hr Storm)														
Sub-Basin	Development	HSG	Area (Acres)	Area (ft2)	RCN	RCN*	Impervious (%)	Rv	Pe (in)	Qe (in)	ESDv (ft3)	Af (Mont Co) sf	Total Af (acres)Mont. Co	Af (Acres)
206	Developable Private Rural	B	0.08	3283	55	55	42.11	0.43	1.8	0.77	211.20	108.3093172	4.518769634	0.00
206	Egan/Mattlyn	B	28.45	1239168	55	55	32.60	0.34	1.8	0.62	63829.57	32733.11051		1.21
206	Fire Station	B	4.08	177622	55	55	37.00	0.38	1.8	0.69	10204.40	5233.024801		0.19
206	Hammer Hill	B	1.34	58560	55	55	30.00	0.32	1.6	0.51	2498.58	1281.322159		0.05
206	Historic Area Commercial	B	0.73	31706	55	55	80.00	0.77	2.2	1.69	4475.88	2295.324061		0.08
206	Historic Property Vacant	B	4.76	207265	55	55	15.40	0.19	1	0.19	3257.51	1670.517229		0.06
206	Historic Property Vacant	D	0.08	3355	77									
206	MD 121	B	3.67	159854	55	56	100.00	0.95	2.6	2.47	32903.35	16873.51305		0.62
206	MD 121	C	0.39	16897	70				2.2					
206	MD 121	D	0.01	502	77				2					
206	MD 355	B	10.09	439325	55	59	48.39	0.49	1.6	0.78	28438.02	14583.59931		0.54
206	MD 355	C	0.97	42132	70				1.6					
206	MD 355	D	1.36	59175	77				1.2					
206	Miles Coppola	B	43.14	1879060	55	57	40.90	0.42	2	0.84	148341.98	76072.81206		2.80
206	Miles Coppola	C	4.97	216647	70				2					
206	Miles Coppola	D	0.76	33095	77				1.8					
206	Pulte County	B	1.48	64485	55	55	0.00	0.05	1.8	0.09	491.12	251.8541542		0.01
206	Pulte County	C	0.02	997	70				1.8					
206	I-270 Median	B	1.63	71154	55	57	100.00	0.95	2.6	2.47	16709.69	8569.073196		0.32
206	I-270 Median	C	0.08	3525	70				2.2					
206	I-270 Median	D	0.15	6501	77				2					
206	Historic District Residential	B	5.88	256177	55	55	15.40	0.19	1	0.19	4026.25	2064.744219		
206	Towne Center Redev	B	17.68	770193	55	55	53.69	0.53	2	1.07	68445.78	35100.40121		
302 (1 yr 24 hr Storm)														
Sub-Basin	Development	HSG	Area (Acres)	Area (ft2)	RCN	RCN*	Impervious (%)	Rv	Pe (in)	Qe (in)	ESDv (ft3)	Af (Mont Co) sf	Total Af (acres)Mont. Co	Af (Acres)
302	Developable Private Rural	B	1.67	72904	55	55	42.11	0.43	1.8	0.77	4692.39	2406.352329	0.055242248	0.09
302	Developable Private Rural	C	0.00	24	70									
303B (1 yr 24 hr Storm)														
Sub-Basin	Development	HSG	Area (Acres)	Area (ft2)	RCN	RCN*	Impervious (%)	Rv	Pe (in)	Qe (in)	ESDv (ft3)	Af (Mont Co) sf	Total Af (acres)Mont. Co	Af (Acres)
303b	Developable Private Rural	B	1.95	85158	55	55	42.11	0.43	1.8	0.77	5499.25	2820.126414	0.064741194	0.10
303b	Developable Private Rural	C	0.01	311	70									
304 (1 yr 24 hr Storm)														
Sub-Basin	Development	HSG	Area (Acres)	Area (ft2)	RCN	RCN*	Impervious (%)	Rv	Pe (in)	Qe (in)	ESDv (ft3)	Af (Mont Co) sf	Total Af (acres)Mont. Co	Af (Acres)
304	Developable Private Rural	B	0.00	0	55	#DIV/0!	42.11	0.43	1.8	0.77	0.00	0	0	0.00
304	Developable Private Rural	C	0.00	0	70				1.8					

Ten Mile Creek Amendment
Appendix 4

Countywide Stream Protection Strategy Score Change Estimate (CSCE) Model: Description and Results

The CSPS Score Change Estimate (CSCE) Model for Potential Stream Biology Impacts

A statistical regression model was developed for the Potomac Subregion Master Plan (2002) to estimate the potential effects of development on stream health, as measured by the County's Indices of Biotic Integrity (IBIs). The model was termed the Potomac Subregion Cumulative Impact (PSCI) model. The PSCI model was revised while preparing the Upper Rock Creek Master Plan (2004) and re-named the Countywide Stream Protection Strategy Score Change Estimate (CSCE) Model. The CSCE model was developed to provide better estimates of potential impacts to stream conditions throughout the County.

An IBI measures the biological health of a stream using invertebrate (mostly insect) and vertebrate (fish) diversity and abundance. The CSCE regression model uses potential changes in impervious cover area as the predictor variable for estimating potential changes in IBI scores. Other watershed variables were also analyzed for potential use as predictor variables, but were found to be too highly correlated with impervious cover to be useful in a statistically-based model. As a result, in the CSCE model, impervious cover functions as an integrator of all of the stream health-related impacts of development, not just the effects of impervious cover itself. After the Upper Rock Creek master plan was completed, the CSCE model was used to estimate potential IBI score changes in other master plans including Olney, Damascus, Germantown, and Great Seneca Science Corridor.

The CSCE model was developed using countywide IBI data collected by the Montgomery County Department of Environmental Protection, and the M-NCPPC Parks Department up to the time when the Potomac Subregion master plan was being prepared (1994-2000). Because of the variability in the data, the regression model was found to be too inaccurate to usefully estimate potential changes in individual IBI scores. But when used to predict potential IBI score changes, rather than individual IBI scores, the model estimates of the 95% confidence intervals have substantially improved. This is because there is more error involved in estimating an individual IBI score than an estimated change in an IBI score.

The score changes estimated by the CSCE model are used in conjunction with actual monitored IBI scores to produce estimates for changes in those scores in response to different potential development scenarios. Used this way, the estimated IBI score change resulting from development in a given watershed is subtracted from the monitored pre-development score to provide an estimate of the resulting post-development IBI score.

The CSCE model was developed using data that reflects pre-ESD development standards (and even most Special Protection Area requirements), and therefore cannot be used to predict potential changes in IBIs that might result from development that uses ESD. Although not enough watershed-scale data exists to predict the additional benefits of ESD on stream health, the model can be used to estimate the potential stream health impact under traditional stormwater management. This estimated impact at least provides an estimate for the degree of impact that could result from traditional stormwater management. ESD would provide an additional safety factor, assuming that it is an improvement over traditional stormwater management.

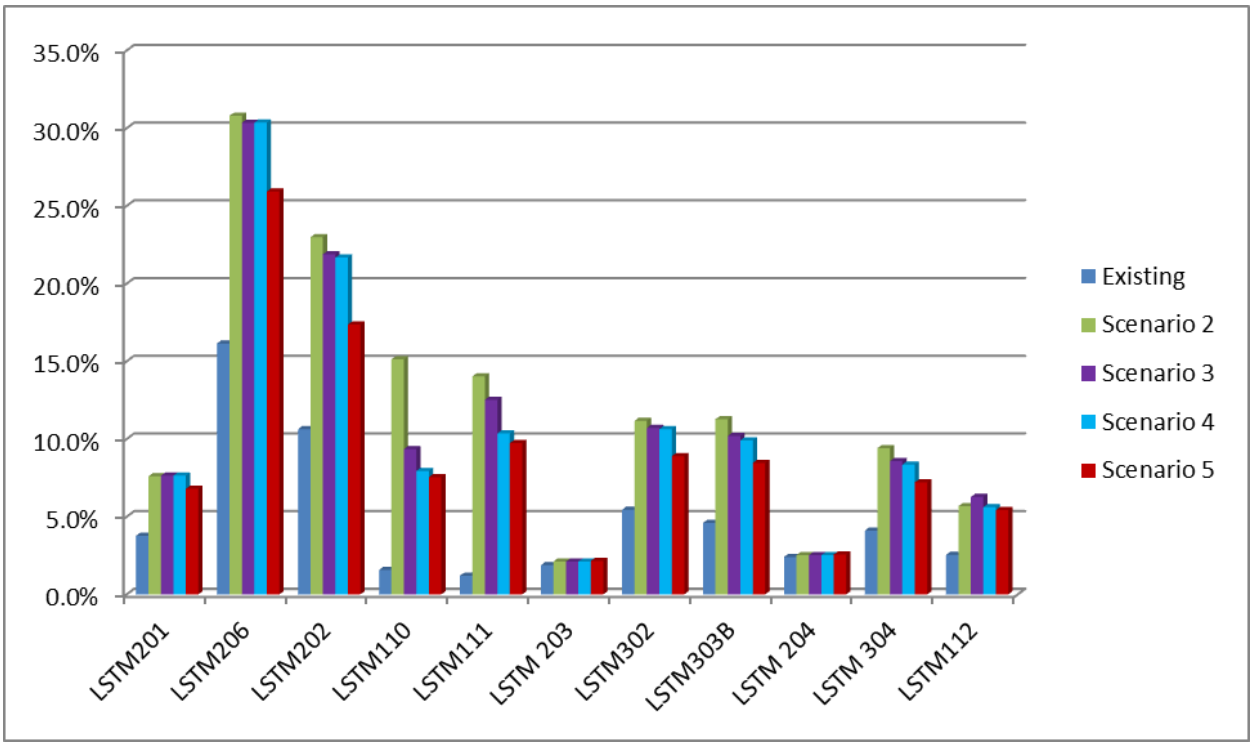
Cumulative Imperviousness Analysis

The following chart reflects the imperviousness by subwatershed resulting from five different development scenarios in the Ten Mile Creek watershed. The subwatersheds are generally shown from the headwaters on the left to the most downstream point on the right. Cumulative imperviousness is calculated by dividing the total projected impervious acreage within an area that drains to a specific

point by the total area of that drainage area. As one moves downstream from headwater areas, imperviousness acreage of subwatersheds that receive flow from upstream is aggregated with the upstream imperviousness and divided by the total area of all the subwatersheds upstream. This is done because the total imperviousness of the entire watershed upstream of the monitoring station is the imperviousness that affects the biology at the monitoring site. The watershed totals for the free-flowing part of the Ten Mile Creek watershed is expressed in the values shown for LSTM304, the most downstream point in the watershed of the free-flowing stream. LSTM112 is a separate subwatershed that flows directly to Little Seneca Lake.

This analysis shows the dramatic increase in the percentage of imperviousness in parts of the Ten Mile Creek watershed under the tested scenarios. The overall watershed cumulative imperviousness is approximately doubled with the 1994 Plan (Scenario 2) from 4.1% to 9.4% (measured at LSTM304). Scenario 5 has the lowest increase with approximately 7% overall imperviousness.

Cumulative Imperviousness for Ten Mile Creek Subwatersheds



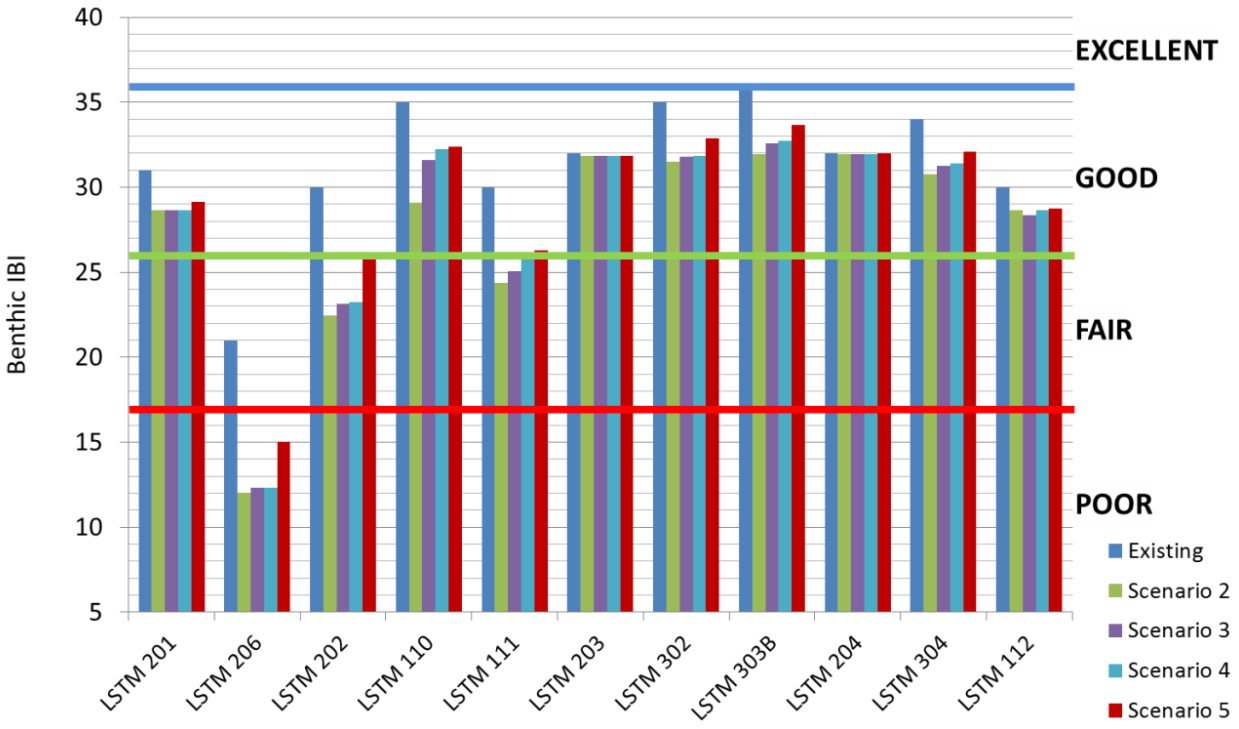
Application of the CSCE Model in Ten Mile Creek

Since it was created, Little Seneca Lake has had a negative effect on the fish community in the upstream portion of Ten Mile Creek, which comprises the study area for the Clarksburg plan amendment. The presence of the lake blocks fish passage between the upper and lower reaches of Ten Mile Creek (and from Seneca Creek), and provides a source of lake fish to the stream, which disrupts natural stream fish communities. Because of this, and the predominance of headwater streams in the Ten Mile Creek study area, the decision was made in conjunction with DEP and Department of Parks staff, to use the benthic macroinvertebrate IBI scores (which are not affected by the lake) as the best indicator of the biological health of Ten Mile Creek. Accordingly, the version of the CSCE model that was developed to estimate changes in the IBI for benthic macroinvertebrates was used to assess potential stream biology changes in Ten Mile Creek.

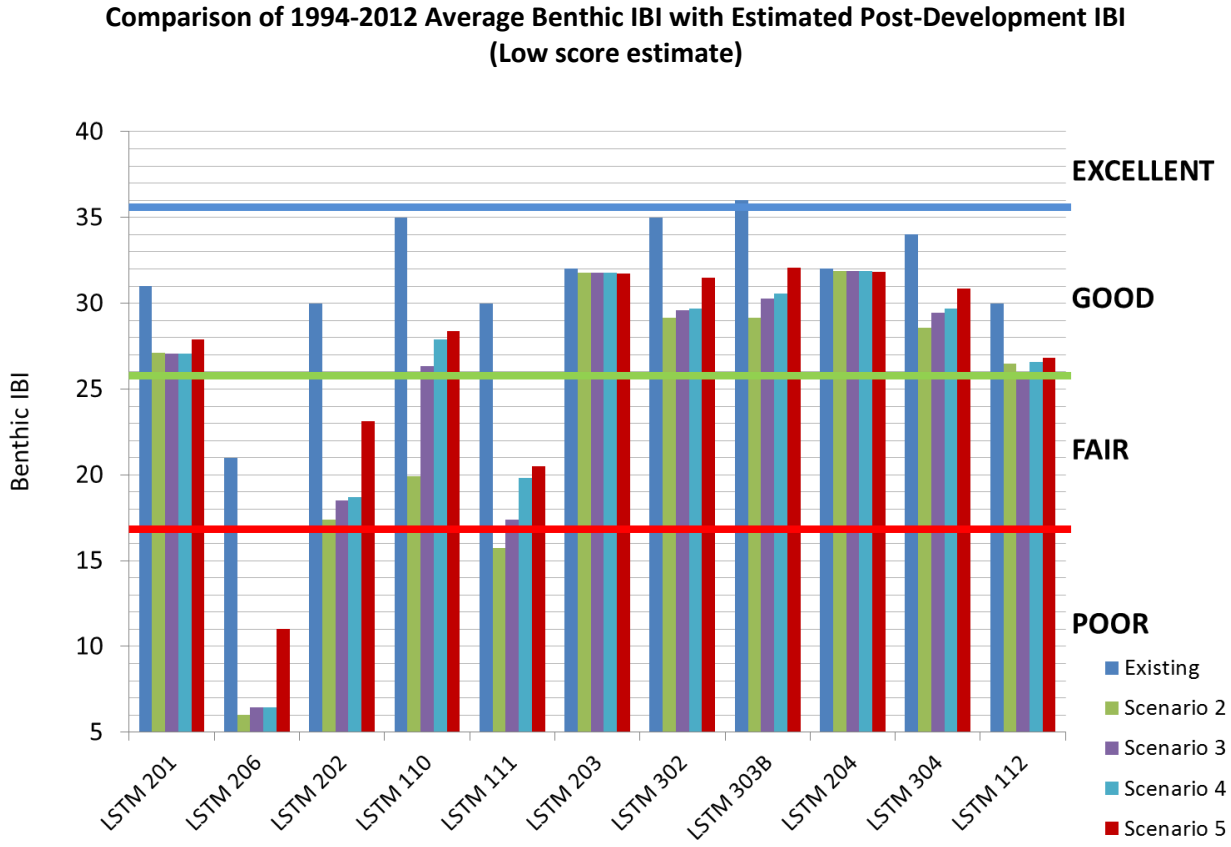
Using the imperviousness projections for five development scenarios, the Countywide Stream Protection Strategy Score Change Estimate (CSCE) Model was applied, which is used to estimate changes in the Index of Biological Integrity (IBI) scores, in response to different development scenarios. By this method, the estimated IBI score change from development in a given watershed is subtracted from the monitored pre-development score to provide an estimate of the resulting post-development IBI score. In addition to this estimated IBI score, the CSCE model also provides a +/- 95% confidence interval of scores around the estimate.

The CSCE model was developed using data that reflects pre-ESD development standards, and therefore cannot predict potential changes in IBIs that might result from development that uses ESD. Until enough data exist to update the CSCE model to predict the benefits of ESD the model can still be used to estimate the potential stream health impact under the old regulations. This model predicts a range of potential results with high-score and low-score predictions. The following chart shows the estimated high IBI scores (upper 95% confidence interval) assuming ESD would produce at least the best result that could be generally achieved with traditional stormwater management.

Comparison of 1994-2012 Average Benthic IBI with Estimated Post-Development IBI (High score estimate)



The following chart shows the estimated low IBI scores (95% confidence interval) with traditional stormwater management.



The following chart shows a composite comparison of the CSCE model, which shows results that would be generally expected with traditional stormwater management within a +/- 95% confidence interval. This chart shows full range of estimated potential outcomes (resulting from the model) within that confidence interval taken from the two charts above, with the top of the striped bar showing the best potential outcome under Scenario 5 and the worst potential outcome of Scenario 2 at the bottom of the striped bar. The cumulative result for Ten Mile Creek as it reaches the ford at Old Baltimore Road is shown as LSTM304 at the far right.

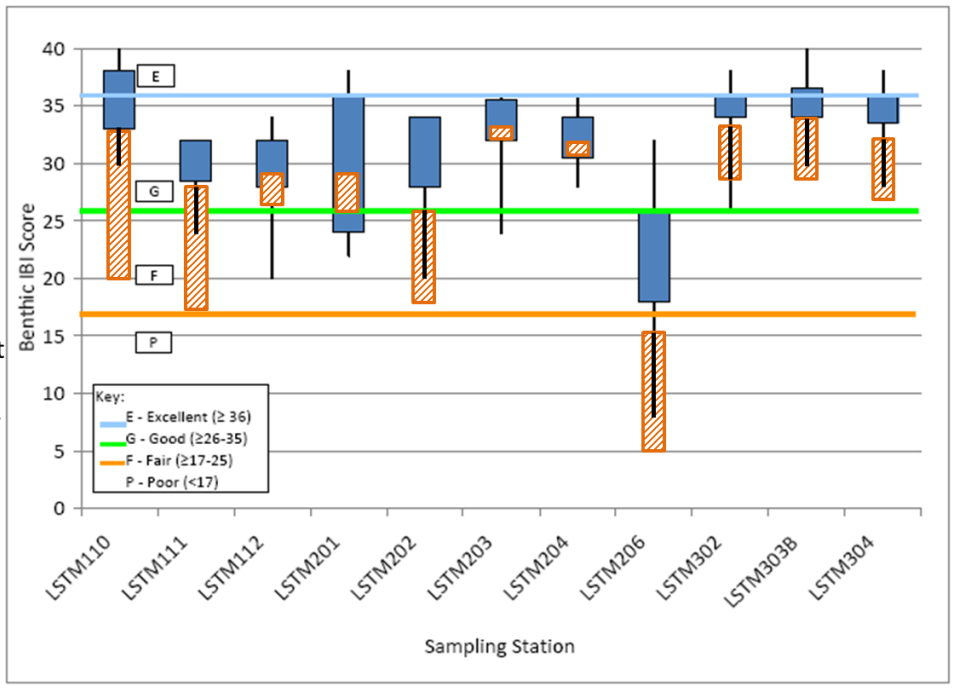
Comparison: Existing Benthic IBI with Estimated Post-Development IBI

1994-2012 Benthic IBI (range of the middle 50% of scores)

Max – Min

Estimated range of Benthic IBI Post Development*

*The top of the striped bar indicates the best potential outcome (high score) for imperviousness resulting from Scenario 5 (7% overall watershed imperviousness), while the bottom is the lowest likely outcome (low score) for Scenario 2 (1994 Plan).



The large increase in imperviousness in the headwaters LSTM206 affects all of the mainstem tributaries downstream. Even with the use of ESD, which cannot completely mitigate development impacts, all the scenarios (beyond existing conditions) will affect stream conditions, almost certainly resulting in a loss of the stream's status as a reference stream (against which other streams are measured).

Ten Mile Creek Amendment
Appendix 5

Additional Environmental References

Ahmed, S.N., Bencala, K.R., and Schulz, C.L., April 2013, 2010 Washington Metropolitan Area Water Reliability Study, Part 2: Potential Impacts of Climate Change, Interstate Commission on the Potomac River Basin, ICBRB Report No.13-07, Interstate Commission on the Potomac River Basin, Rockville, MD.

Froelich, A.J., 1975. Bedrock Map of Montgomery County, Maryland, USGS, Map I-920-D

Froelich, A.J., 1975. Contour Map of the Base of Saprolite, Montgomery County, Maryland, USGS, Map I-920-C

Froelich, A.J. 1975. Surface Materials Map of Montgomery County, Maryland, USGS, Map I-920-A

Froelich, A.J. 1975. Thickness of Overburden Map of Montgomery County, Maryland, USGS, Map I-920-B

Jackson, S., Pond, G., and Gerrittsen, J., March 27, 2013. Biological Condition Gradient:
A Headwater Steam Catchment in the Northern Piedmont Region, Montgomery County, Maryland

Maryland Department of the Environment, 2000. 2000 Maryland Stormwater Design Manual Volumes I & II

Maryland-National Capital Park and Planning Commission, March 2000. Stream Condition Cumulative Impact Models for the Potomac Subregion, Maryland-National Capital Park & Planning Commission, Silver Spring, MD.

Maryland-National Capital Park & Planning Commission, July 1997. Wetlands Study in Clarksburg, Maryland, Final Report, Submitted by Chris Athanas, Ph.D. & Associates, Inc., Maryland-National Capital Park & Planning Commission, Silver Spring, MD.

Maryland-National Capital Park and Planning Commission, June 30, 1992. Clarksburg Environmental & Water Resources Study, Final Report, Prepared by Greenhorne and O'Mara, Inc., Maryland-National Capital Park & Planning Commission, Silver Spring, MD.

Maryland-National Capital Park and Planning Commission, April 6, 1992. Clarksburg Environmental & Water Resources Study, Technical Appendix, Prepared by Greenhorne and O'Mara, Inc., Maryland-National Capital Park and Planning Commission, Silver Spring, MD.

Maryland-National Capital Park and Planning Commission, Environmental Planning Division, Gregory B. Fick, May 1993. Natural Resources Inventory Study, Clarksburg Area Stream Survey Using EPA's Rapid Bioassessment Techniques, Winter 1992-1993 Sampling Report, Maryland-National Capital Park and Planning Commission, Silver Spring, MD.

Maryland-National Capital park and Planning Commission, John E. Hench, Ph.D. and Tanya Schmieler, M.A., November 18, 1991. Clarksburg Master Plan: Recommendations on Natural and Cultural Resources and Public Park and Recreation Needs, Maryland-National Capital park and Planning Commission, Silver Spring, MD.

Maryland-National Capital Park and Planning Commission, August 1989. Environmental Inventory and Opportunities and Constraints Mapping of the Clarksburg Planning Area, Summary Report, Submitted by

Greenhorne & O'Mara, Inc., Maryland-National Capital Park and Planning Commission, Silver Spring, MD.

Montgomery County Department of Environmental Protection, 2011. Special Protection Areas (SPA) Report, Montgomery County Department of Environmental Protection, Rockville, MD.

Ortt, Jr. R.A., Wells, D.V., and VanRyswick, S., May 2011. Bathymetry and Sediment Accumulation of Little Seneca Lake, Coastal and Estuarine Geology File Report No. 11-03, Maryland Geological Survey

Otton, E.G., 1981. The Availability of Groundwater in Western Montgomery County, Maryland, Maryland Geological Survey, Report of Investigations No. 34

Potomac Investment Associates and Rodgers & Associates, Inc., August 8, 1991, Revised April 24, 1992. Bennett, King & Shiloh Properties: Land Use, Sewer Service & Environmental Protection Proposals for a Portion of the Eastern Ten Mile Creek Watershed

United States Department of Agriculture, Natural Resources Conservation Service, July 1995, Soil Survey of Montgomery County, Maryland

Ten Mile Creek Amendment
Appendix 6

Transportation Modeling

Transportation Analysis

Introduction

This Transportation Appendix presents an analysis of the existing roadway and transit networks and offers recommendations on approaches for improving both in the context of the land use alternatives considered in the development of the Plan.

This Appendix consists of the following components: (1) a technical memorandum developed by the Planning Department's transportation consultant that reports the results of the local road network traffic analysis performed in support of the Plan; (2) an analysis by Planning Department staff of the existing transit service and the presentation of a framework for enhancing transit service over the long term and; (3) a discussion of forecasted area-wide traffic conditions based on a Transportation Policy Area Review (TPAR) analysis of the Plan.

Local Area Traffic Analysis

Transportation
Land Development
Environmental
Services

Vanasse Hangen Brustlin, Inc.

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www.vhb.com

Memorandum

To: Eric Graye, AICP, PTP
Montgomery County Department of Planning

Date: August 4, 2012

Project No.: 38102.01

From: Dan Goldfarb, P.E.

Re: Clarksburg Traffic Analysis Summary

Introduction

The purpose of this memorandum is to provide a brief preliminary summary of the traffic analysis for the Clarksburg Sector Plan. The analysis focused on seven intersections that represent gateways into the study area, as well as key internal junctions. The intersections include:

- Interchange ramp terminals for I-270 and Clarksburg Road (MD 121) for both the eastern and western side of the interchange;
- Clarksburg Road (MD 121) & Frederick Road (MD 355);
- Shawnee Lane & Frederick Road (MD 355);
- Stringtown Road (MD 121A) & Frederick Road (MD 355);
- Gateway Center Drive & Clarksburg Road (MD 121)/Stringtown Road;
- New By-pass Road/Observation Drive & Stringtown Road (MD 121A).

There was no data collection effort associated with this analysis effort. The County supplied two lists of intersections to be reviewed. The above intersections are the only intersections that we were able to obtain existing count data. The interchange of I-270 and MD 121 represents a gateway into the study area, as well as the intersection of Shawnee Lane and Frederick Road. The list of intersections requested by the County included Clarksburg Road and Old Baltimore Road as well as West Baltimore and Frederick Road. There were no counts available from SHA for these intersections, but the two gateway intersections above capture traffic just upstream to the intersections on Old Baltimore Road.

The year 2040 forecast were developed using the County's TRAVEL/3 travel demand forecast model and land use supplied by the County for a high land use scenario, denoted as "HI" on the CLV sheets. The Cooperative Land Use totals at the regional level were held

constant for the HI scenario with balancing done in neighboring jurisdictions. A no-build and build alternatives were run with both land use scenarios. Given the localized highway improvement the trip tables were developed using the full TRAVEL/3 model run for both land use scenarios and then assigned to the alternative specific networks. The trip tables were not changed for the different network configurations since the addition of the by-pass was determined to have minimal impact on the trip distribution and mode choice. A subarea for the Clarksburg area was developed from the regional highway network and trips were assigned to the subarea network. The resulting ADT traffic volumes were post-processed using techniques outlined in NCHRP 255. Peak hour volumes were derived from the existing peak to daily and directional ratios for both morning and evening weekday.

Preliminary Traffic Assessment findings:

- With the added development by the year 2040 there will be a need for added capacity for travel north and south in the Clarksburg area.
- Frederick Road (MD 355) with a two lane cross section provides limited capacity for trips traveling north and south.
- The additional by-pass facility provides added capacity for north and south travel along the corridor.
- Even with the new facility there is a need for additional capacity improvements. These could include improved intersection geometrics, added lanes on the by-pass and MD 355, new facilities to the east of MD 355.

The Table 1 provides a summary of the critical lane volume analysis. The critical lane volume worksheets are attached.

Table 1 - Summary of Preliminary Intersection Analysis Level of Service and Critical Lane Volumes

Intersection	Existing				2040 No-Build				2040 Build				2040 HI No-Build				2040 HI Build			
	AM		PM		AM		PM		AM		PM		AM		PM		AM		PM	
MD 121 & I-270 Western Intersection	A	365	A	250	B	1125	A	675	B	1125	A	675	B	1125	A	675	B	1125	A	700
I-270 & MD 121 Eastern Intersection	A	609	A	480	C	1213	D	1325	C	1200	D	1325	D	1306	D	1325	D	1306	D	1350
MD 355 & MD 121	C	1225	C	1150	D	1425	**F**	**1850**	A	875	**F**	**1800**	E	1525	**F**	**1850**	A	950	**F**	**1800**
MD 355 & Shawnee Lane	A	750	A	875	B	1083	B	1117	B	1096	B	1142	C	1183	B	1100	C	1196	C	1225
MD 355 & Stringtown Road	A	914	B	1068	**F**	**1719**	**F**	**2431**	B	1073	E	1522	**F**	**1970**	**F**	**2431**	C	1210	**F**	**1657**
Gateway Center Dr. & Stringtown Road	A	667	A	846	D	1397	D	1325	E	1540	E	1468	**F**	**1721**	D	1325	**F**	**1802**	**F**	**1870**
Observation Drive & Stringtown Road									D	1386	**F**	**1616**					D	1445	**F**	**1801**

A secondary analysis effort was done to supplement the preliminary analysis. The objective was to determine what network improvements would be needed in order to accommodate the additional traffic generated from the future development without constructing the new MD 355 by-pass facility. This exercise included intersection level improvements and was performed at a sketch planning level. The modified network with the improved intersection lane configurations was evaluated using the critical lane methodology.

The following list provides an overview of the intersection improvements. Intersection Improvements:

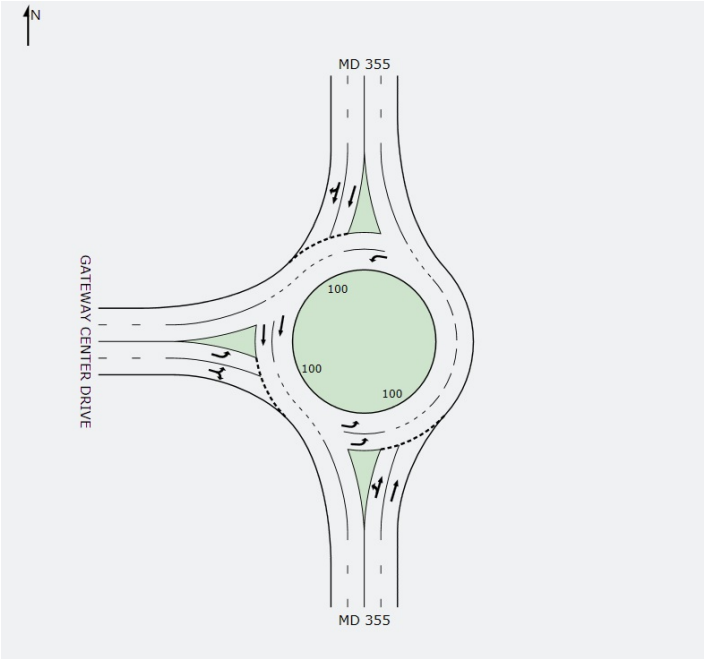
- MD 355 & MD 121 – Addition of a northbound and southbound through lane.
- MD 355 & Stringtown Road – Addition of a northbound and southbound through lane; the addition of an eastbound and westbound through lane as well as an additional eastbound left turn lane to northbound MD 355 and a southbound left turn lane to westbound Stringtown Road.
- Gateway Center Drive & Stringtown Road – Addition of an eastbound and westbound through lane; a dedicated eastbound free flow right turn to southbound Gateway Center Drive; the addition of a free flow right turn lane from northbound Gateway Center Drive to eastbound Stringtown Road.

Summary secondary analysis findings:

- Overall improvements could be made at the key intersections that would address the traffic and result in acceptable levels of service.
- The key intersections included those with LOS "F" which included the intersections along MD 355 as well as the intersection of Gateway Center Drive and Stringtown Road.
- The improvements resulted in LOS "D" or better compared to the previous LOS "F" at those key intersection.
- With the intersection improvements, in order for the roadways to function at acceptable levels MD 355 would have to be increased to a possible three lane section between Stringtown Road and Clarksburg Road (MD 121). The middle lane would have to serve as a contraflow lane during peak periods. At the key intersections along MD 355 there would be a need to include two lanes in each direction making it a four lane cross section. This would be required to address the addition through lanes at the intersections on MD 355.
- The four lane section on MD 355 would have to be tapered down to a three lane cross section. The ability to taper down would present a challenge given the short distance between the two key intersections on MD 355.
- It was determined that the tapering is not very feasible and the by-pass would be required if MD 355 is to remain in the current right of way and not impact the historical district of Clarksburg.
- The ability to build the new by-pass would provide an opportunity to construct a more complete street including the ability to serve non-motorized travel modes. It

would be a hard to construct these types of facilities on MD 355 given the restrictions in the historical district.

As part of this analysis the termini for where the MD 355 by-pass rejoins MD 355 north of Clarksburg was evaluate using a roundabout. The following figure provides a schematic for a typical roundabout that would fit this location.



The roundabout would have two circulation lanes and the approaches would all need to have four lane cross sections. Although forecast volumes were not prepared as part of this analysis, a series of test volumes were analyzed using this configuration. This configuration is able to serve the volumes adequately. The roundabout configuration would provide for a more efficient transition for vehicles using the by-pass to enter back onto MD 355 north of Clarksburg. If the demand is too high then a signalized intersection would be required. With a demand based on the surrounding intersection the LOS would be approximately "C" or "D" given different sensitivity tests. The PM peak hour volumes were determined to be the critical volumes, with the northbound through volumes on MD 355 and the eastbound left turning volumes showing the highest demand. The roundabout did function and there is the ability to add an additional lane going northbound around the roundabout, creating a three lane section where the majority of the traffic is staying in those lanes and continuing northbound.

Table 2 provides a summary of the critical lane volume analysis for the secondary analysis. The critical lane volume worksheets follow the tables. Table 3 provides a summary of intersections improvements with the By-pass facility to bring all of the intersections to an acceptable level of service. In table 3 there are two intersections, MD 355 & Stringtown Road and Observation Road/New By-pass & Stringtown Road where improvements were made to bring the intersections to acceptable levels of service. These improvements included additional east-west through lanes, free-flow right turn lanes, and double left turn lanes. The CLV sheets are attached to this memorandum.

Additional analysis was done for the Clarksburg plan update using an alternative methodology and performance measure. The preliminary and secondary traffic analysis for the Clarksburg plan update used the Critical Lane Volume (CLV) methodology. At the request of the Planning Department an alternative analysis methodology was used. This methodology was based on the procedures and performance measures outlined in the Highway Capacity Manual. Synchro software was used to do this analysis. There were Synchro files for areas south of Clarksburg, but the County was unable to provide Synchro files that covered the defined study area that this analysis is focused on. Therefore VHB developed a network in Synchro for the defined study area. The signal times as well as optimization and coordination were based on patterns observed in the Synchro files provided for areas south of our study area.

The original intent of the preliminary traffic analysis was to develop a traffic forecast for year 2040 for both the planned development and a potential higher development plan. Two network scenarios were evaluated – with and without the MD 355 By-pass. The original effort included a preliminary review of the intersection operations in order to evaluate if the by-pass was required given the available network capacity. The approach used for the CLV based analysis was very basic and did no evaluate any complex type of signal phasing. It focused on two phases at each signal. This was determined to be adequate for the purpose of understanding the capacity constraints on the study area network. The HCM based analysis involved a level of greater complexity given the need for signal timings and coordination.

CLV is a planning tool focusing on the lane capacity supplied and the capacity consumed. The CLV analysis tool functions at a high level of coarseness. Earlier applications of the procedure would categorize results as under-capacity, near-capacity, and over-capacity as compared to providing a discrete level of service grade. The 1985 Highway Capacity Manual used such categories with the CLV procedures. Given the need for comparing results many planning and transportation departments, as well as other agencies, have developed level of service standards similar to the Highway Capacity Manual operational analysis. In this framework levels of service are described in terms of a grade, "A" through "F".

Table 4 shows the results comparing the two methodologies. There were some differences, but overall the results were compatible. The greatest difference between the two methodologies was with the interchange terminal intersections. The HCM based analysis incorporates a greater number of attributes and requires more input data. The ramps provide an example of how the HCM based analysis has a greater sensitivity to how the intersection functions. For the interchange ramps the saturation flow rate was increased to reflect the higher speeds. The CLV analysis did not differentiate between entering saturation flows or receiving saturation flows, it only focuses on a capacity of the intersections as a functions of the number of lanes approaching the intersection.

Overall the two methodologies would tend to lead to the same conclusion that there needs to be added capacity in the defined study area. The MD 355 By-pass is important addition to the capacity in the defined study area. The HCM analysis is probably more accurate given the additional data demands.

Table 2 - Summary of Secondary Intersection Analysis Level of Service and Critical Lane Volumes

Intersection	Existing				2040 No-Build With Improvements				2040 HI No-Build With Improvements			
	AM		PM		**AM**		**PM**		**AM**		**PM**	
MD 121 & I-270 Western Intersection	A	365	A	250	B	1125	A	675	B	1125	A	675
I-270 & MD 121 Eastern Intersection	A	609	A	480	C	1213	D	1325	D	1306	D	1325
MD 355 & MD 121	C	1225	C	1150	A	955	C	1157	B	1090	C	1157
MD 355 & Shawnee Lane	A	750	A	875	B	1083	B	1117	C	1183	B	1100
MD 355 & Stringtown Road	A	914	B	1068	B	1125	C	1299	D	1394	D	1416
Gateway Center Dr. & Stringtown Road	A	667	A	846	D	1397	D	1325	C	1204	C	1202
Observation Drive & Stringtown Road												

Intersection Improvement

Table 3 - Summary of Intersection Analysis Level of Service and Critical Lane Volumes with Improvements

Intersection	Existing				2040 Build				2040 Build With Improvements			
	AM		PM		**AM**		**PM**		**AM**		**PM**	
MD 121 & I-270 Western Intersection	A	365	A	250	B	1125	A	675	B	1125	A	675
I-270 & MD 121 Eastern Intersection	A	609	A	480	C	1200	D	1325	C	1200	D	1325
MD 355 & MD 121	C	1225	C	1150	A	875	**F**	**1800**	A	875	**D**	**1409**
MD 355 & Shawnee Lane	A	750	A	875	B	1096	B	1142	B	1096	B	1142
MD 355 & Stringtown Road	A	914	B	1068	B	1073	E	1522	B	1073	E	1522
Gateway Center Dr. & Stringtown Road	A	667	A	846	E	1540	E	1468	E	1540	E	1468
Observation Drive & Stringtown Road					D	1386	**F**	**1616**	D	1386	**D**	**1430**

Intersection Improvement

Table 4 Level of Service Summary and Comparison

Intersection	2040 No-Build								2040 Build							
	AM Peak				PM Peak				AM Peak				PM Peak			
	Synchro/HCM		CLV		Synchro/HCM		CLV		Synchro/HCM		CLV		Synchro/HCM		CLV	
	Delay	LOS	V/C	LOS	Delay	LOS	V/C	LOS	Delay	LOS	V/C	LOS	Delay	LOS	V/C	LOS
MD 121 & I-270 SB Ramp	14.2	B	0.70	B	16.2	B	0.42	A	11.0	B	0.70	B	15.1	B	0.42	A
MD 121 & I-270 NB Ramp	3.6	A	0.76	C	10.4	B	0.83	D	2.8	A	0.75	C	8.9	A	0.83	D
Clarksburg Rd & Gateway Center	25.8	C	0.87	D	28.1	C	0.83	D	45.2	D	0.96	E	37.0	D	0.92	E
MD 355 & Stringtown Road	198.4	F	1.07	F	201.1	F	1.52	F	27.9	C	0.67	B	78.7	E	0.95	E
MD 355 & MD 121	46.3	D	0.89	D	152.1	F	1.16	F	22.6	C	0.55	A	93.6	F	1.13	F
MD 355 & Shawnee Lane	20.3	C	0.68	B	29.2	C	0.70	B	17.6	B	0.68	B	29.2	C	0.71	B
New Road/Observation Drive & Stringtown Road	--	--	--	--	--	--	--	--	35.0	D	0.87	D	90.9	F	1.01	F

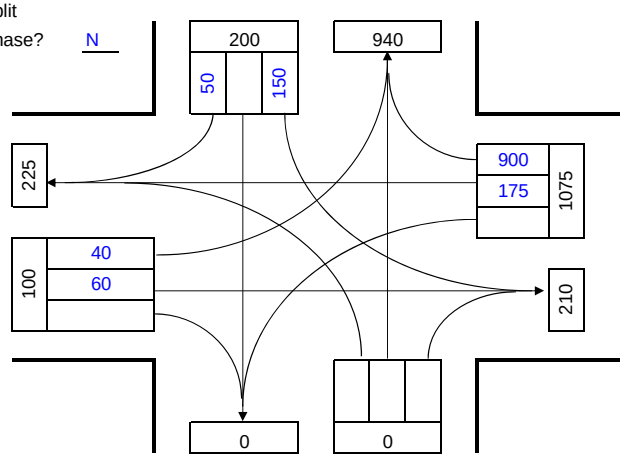
Critical Lane Volume
Level of Service Worksheet

Intersection	MD 121 & I-270 Western Intersection
Major Approach:	I-270
Minor Approach:	MD 121
County/State:	Montgomery County/Maryland
Scenario:	Existing
Analyst:	DSG/VHB

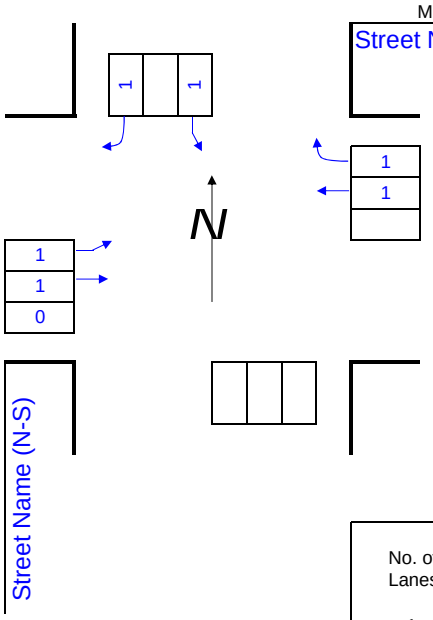
VHB Vanasse Hangen Brustlin, Inc.
8300 Boone Blvd, Suite 700
Vienna, Virginia 22182
Telephone 703.841.3071

Morning Peak Hour

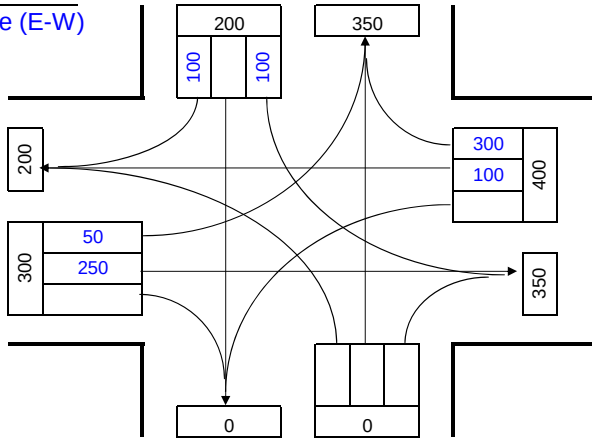
Split Phase? N



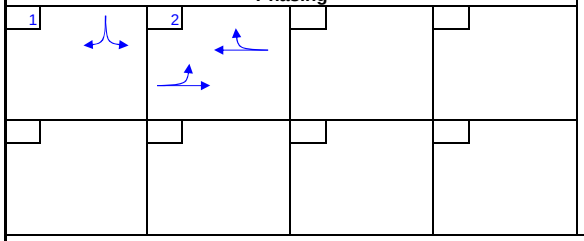
Lane Configuration



Evening Peak Hour



Phasing



No. of Lanes	Lane Use Factor
1	1.00
2	0.53
3	0.37
4	0.30
Dbl-lft	0.53

LOS	Critical Lane Volume	
A	0	999
B	1000	1149
C	1150	1299
D	1300	1449
E	1450	1600
F	1601	9999

Opposing Volume (vph)	PCE
<= 199	1.1
<= 599	2.0
<= 799	3.0
<= 999	4.0
> 1000	5.0

AM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	SBL	0	1.00	0	150	1.00	150	150	C
2	EB	60	1.00	60	0	1.00	0	60	
2	WB	175	1.00	175	40	1.00	40	215	C
	C: Critical Volume					Total		365	
						V/C		0.23	
						LOS		A	

PM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	SBL		1.00	0	100	1.00	100	100	C
2	EB	250	1.00	250	0	1.00	0	250	
2	WB	100	1.00	100	50	1.00	50	150	C
	C: Critical Volume					Total		250	
						V/C		0.16	
						LOS		A	

Critical Lane Volume
Level of Service Worksheet

Intersection	I-270 & MD 121 Eastern Intersection
Major Approach:	I-270
Minor Approach:	MD 121
County/State:	Montgomery County/Maryland
Scenario:	Existing
Analyst:	DSG/VHB

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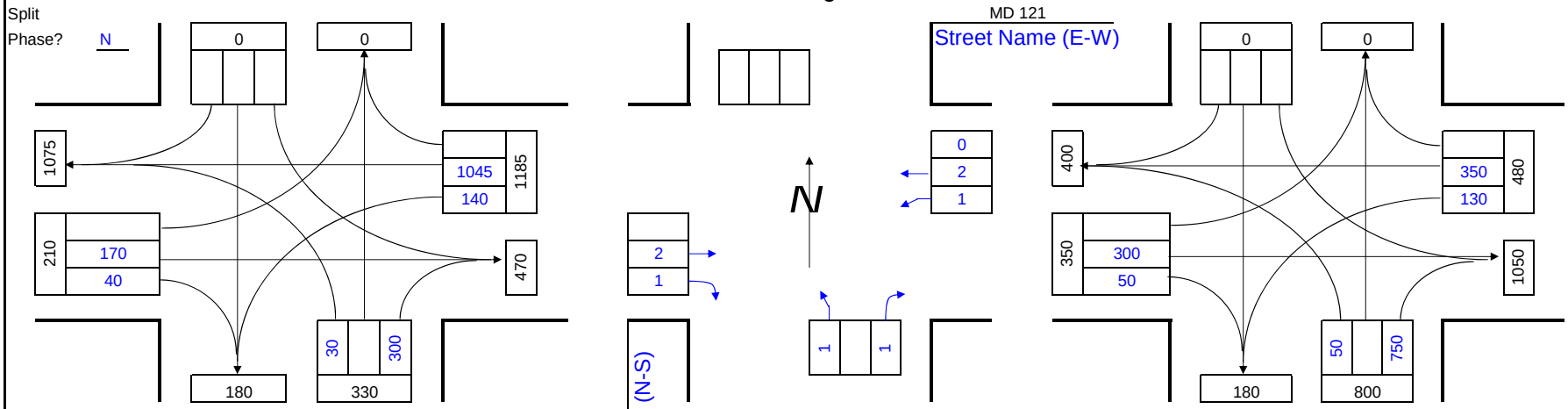
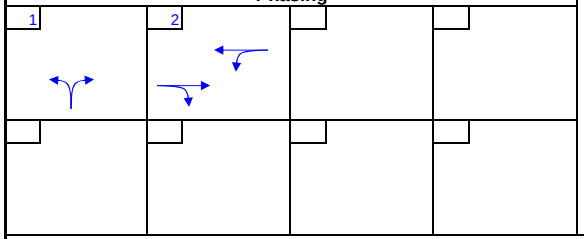
Morning Peak Hour

Lane Configuration

Evening Peak Hour



Phasing



No. of Lanes	Lane Use Factor
1	1.00
2	0.53
3	0.37
4	0.30
Dbl-lft	0.53

LOS	Critical Lane Volume	
A	0	999
B	1000	1149
C	1150	1299
D	1300	1449
E	1450	1600
F	1601	9999

Opposing Volume (vph)	PCE
<= 199	1.1
<= 599	2.0
<= 799	3.0
<= 999	4.0
> 1000	5.0

AM

Phase	Movement	(1) Volume	(2)Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NBL	30	1.00	30	25	1.00	25	55	C
2	EB	170	0.53	90	140	1.00	140	230	
2	WB	1045	0.53	554		1.00	0	554	C
	C: Critical Volume					Total		609	
						V/C		0.38	
						LOS		A	

PM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NBL	50	1.00	50	0	1.00	0	50	C
2	EB	350	1.00	350	0	1.00	0	350	
2	WB	300	1.00	300	130	1.00	130	430	C
	C: Critical Volume					Total		480	
						V/C		0.30	
						LOS		A	

Critical Lane Volume
Level of Service Worksheet

Intersection	MD 355 & MD 121
Major Approach:	MD 355
Minor Approach:	Clarksburg Road (MD 121)
County/State:	Montgomery County/Maryland
Scenario:	Existing
Analyst:	DSG/VHB

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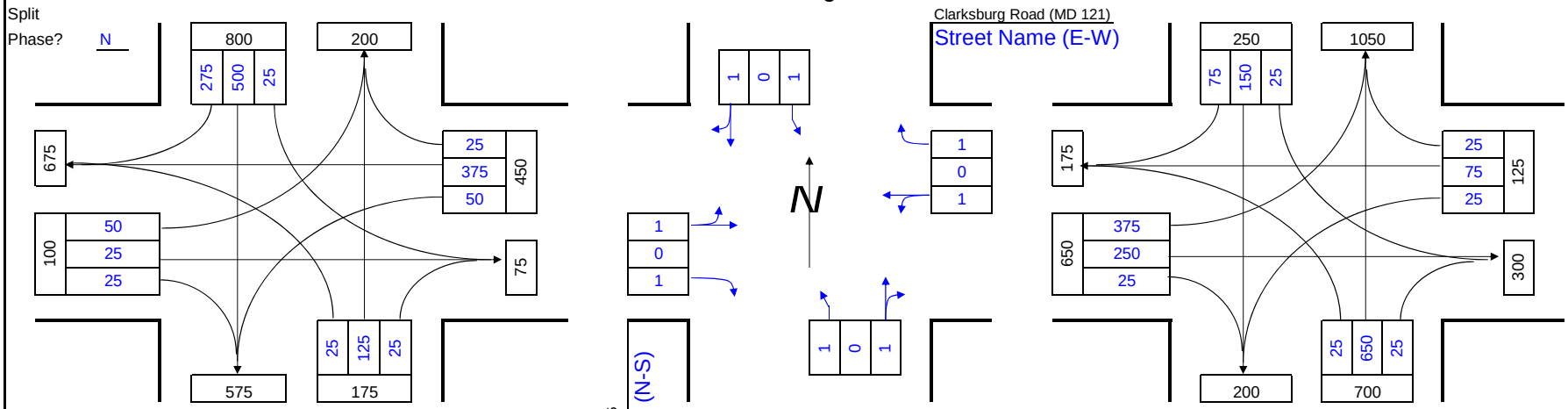
Morning Peak Hour

Lane Configuration

Evening Peak Hour



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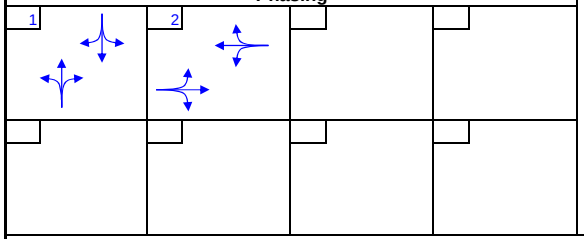

No. of Lanes	Lane Use Factor
1	1.00
2	0.53
3	0.37
4	0.30
Dbl-lft	0.53

LOS	Critical Lane Volume	
A	0	999
B	1000	1149
C	1150	1299
D	1300	1449
E	1450	1600
F	1601	9999

Opposing Volume (vph)	PCE
<= 199	1.1
<= 599	2.0
<= 799	3.0
<= 999	4.0
> 1000	5.0

AM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	150	1.00	150	25	1.00	25	175	
1	SB	775	1.00	775	25	1.00	25	800	C
2	EB	375	1.00	375	50	1.00	50	425	C
2	WB	25	1.00	25	50	1.00	50	75	

C: Critical Volume — Total 1225; V/C 0.77; LOS C

PM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	675	1.00	675	25	1.00	25	700	C
1	SB	225	1.00	225	25	1.00	25	250	
2	EB	250	1.00	250	25	1.00	25	275	
2	WB	75	1.00	75	375	1.00	375	450	C

C: Critical Volume — Total 1150; V/C 0.72; LOS C

Critical Lane Volume
Level of Service Worksheet

Intersection	MD 355 & Shawnee Lane
Major Approach:	MD 355
Minor Approach:	Shawnee Lane
County/State:	Montgomery County/Maryland
Scenario:	Existing
Analyst:	DSG/VHB

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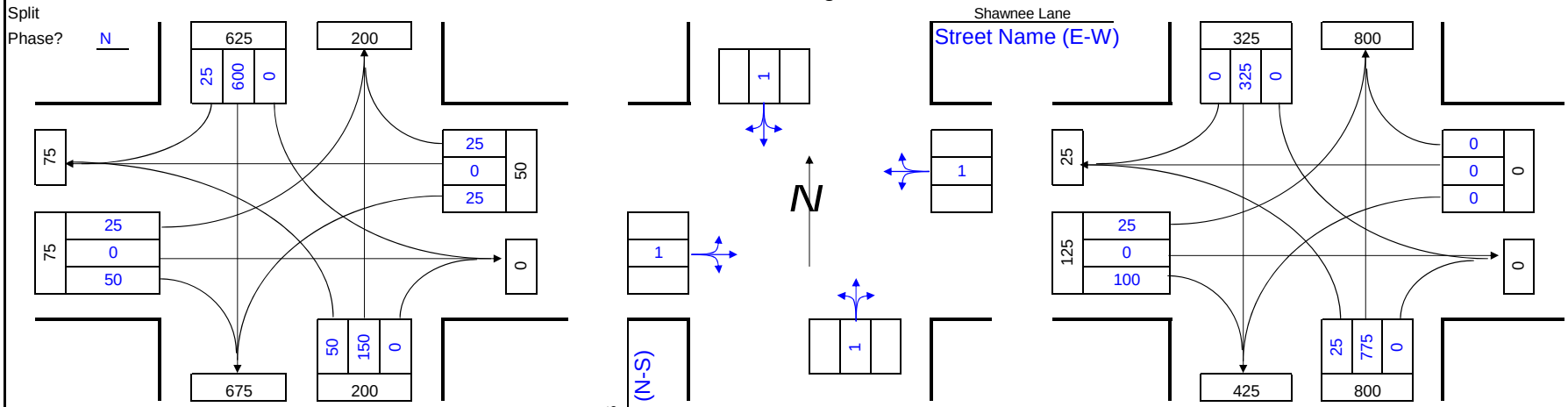
Morning Peak Hour

Lane Configuration

Evening Peak Hour

Split Phase? N



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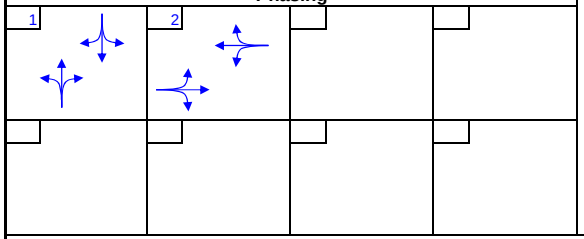

No. of Lanes	Lane Use Factor
1	1.00
2	0.53
3	0.37
4	0.30
Dbl-lft	0.53

LOS	Critical Lane Volume	
A	0	999
B	1000	1149
C	1150	1299
D	1300	1449
E	1450	1600
F	1601	9999

Opposing Volume (vph)	PCE
<= 199	1.1
<= 599	2.0
<= 799	3.0
<= 999	4.0
> 1000	5.0

AM

Phase	Movement	(1) Volume	(2)Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	150	1.00	150	0	1.00	0	150	
1	SB	625	1.00	625	50	1.00	50	675	C
2	EB	50	1.00	50	25	1.00	25	75	C
2	WB	25	1.00	25	25	1.00	25	50	

C: Critical Volume

Total	750
V/C	0.47
LOS	A

PM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	775	1.00	775	0	1.00	0	775	C
1	SB	325	1.00	325	25	1.00	25	350	
2	EB	100	1.00	100	0	1.00	0	100	C
2	WB	0	1.00	0	25	1.00	25	25	

C: Critical Volume

Total	875
V/C	0.55
LOS	A

Critical Lane Volume
Level of Service Worksheet

Intersection	MD 355 & Stringtown Road
Major Approach:	MD 355
Minor Approach:	Stringtown Road
County/State:	Montgomery County/Maryland
Scenario:	Existing
Analyst:	DSG/VHB

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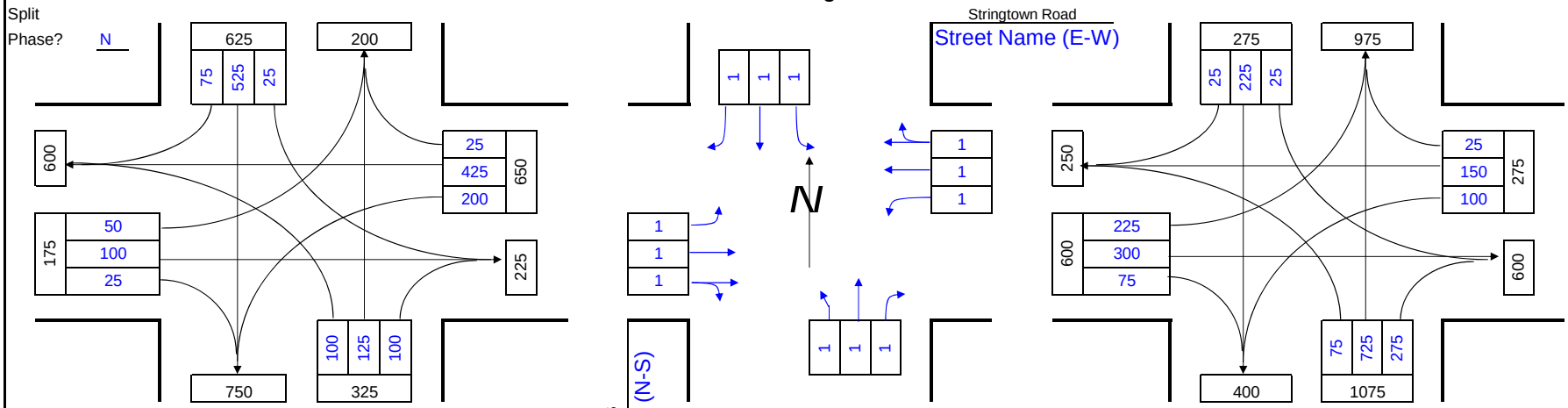
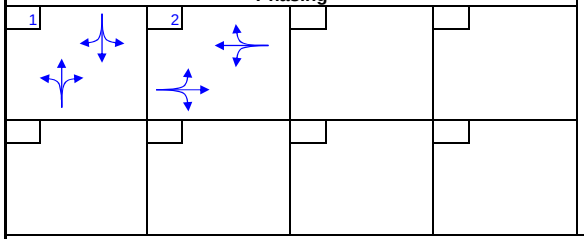
Morning Peak Hour

Lane Configuration

Evening Peak Hour



Phasing



No. of Lanes	Lane Use Factor
1	1.00
2	0.53
3	0.37
4	0.30
Dbl-lft	0.53

LOS	Critical Lane Volume	
A	0	999
B	1000	1149
C	1150	1299
D	1300	1449
E	1450	1600
F	1601	9999

Opposing Volume (vph)	PCE
<= 199	1.1
<= 599	2.0
<= 799	3.0
<= 999	4.0
> 1000	5.0

AM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	125	1.00	125	25	1.00	25	150	
1	SB	525	1.00	525	100	1.00	100	625	C
2	EB	125	0.53	66	200	1.00	200	266	
2	WB	450	0.53	239	50	1.00	50	289	C

C: Critical Volume — Total 914; V/C 0.57; LOS A

PM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	725	1.00	725	25	1.00	25	750	C
1	SB	225	1.00	225	75	1.00	75	300	
2	EB	375	0.53	199	100	1.00	100	299	
2	WB	175	0.53	93	225	1.00	225	318	C

C: Critical Volume — Total 1068; V/C 0.67; LOS B

Critical Lane Volume
Level of Service Worksheet

Intersection	Gateway Center Dr. & Stringtown Road
Major Approach:	Gateway Center Dr
Minor Approach:	Stringtown Road
County/State:	Montgomery County/Maryland
Scenario:	Existing
Analyst:	DSG/VHB

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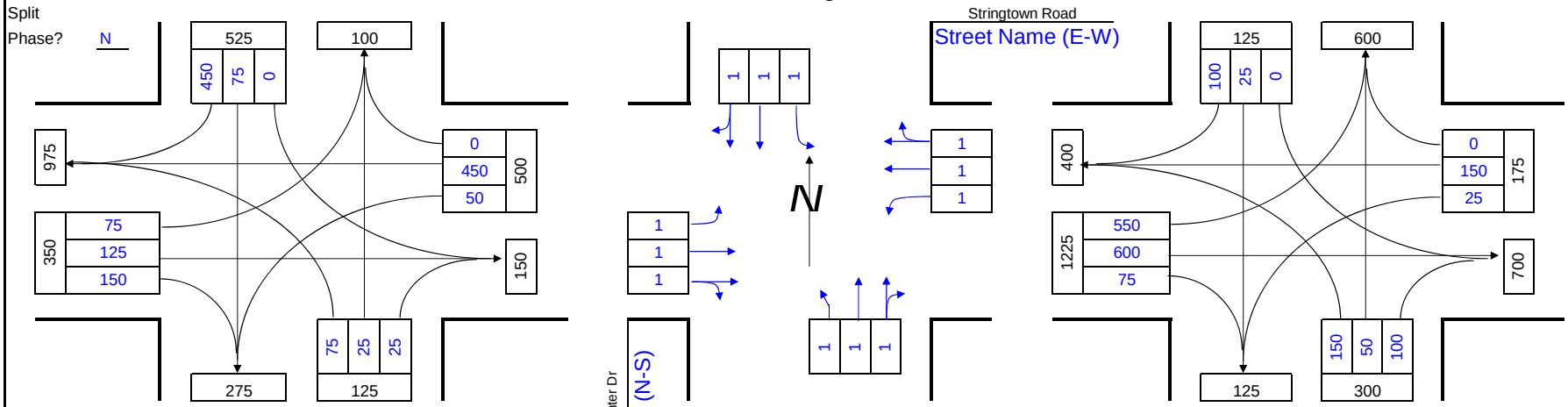
Morning Peak Hour

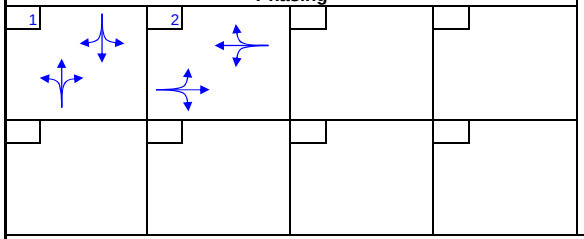
Lane Configuration

Evening Peak Hour

Split Phase? N



Phasing



No. of Lanes	Lane Use Factor
1	1.00
2	0.53
3	0.37
4	0.30
Dbl-lft	0.53

LOS	Critical Lane Volume	
A	0	999
B	1000	1149
C	1150	1299
D	1300	1449
E	1450	1600
F	1601	9999

Opposing Volume (vph)	PCE
<= 199	1.1
<= 599	2.0
<= 799	3.0
<= 999	4.0
> 1000	5.0

AM

Phase	Movement	(1) Volume	(2)Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	50	0.53	27	0	1.00	0	27	
1	SB	525	0.53	278	75	1.00	75	353	C
2	EB	275	0.53	146	50	1.00	50	196	
2	WB	450	0.53	239	75	1.00	75	314	C

C: Critical Volume — Total 667; V/C 0.42; LOS A

PM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	150	0.53	80	0	1.00	0	80	
1	SB	125	0.53	66	150	1.00	150	216	C
2	EB	675	0.53	358	25	1.00	25	383	
2	WB	150	0.53	80	550	1.00	550	630	C

C: Critical Volume — Total 846; V/C 0.53; LOS A

Critical Lane Volume
Level of Service Worksheet

Intersection	MD 121 & I-270 Western Intersection
Major Approach:	I-270
Minor Approach:	MD 121
County/State:	Montgomery County/Maryland
Scenario:	2040 No-Build
Analyst:	DSG/VHB

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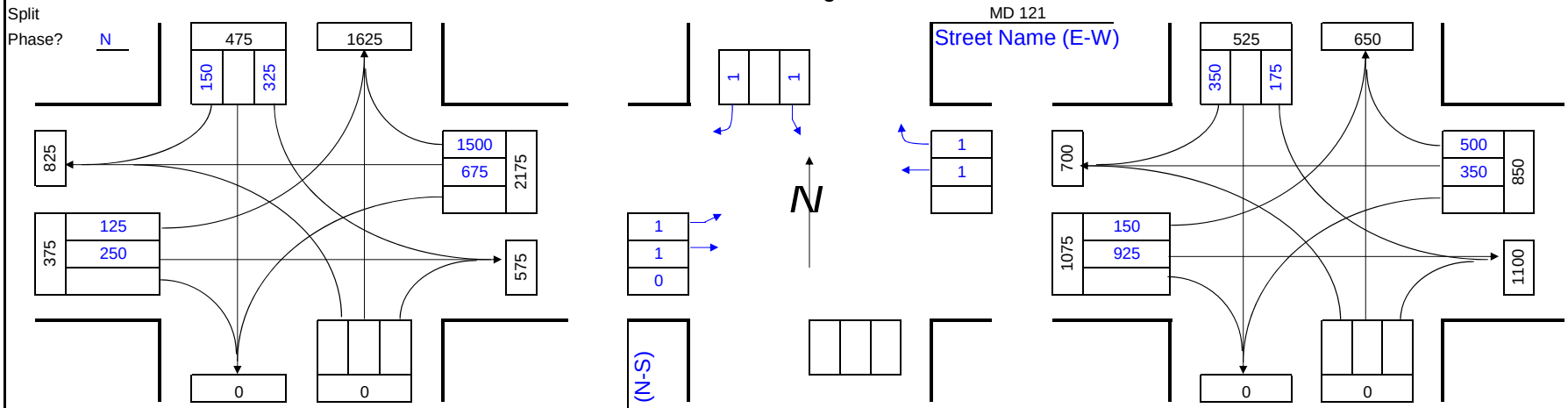
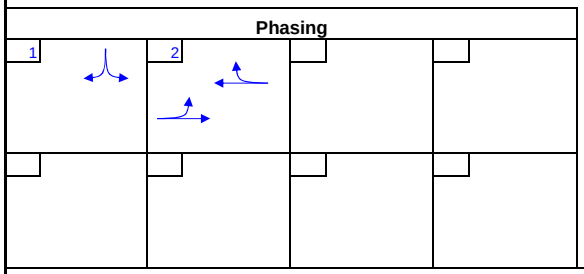
Morning Peak Hour

Lane Configuration

Evening Peak Hour





No. of Lanes	Lane Use Factor
1	1.00
2	0.53
3	0.37
4	0.30
Dbl-lft	0.53

LOS	Critical Lane Volume	
A	0	999
B	1000	1149
C	1150	1299
D	1300	1449
E	1450	1600
F	1601	9999

Opposing Volume (vph)	PCE
<= 199	1.1
<= 599	2.0
<= 799	3.0
<= 999	4.0
> 1000	5.0

AM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	SBL	0	1.00	0	325	1.00	325	325	C
2	EB	250	1.00	250	0	1.00	0	250	
2	WB	675	1.00	675	125	1.00	125	800	C

C: Critical Volume — Total 1125; V/C 0.70; LOS B

PM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	SBL		1.00	0	175	1.00	175	175	C
2	EB	925	1.00	925	0	1.00	0	925	
2	WB	350	1.00	350	150	1.00	150	500	C

C: Critical Volume — Total 675; V/C 0.42; LOS A

Critical Lane Volume
Level of Service Worksheet

Intersection	MD 121 & I-270 Eastern Intersection
Major Approach:	I-270
Minor Approach:	MD 121
County/State:	Montgomery County/Maryland
Scenario:	2040 No-Build
Analyst:	DSG/VHB

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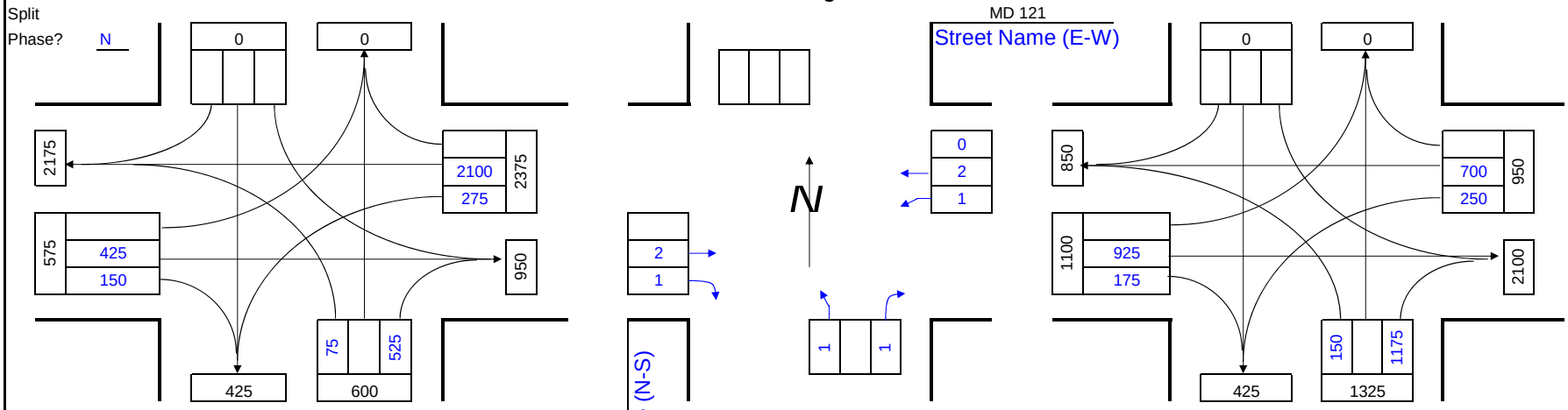
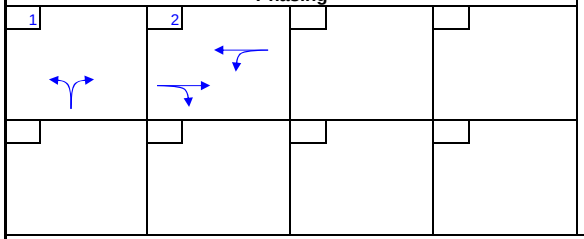
Morning Peak Hour

Lane Configuration

Evening Peak Hour



Phasing



No. of Lanes	Lane Use Factor
1	1.00
2	0.53
3	0.37
4	0.30
Dbl-lft	0.53

LOS	Critical Lane Volume	
A	0	999
B	1000	1149
C	1150	1299
D	1300	1449
E	1450	1600
F	1601	9999

Opposing Volume (vph)	PCE
<= 199	1.1
<= 599	2.0
<= 799	3.0
<= 999	4.0
> 1000	5.0

AM

Phase	Movement	(1) Volume	(2)Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NBL	75	1.00	75	25	1.00	25	100	C
2	EB	425	0.53	225	275	1.00	275	500	
2	WB	2100	0.53	1113		1.00	0	1113	C
		C: Critical Volume				Total		1213	
						V/C		0.76	
						LOS		C	

PM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NBL	150	1.00	150	0	1.00	0	150	C
2	EB	700	1.00	700	0	1.00	0	700	
2	WB	925	1.00	925	250	1.00	250	1175	C
		C: Critical Volume				Total		1325	
						V/C		0.83	
						LOS		D	

Critical Lane Volume
Level of Service Worksheet

Intersection	MD 355 & MD 121
Major Approach:	MD 355
Minor Approach:	Clarksburg Road (MD 121)
County/State:	Montgomery County/Maryland
Scenario:	2040 No-Build
Analyst:	DSG/VHB

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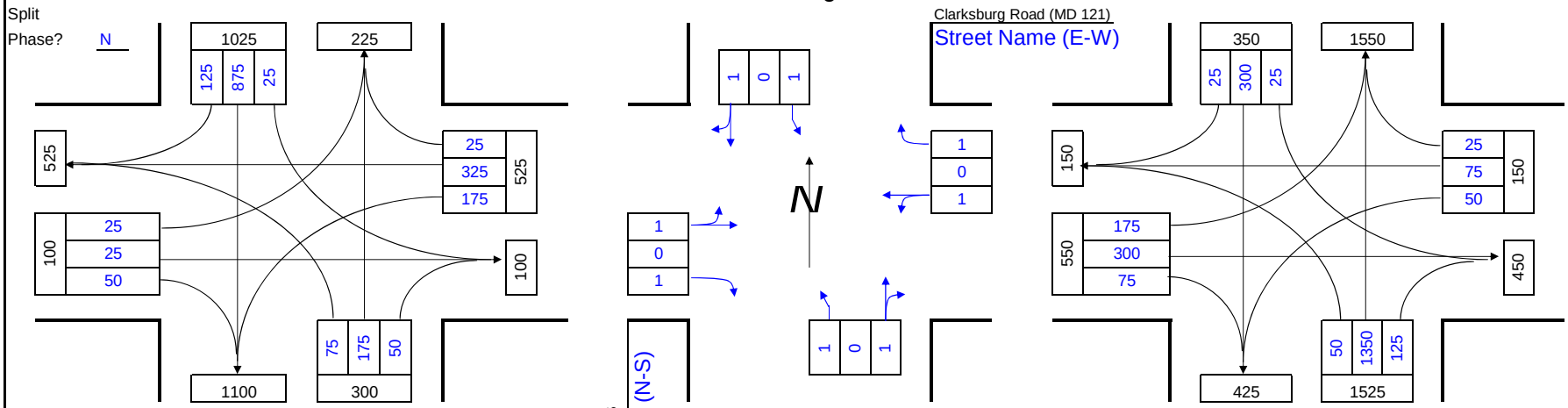
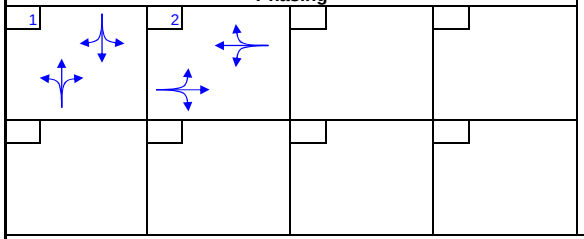
Morning Peak Hour

Lane Configuration

Evening Peak Hour



Phasing



No. of Lanes	Lane Use Factor
1	1.00
2	0.53
3	0.37
4	0.30
Dbl-lft	0.53

LOS	Critical Lane Volume	
A	0	999
B	1000	1149
C	1150	1299
D	1300	1449
E	1450	1600
F	1601	9999

Opposing Volume (vph)	PCE
<= 199	1.1
<= 599	2.0
<= 799	3.0
<= 999	4.0
> 1000	5.0

AM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	225	1.00	225	25	1.00	25	250	
1	SB	1000	1.00	1000	75	1.00	75	1075	C
2	EB	325	1.00	325	25	1.00	25	350	C
2	WB	25	1.00	25	175	1.00	175	200	

C: Critical Volume — Total 1425; V/C 0.89; LOS D

PM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	1475	1.00	1475	25	1.00	25	1500	C
1	SB	325	1.00	325	50	1.00	50	375	
2	EB	300	1.00	300	50	1.00	50	350	C
2	WB	75	1.00	75	175	1.00	175	250	

C: Critical Volume — Total 1850; V/C 1.16; LOS F

Critical Lane Volume
Level of Service Worksheet

Intersection	MD 355 & Shawnee Lane
Major Approach:	MD 355
Minor Approach:	Shawnee Lane
County/State:	Montgomery County/Maryland
Scenario:	2040 No-Build
Analyst:	DSG/VHB

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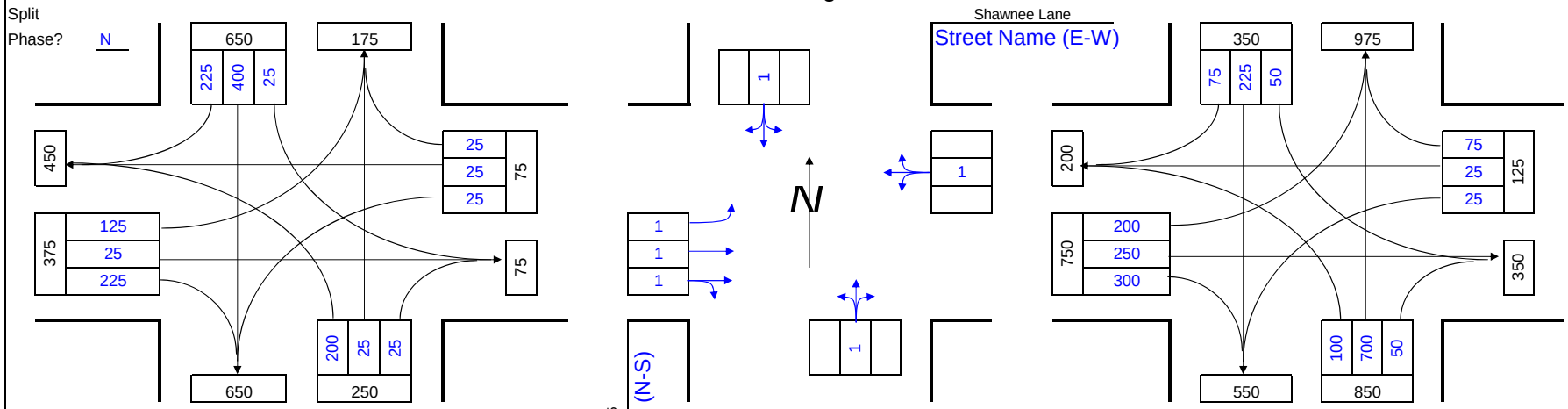
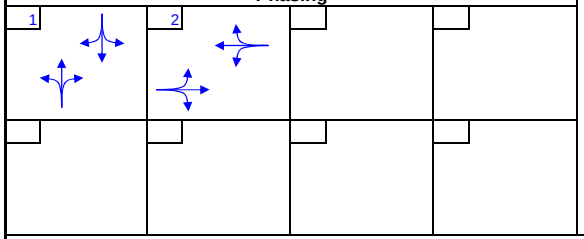
Morning Peak Hour

Lane Configuration

Evening Peak Hour



Phasing



No. of Lanes	Lane Use Factor
1	1.00
2	0.53
3	0.37
4	0.30
Dbl-lft	0.53

LOS	Critical Lane Volume	
A	0	999
B	1000	1149
C	1150	1299
D	1300	1449
E	1450	1600
F	1601	9999

Opposing Volume (vph)	PCE
<= 199	1.1
<= 599	2.0
<= 799	3.0
<= 999	4.0
> 1000	5.0

AM

Phase	Movement	(1) Volume	(2)Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	50	1.00	50	25	1.00	25	75	
1	SB	625	1.00	625	200	1.00	200	825	C
2	EB	250	0.53	133	125	1.00	125	258	C
2	WB	50	1.00	50	25	1.00	25	75	

C: Critical Volume

Total	1083
V/C	0.68
LOS	B

PM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	750	1.00	750	50	1.00	50	800	C
1	SB	300	1.00	300	100	1.00	100	400	
2	EB	550	0.53	292	25	1.00	25	317	C
2	WB	100	1.00	100	200	1.00	200	300	

C: Critical Volume

Total	1117
V/C	0.70
LOS	B

Critical Lane Volume
Level of Service Worksheet

Intersection	MD 355 & Stringtown Road
Major Approach:	MD 355
Minor Approach:	Stringtown Road
County/State:	Montgomery County/Maryland
Scenario:	2040 No-Build
Analyst:	DSG/VHB

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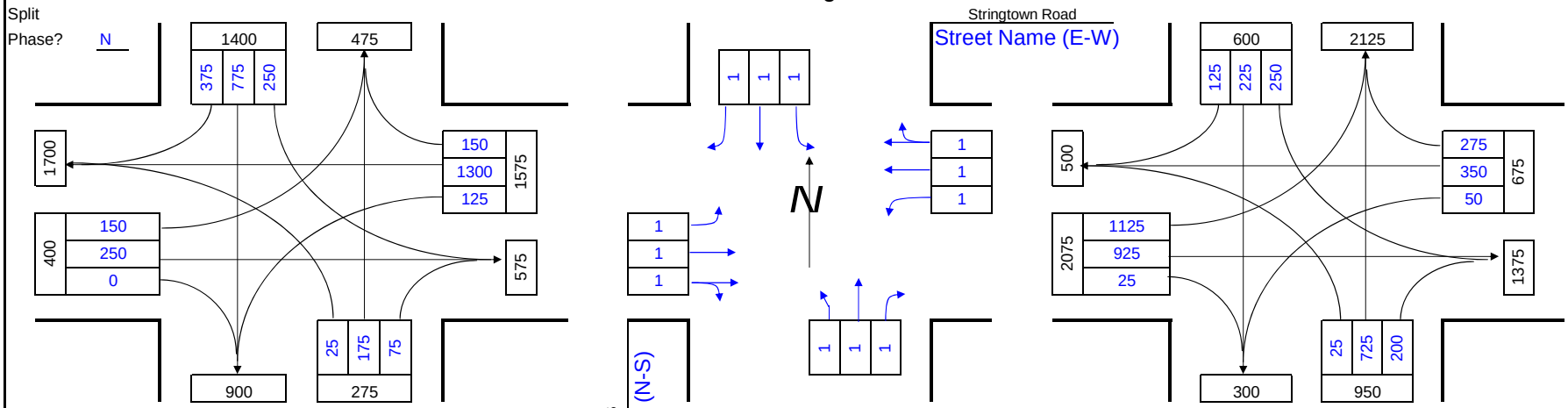
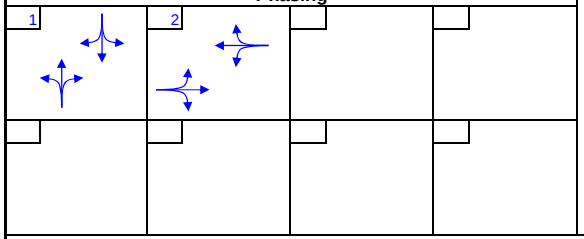
Morning Peak Hour

Lane Configuration

Evening Peak Hour



Phasing



No. of Lanes	Lane Use Factor
1	1.00
2	0.53
3	0.37
4	0.30
Dbl-lft	0.53

LOS	Critical Lane Volume	
A	0	999
B	1000	1149
C	1150	1299
D	1300	1449
E	1450	1600
F	1601	9999

Opposing Volume (vph)	PCE
<= 199	1.1
<= 599	2.0
<= 799	3.0
<= 999	4.0
> 1000	5.0

AM

Phase	Movement	(1) Volume	(2)Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	175	1.00	175	250	1.00	250	425	
1	SB	775	1.00	775	25	1.00	25	800	C
2	EB	250	0.53	133	125	1.00	125	258	
2	WB	1450	0.53	769	150	1.00	150	919	C
C: Critical Volume						Total		1719	
						V/C		1.07	
						LOS		F	

PM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	725	1.00	725	250	1.00	250	975	C
1	SB	225	1.00	225	25	1.00	25	250	
2	EB	950	0.53	504	50	1.00	50	554	
2	WB	625	0.53	331	1125	1.00	1125	1456	C
C: Critical Volume						Total		2431	
						V/C		1.52	
						LOS		F	

Critical Lane Volume
Level of Service Worksheet

Intersection	Gateway Center Dr & Stringtown Rd
Major Approach:	Gateway Center Dr
Minor Approach:	Stringtown Road
County/State:	Montgomery County/Maryland
Scenario:	2040 No-Build
Analyst:	DSG/VHB

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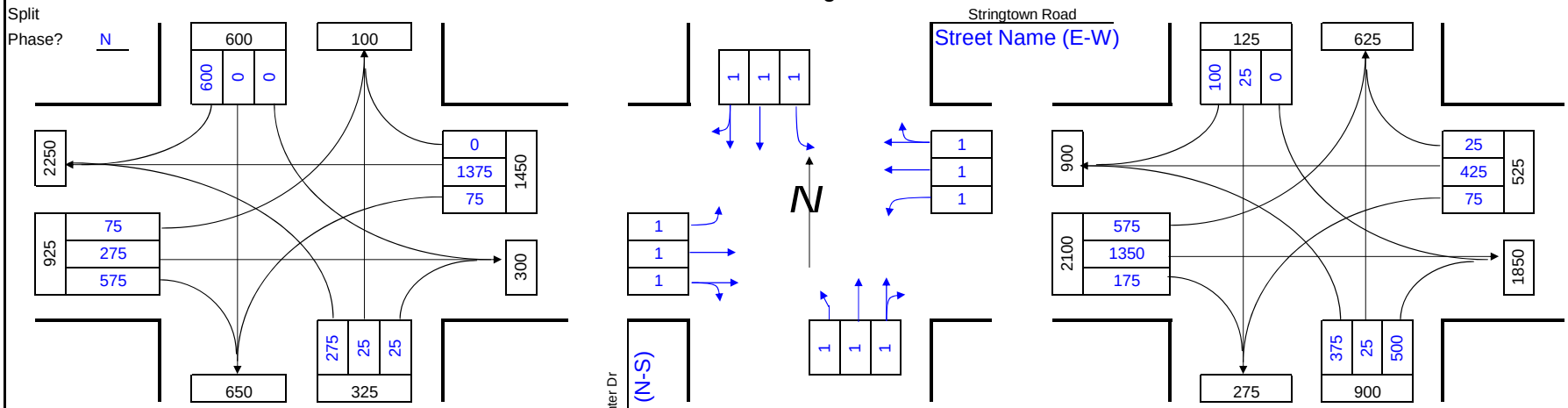
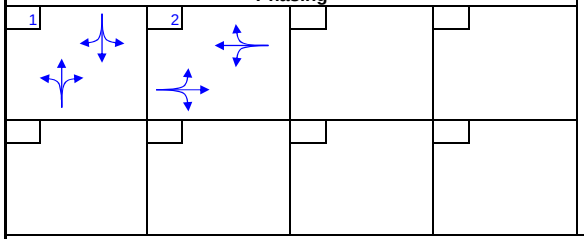
Morning Peak Hour

Lane Configuration

Evening Peak Hour



Phasing



No. of Lanes	Lane Use Factor
1	1.00
2	0.53
3	0.37
4	0.30
Dbl-lft	0.53

LOS	Critical Lane Volume	
A	0	999
B	1000	1149
C	1150	1299
D	1300	1449
E	1450	1600
F	1601	9999

Opposing Volume (vph)	PCE
<= 199	1.1
<= 599	2.0
<= 799	3.0
<= 999	4.0
> 1000	5.0

AM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	50	0.53	27	0	1.00	0	27	
1	SB	600	0.53	318	275	1.00	275	593	C
2	EB	850	0.53	451	75	1.00	75	526	
2	WB	1375	0.53	729	75	1.00	75	804	C
C: Critical Volume							Total	1397	
							V/C	0.87	
							LOS	D	

PM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	525	0.53	278	0	1.00	0	278	
1	SB	125	0.53	66	375	1.00	375	441	C
2	EB	1525	0.53	808	75	1.00	75	883	C
2	WB	450	0.53	239	575	1.00	575	814	
C: Critical Volume							Total	1325	
							V/C	0.83	
							LOS	D	

Critical Lane Volume
Level of Service Worksheet

Intersection	MD 121 & I-270 Western Intersection
Major Approach:	I-270
Minor Approach:	MD 121
County/State:	Montgomery County/Maryland
Scenario:	2040 Build
Analyst:	DSG/VHB

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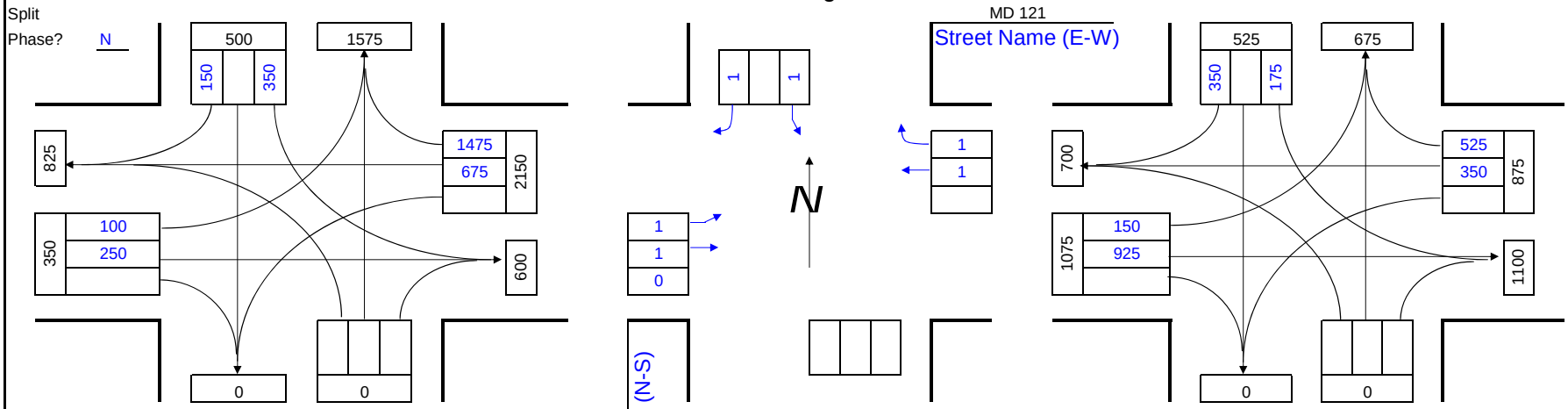
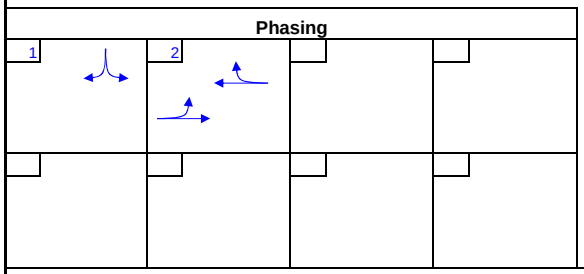
Morning Peak Hour

Lane Configuration

Evening Peak Hour





No. of Lanes	Lane Use Factor
1	1.00
2	0.53
3	0.37
4	0.30
Dbl-lft	0.53

LOS	Critical Lane Volume	
A	0	999
B	1000	1149
C	1150	1299
D	1300	1449
E	1450	1600
F	1601	9999

Opposing Volume (vph)	PCE
<= 199	1.1
<= 599	2.0
<= 799	3.0
<= 999	4.0
> 1000	5.0

AM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	SBL	0	1.00	0	350	1.00	350	350	C
2	EB	250	1.00	250	0	1.00	0	250	
2	WB	675	1.00	675	100	1.00	100	775	C

C: Critical Volume — Total 1125; V/C 0.70; LOS B

PM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	SBL		1.00	0	175	1.00	175	175	C
2	EB	925	1.00	925	0	1.00	0	925	
2	WB	350	1.00	350	150	1.00	150	500	C

C: Critical Volume — Total 675; V/C 0.42; LOS A

Critical Lane Volume
Level of Service Worksheet

Intersection	MD 121 & I-270 Eastern Intersection
Major Approach:	I-270
Minor Approach:	MD 121
County/State:	Montgomery County/Maryland
Scenario:	2040 Build
Analyst:	DSG/VHB

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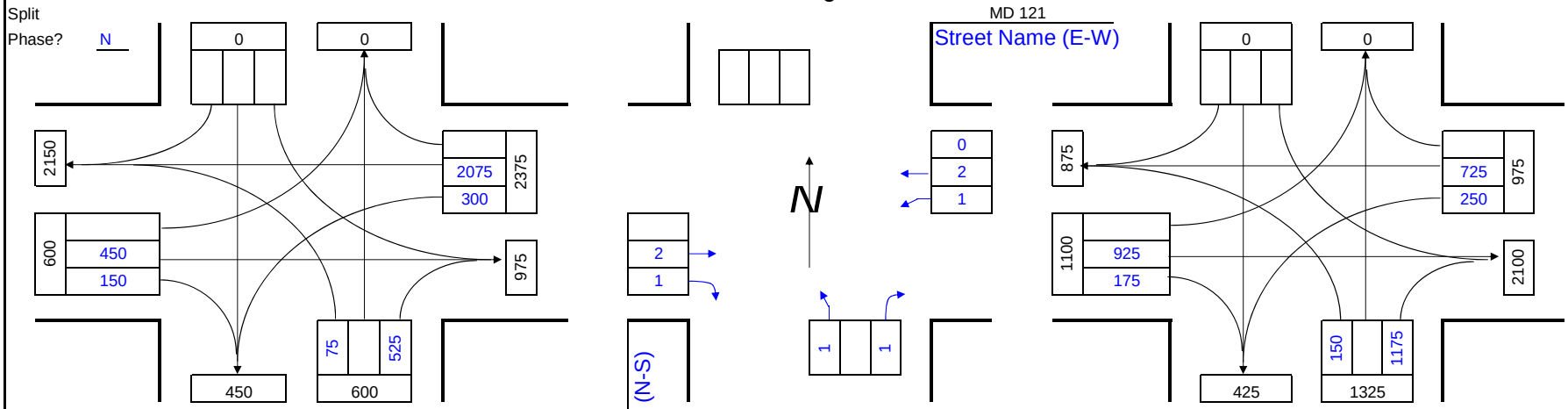
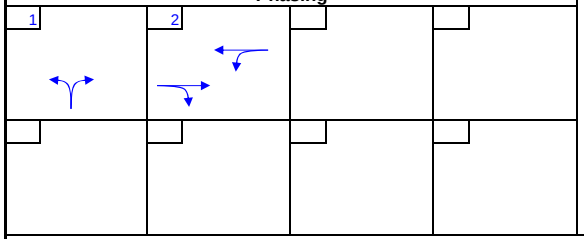
Morning Peak Hour

Lane Configuration

Evening Peak Hour



Phasing



No. of Lanes	Lane Use Factor
1	1.00
2	0.53
3	0.37
4	0.30
Dbl-lft	0.53

LOS	Critical Lane Volume	
A	0	999
B	1000	1149
C	1150	1299
D	1300	1449
E	1450	1600
F	1601	9999

Opposing Volume (vph)	PCE
<= 199	1.1
<= 599	2.0
<= 799	3.0
<= 999	4.0
> 1000	5.0

AM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NBL	75	1.00	75	25	1.00	25	100	C
2	EB	450	0.53	239	300	1.00	300	539	
2	WB	2075	0.53	1100		1.00	0	1100	C
	C: Critical Volume						Total	1200	
							V/C	0.75	
							LOS	C	

PM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NBL	150	1.00	150	0	1.00	0	150	C
2	EB	725	1.00	725	0	1.00	0	725	
2	WB	925	1.00	925	250	1.00	250	1175	C
	C: Critical Volume						Total	1325	
							V/C	0.83	
							LOS	D	

Critical Lane Volume
Level of Service Worksheet

Intersection	MD 355 & MD 121
Major Approach:	MD 355
Minor Approach:	Clarksburg Road (MD 121)
County/State:	Montgomery County/Maryland
Scenario:	2040 Build
Analyst:	DSG/VHB

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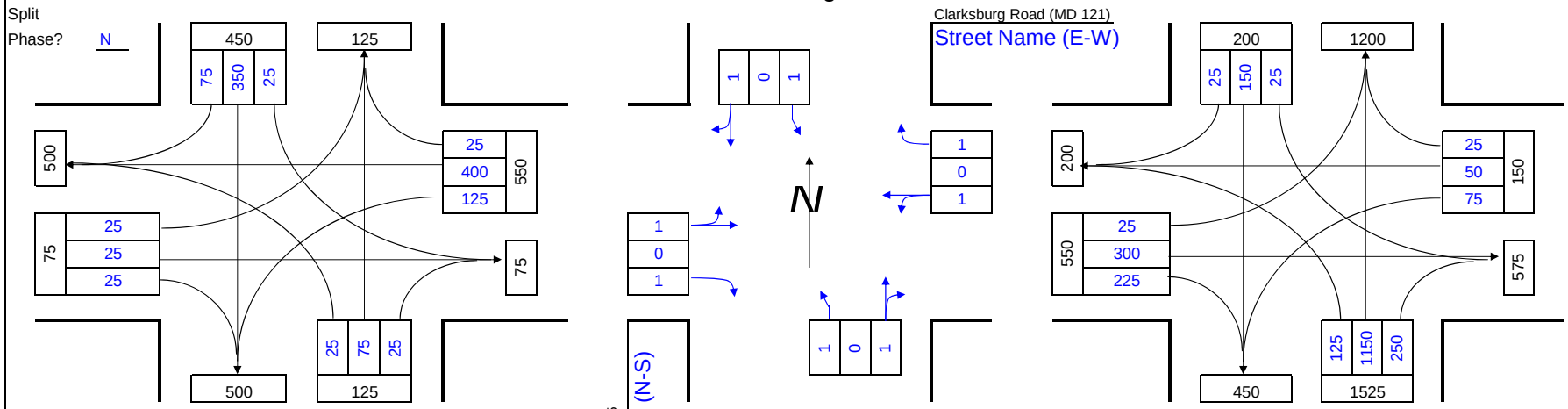
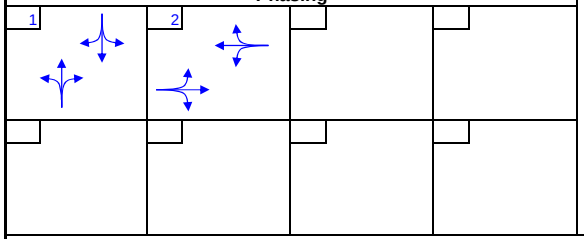
Morning Peak Hour

Lane Configuration

Evening Peak Hour



Phasing



No. of Lanes	Lane Use Factor
1	1.00
2	0.53
3	0.37
4	0.30
Dbl-lft	0.53

LOS	Critical Lane Volume	
A	0	999
B	1000	1149
C	1150	1299
D	1300	1449
E	1450	1600
F	1601	9999

Opposing Volume (vph)	PCE
<= 199	1.1
<= 599	2.0
<= 799	3.0
<= 999	4.0
> 1000	5.0

AM

Phase	Movement	(1) Volume	(2)Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	100	1.00	100	25	1.00	25	125	
1	SB	425	1.00	425	25	1.00	25	450	C
2	EB	400	1.00	400	25	1.00	25	425	C
2	WB	25	1.00	25	125	1.00	125	150	

C: Critical Volume

Total	875
V/C	0.55
LOS	A

PM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	1400	1.00	1400	25	1.00	25	1425	C
1	SB	175	1.00	175	125	1.00	125	300	
2	EB	300	1.00	300	75	1.00	75	375	C
2	WB	50	1.00	50	25	1.00	25	75	

C: Critical Volume

Total	1800
V/C	1.13
LOS	F

Critical Lane Volume
Level of Service Worksheet

Intersection	MD 355 & Shawnee Lane
Major Approach:	MD 355
Minor Approach:	Shawnee Lane
County/State:	Montgomery County/Maryland
Scenario:	2040 Build
Analyst:	DSG/VHB

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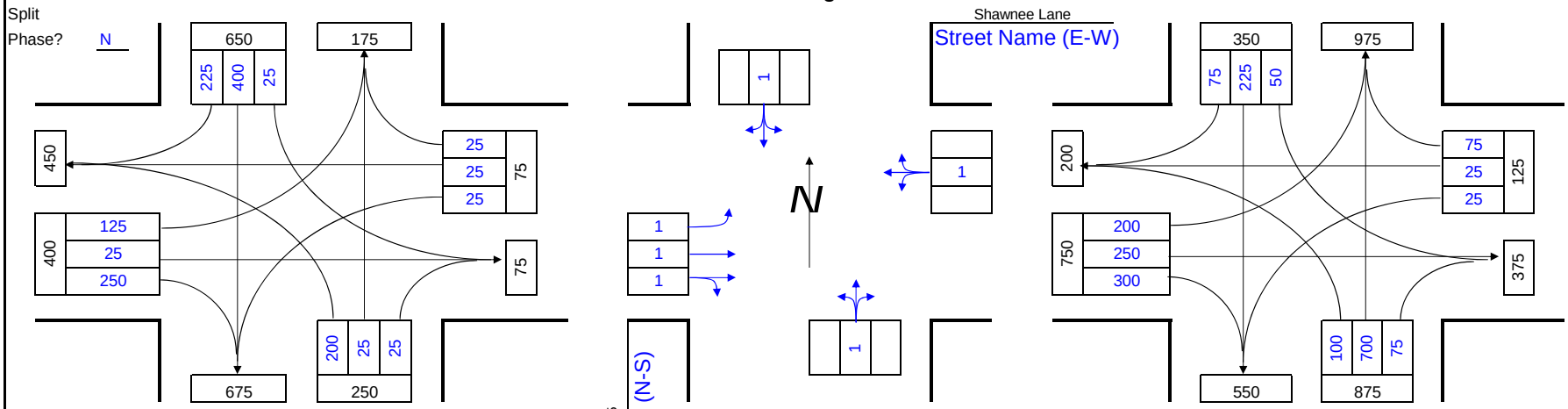
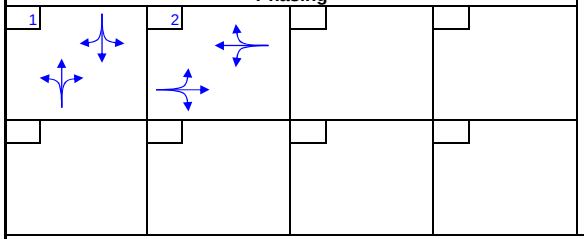
Morning Peak Hour

Lane Configuration

Evening Peak Hour



Phasing



No. of Lanes	Lane Use Factor
1	1.00
2	0.53
3	0.37
4	0.30
Dbl-lft	0.53

LOS	Critical Lane Volume	
A	0	999
B	1000	1149
C	1150	1299
D	1300	1449
E	1450	1600
F	1601	9999

Opposing Volume (vph)	PCE
<= 199	1.1
<= 599	2.0
<= 799	3.0
<= 999	4.0
> 1000	5.0

AM

Phase	Movement	(1) Volume	(2)Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	50	1.00	50	25	1.00	25	75	
1	SB	625	1.00	625	200	1.00	200	825	C
2	EB	275	0.53	146	125	1.00	125	271	C
2	WB	50	1.00	50	25	1.00	25	75	

C: Critical Volume — Total 1096; V/C 0.68; LOS B

PM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	775	1.00	775	50	1.00	50	825	C
1	SB	300	1.00	300	100	1.00	100	400	
2	EB	550	0.53	292	25	1.00	25	317	C
2	WB	100	1.00	100	200	1.00	200	300	

C: Critical Volume — Total 1142; V/C 0.71; LOS B

Critical Lane Volume
Level of Service Worksheet

Intersection	MD 355 & Stringtown Road
Major Approach:	MD 355
Minor Approach:	Stringtown Road
County/State:	Montgomery County/Maryland
Scenario:	2040 Build
Analyst:	DSG/VHB

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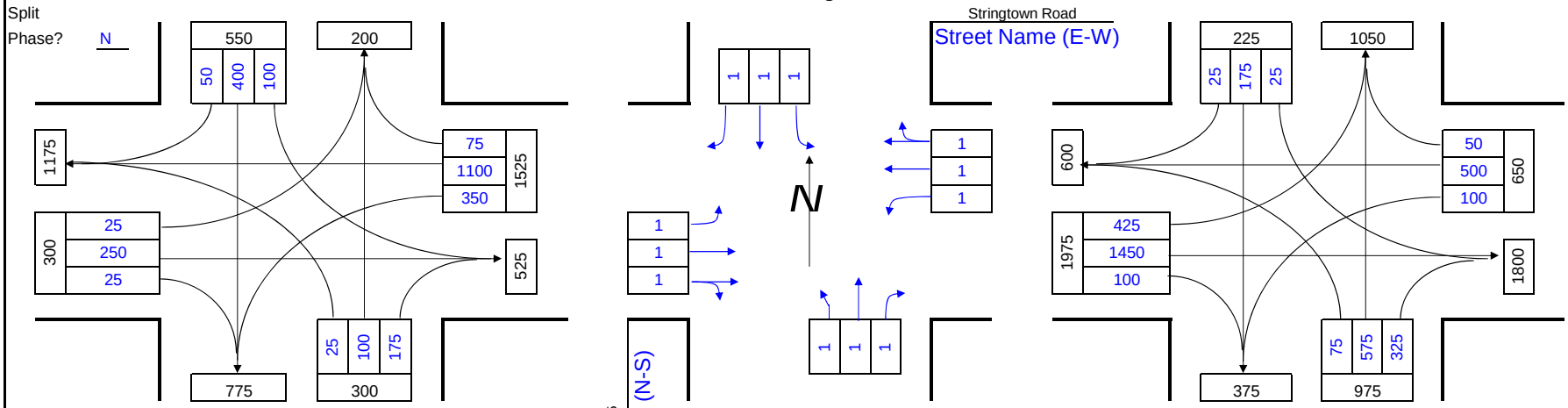
Morning Peak Hour

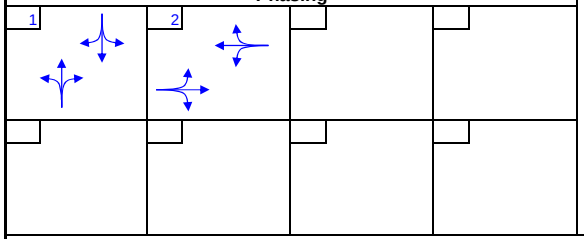
Lane Configuration

Evening Peak Hour

Split Phase? N



Phasing



No. of Lanes	Lane Use Factor
1	1.00
2	0.53
3	0.37
4	0.30
Dbl-lft	0.53

LOS	Critical Lane Volume	
A	0	999
B	1000	1149
C	1150	1299
D	1300	1449
E	1450	1600
F	1601	9999

Opposing Volume (vph)	PCE
<= 199	1.1
<= 599	2.0
<= 799	3.0
<= 999	4.0
> 1000	5.0

AM

Phase	Movement	(1) Volume	(2)Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	100	1.00	100	100	1.00	100	200	
1	SB	400	1.00	400	25	1.00	25	425	C
2	EB	275	0.53	146	350	1.00	350	496	
2	WB	1175	0.53	623	25	1.00	25	648	C
C: Critical Volume							Total	1073	
							V/C	0.67	
							LOS	B	

PM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	575	1.00	575	25	1.00	25	600	C
1	SB	175	1.00	175	75	1.00	75	250	
2	EB	1550	0.53	822	100	1.00	100	922	C
2	WB	550	0.53	292	425	1.00	425	717	
C: Critical Volume							Total	1522	
							V/C	0.95	
							LOS	E	

Critical Lane Volume
Level of Service Worksheet

Intersection	Gateway Center Dr & Stringtown Road
Major Approach:	Gateway Center Dr
Minor Approach:	Stringtown Road
County/State:	Montgomery County/Maryland
Scenario:	2040 Build
Analyst:	DSG/VHB

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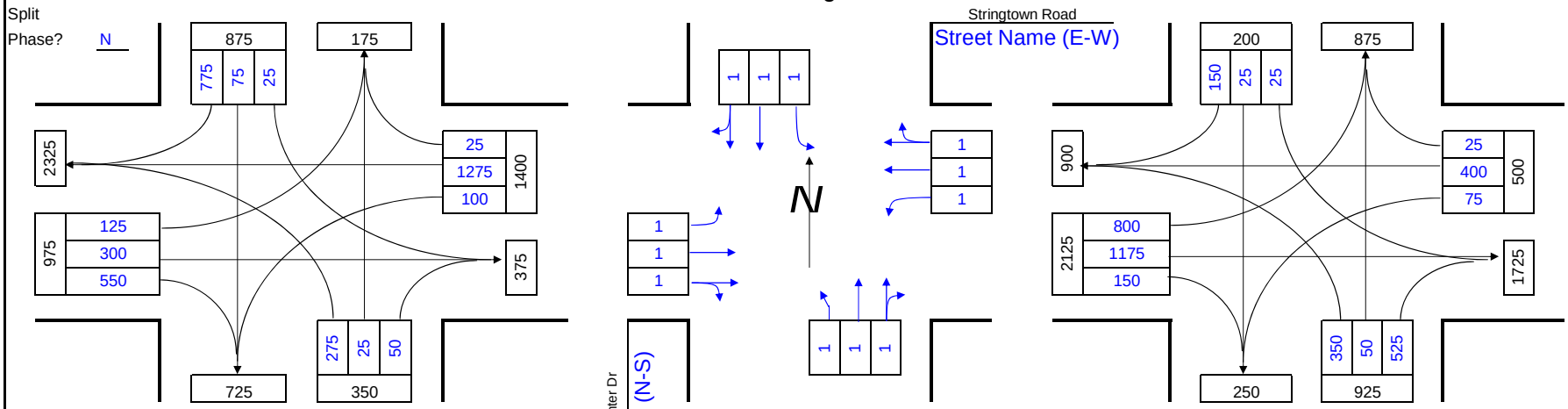
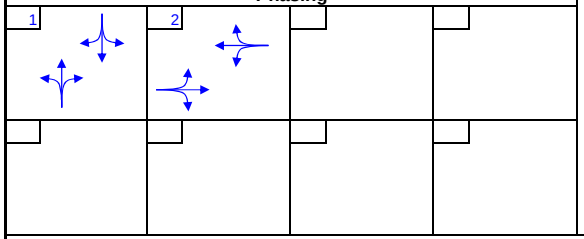
Morning Peak Hour

Lane Configuration

Evening Peak Hour



Phasing



No. of Lanes	Lane Use Factor
1	1.00
2	0.53
3	0.37
4	0.30
Dbl-lft	0.53

LOS	Critical Lane Volume	
A	0	999
B	1000	1149
C	1150	1299
D	1300	1449
E	1450	1600
F	1601	9999

Opposing Volume (vph)	PCE
<= 199	1.1
<= 599	2.0
<= 799	3.0
<= 999	4.0
> 1000	5.0

AM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	75	0.53	40	25	1.00	25	65	
1	SB	850	0.53	451	275	1.00	275	726	C
2	EB	850	0.53	451	100	1.00	100	551	
2	WB	1300	0.53	689	125	1.00	125	814	C
C: Critical Volume						Total		1540	
						V/C		0.96	
						LOS		E	

PM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	575	0.53	305	25	1.00	25	330	
1	SB	175	0.53	93	350	1.00	350	443	C
2	EB	1325	0.53	702	75	1.00	75	777	
2	WB	425	0.53	225	800	1.00	800	1025	C
C: Critical Volume						Total		1468	
						V/C		0.92	
						LOS		E	

Critical Lane Volume
Level of Service Worksheet

Intersection	New Road & Stringtown Road
Major Approach:	New Road
Minor Approach:	Stringtown Road
County/State:	Montgomery County/Maryland
Scenario:	2040 Build
Analyst:	DSG/VHB

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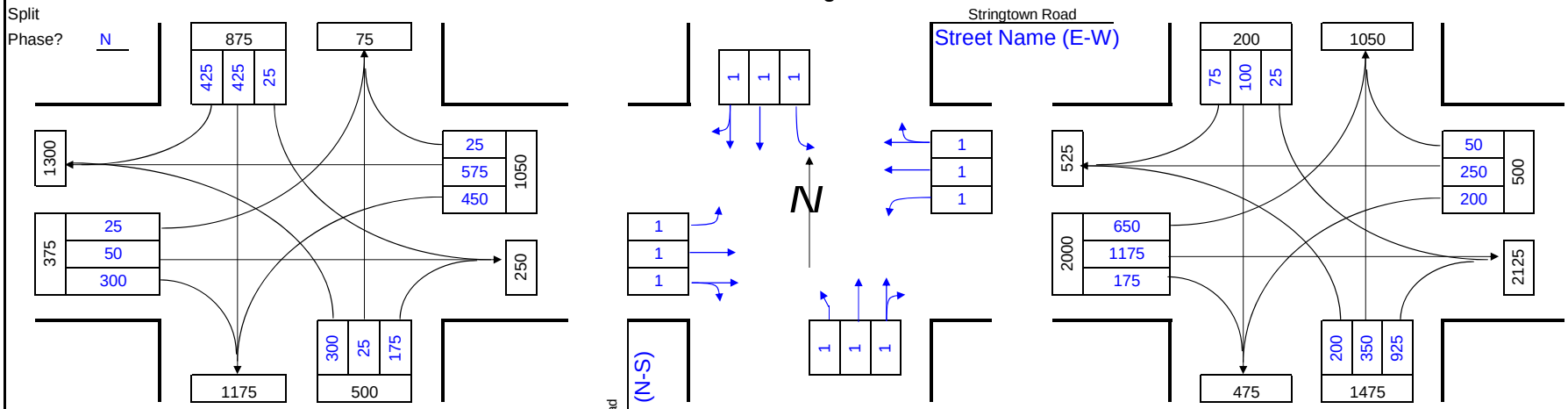
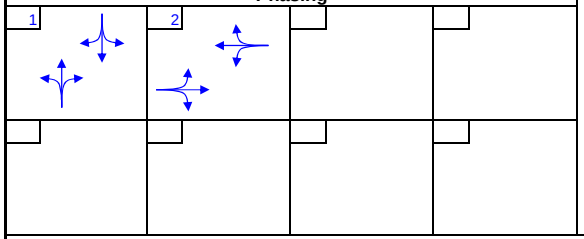
Morning Peak Hour

Lane Configuration

Evening Peak Hour



Phasing



No. of Lanes	Lane Use Factor
1	1.00
2	0.53
3	0.37
4	0.30
Dbl-lft	0.53

LOS	Critical Lane Volume	
A	0	999
B	1000	1149
C	1150	1299
D	1300	1449
E	1450	1600
F	1601	9999

Opposing Volume (vph)	PCE
<= 199	1.1
<= 599	2.0
<= 799	3.0
<= 999	4.0
> 1000	5.0

AM

Phase	Movement	(1) Volume	(2)Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	200	0.53	106	25	1.00	25	131	
1	SB	850	0.53	451	300	1.00	300	751	C
2	EB	350	0.53	186	450	1.00	450	636	C
2	WB	600	0.53	318	25	1.00	25	343	

C: Critical Volume

Total	1386
V/C	0.87
LOS	D

PM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	1275	0.53	676	25	1.00	25	701	C
1	SB	175	0.53	93	200	1.00	200	293	
2	EB	1350	0.53	716	200	1.00	200	916	C
2	WB	300	0.53	159	650	1.00	650	809	

C: Critical Volume

Total	1616
V/C	1.01
LOS	F

Critical Lane Volume
Level of Service Worksheet

Intersection	MD 121 & I-270 Western Intersection
Major Approach:	I-270
Minor Approach:	MD 121
County/State:	Montgomery County/Maryland
Scenario:	2040 HI Build
Analyst:	DSG/VHB

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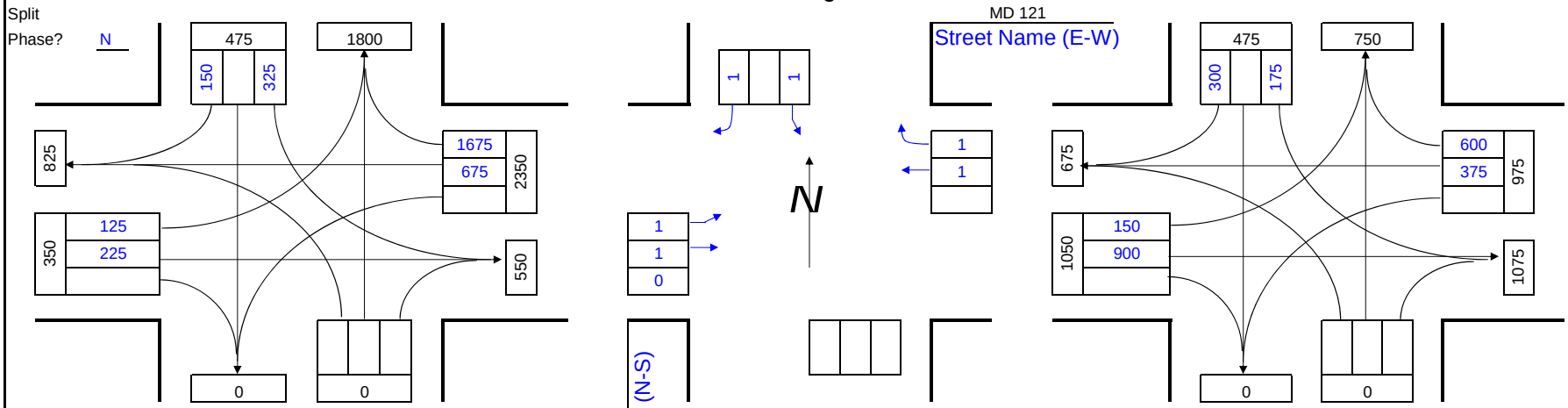
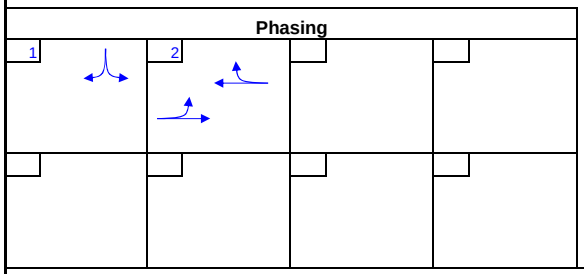
Morning Peak Hour

Lane Configuration

Evening Peak Hour





No. of Lanes	Lane Use Factor
1	1.00
2	0.53
3	0.37
4	0.30
Dbl-lft	0.53

LOS	Critical Lane Volume	
A	0	999
B	1000	1149
C	1150	1299
D	1300	1449
E	1450	1600
F	1601	9999

Opposing Volume (vph)	PCE
<= 199	1.1
<= 599	2.0
<= 799	3.0
<= 999	4.0
> 1000	5.0

AM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	SBL	0	1.00	0	325	1.00	325	325	C
2	EB	225	1.00	225	0	1.00	0	225	
2	WB	675	1.00	675	125	1.00	125	800	C

C: Critical Volume — Total 1125; V/C 0.70; LOS B

PM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	SBL		1.00	0	175	1.00	175	175	C
2	EB	900	1.00	900	0	1.00	0	900	
2	WB	375	1.00	375	150	1.00	150	525	C

C: Critical Volume — Total 700; V/C 0.44; LOS A

Critical Lane Volume
Level of Service Worksheet

Intersection	MD 121 & I-270 Eastern Intersection
Major Approach:	I-270
Minor Approach:	MD 121
County/State:	Montgomery County/Maryland
Scenario:	2040 HI Build
Analyst:	DSG/VHB

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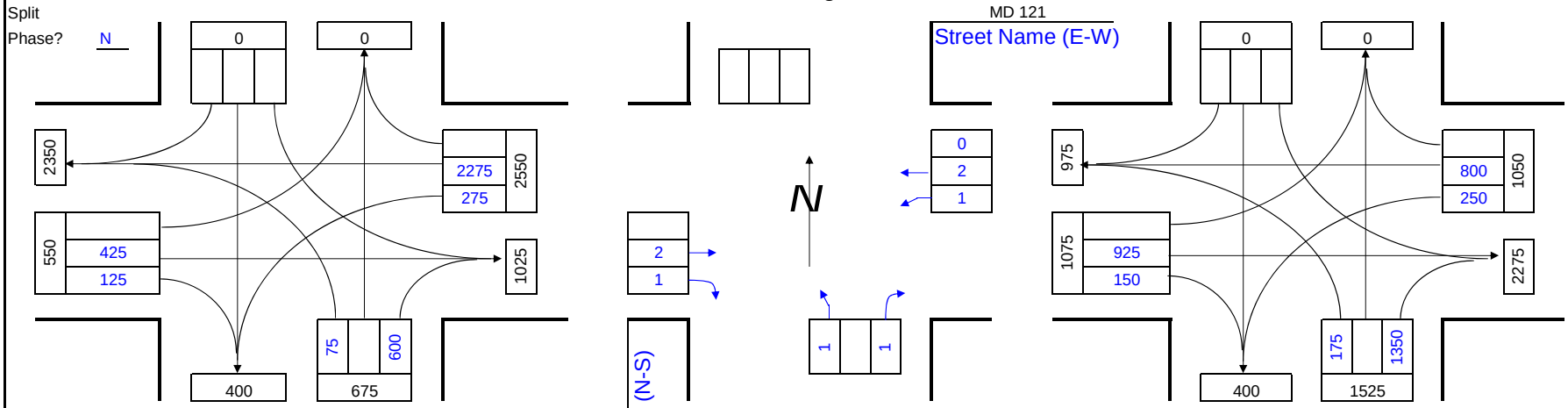
Morning Peak Hour

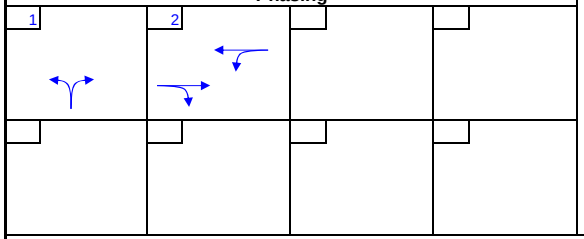
Lane Configuration

Evening Peak Hour

Split Phase? N



Phasing



No. of Lanes	Lane Use Factor
1	1.00
2	0.53
3	0.37
4	0.30
Dbl-lft	0.53

LOS	Critical Lane Volume	
A	0	999
B	1000	1149
C	1150	1299
D	1300	1449
E	1450	1600
F	1601	9999

Opposing Volume (vph)	PCE
<= 199	1.1
<= 599	2.0
<= 799	3.0
<= 999	4.0
> 1000	5.0

AM

Phase	Movement	(1) Volume	(2)Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NBL	75	1.00	75	25	1.00	25	100	C
2	EB	425	0.53	225	275	1.00	275	500	
2	WB	2275	0.53	1206		1.00	0	1206	C
		C: Critical Volume				Total		1306	
						V/C		0.82	
						LOS		D	

PM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NBL	175	1.00	175	0	1.00	0	175	C
2	EB	800	1.00	800	0	1.00	0	800	
2	WB	925	1.00	925	250	1.00	250	1175	C
		C: Critical Volume				Total		1350	
						V/C		0.84	
						LOS		D	

Critical Lane Volume
Level of Service Worksheet

Intersection	MD 355 & MD 121
Major Approach:	MD 355
Minor Approach:	Clarksburg Road (MD 121)
County/State:	Montgomery County/Maryland
Scenario:	2040 HI Build
Analyst:	DSG/VHB

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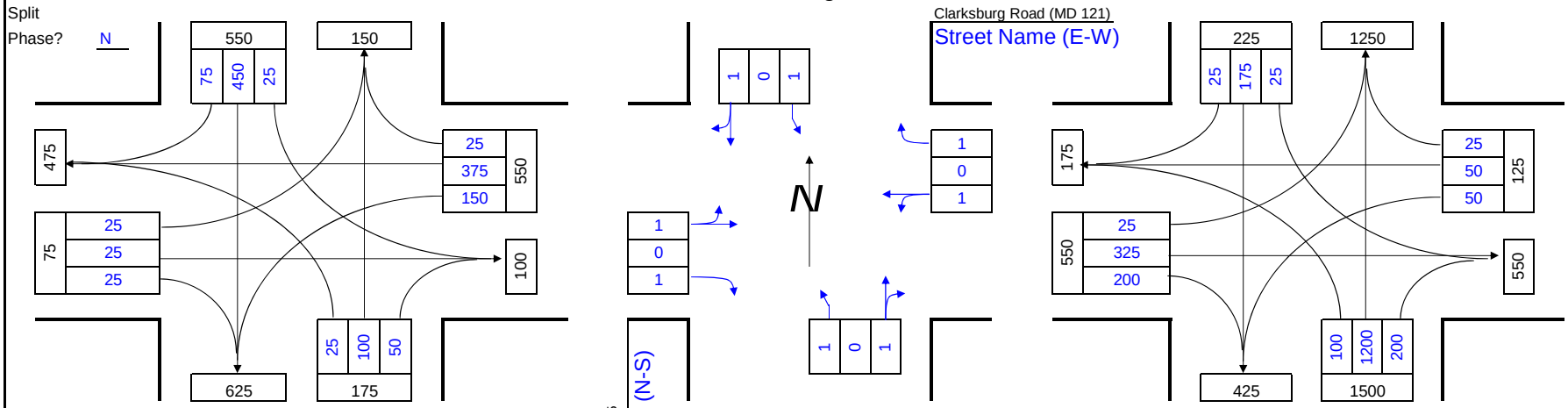
Morning Peak Hour

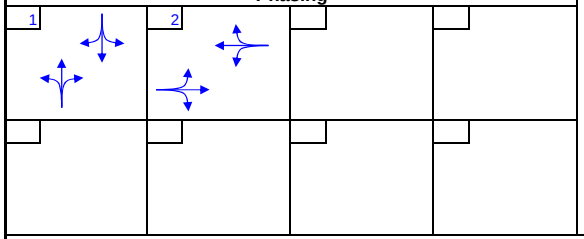
Lane Configuration

Evening Peak Hour

Split Phase? N



Phasing



No. of Lanes	Lane Use Factor
1	1.00
2	0.53
3	0.37
4	0.30
Dbl-lft	0.53

LOS	Critical Lane Volume	
A	0	999
B	1000	1149
C	1150	1299
D	1300	1449
E	1450	1600
F	1601	9999

Opposing Volume (vph)	PCE
<= 199	1.1
<= 599	2.0
<= 799	3.0
<= 999	4.0
> 1000	5.0

AM

Phase	Movement	(1) Volume	(2)Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	150	1.00	150	25	1.00	25	175	
1	SB	525	1.00	525	25	1.00	25	550	C
2	EB	375	1.00	375	25	1.00	25	400	C
2	WB	25	1.00	25	150	1.00	150	175	

C: Critical Volume — Total 950; V/C 0.59; LOS A

PM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	1400	1.00	1400	25	1.00	25	1425	C
1	SB	200	1.00	200	100	1.00	100	300	
2	EB	325	1.00	325	50	1.00	50	375	C
2	WB	50	1.00	50	25	1.00	25	75	

C: Critical Volume — Total 1800; V/C 1.13; LOS F

Critical Lane Volume
Level of Service Worksheet

Intersection	MD 355 & Shawnee Lane
Major Approach:	MD 355
Minor Approach:	Shawnee Lane
County/State:	Montgomery County/Maryland
Scenario:	2040 HI Build
Analyst:	DSG/VHB

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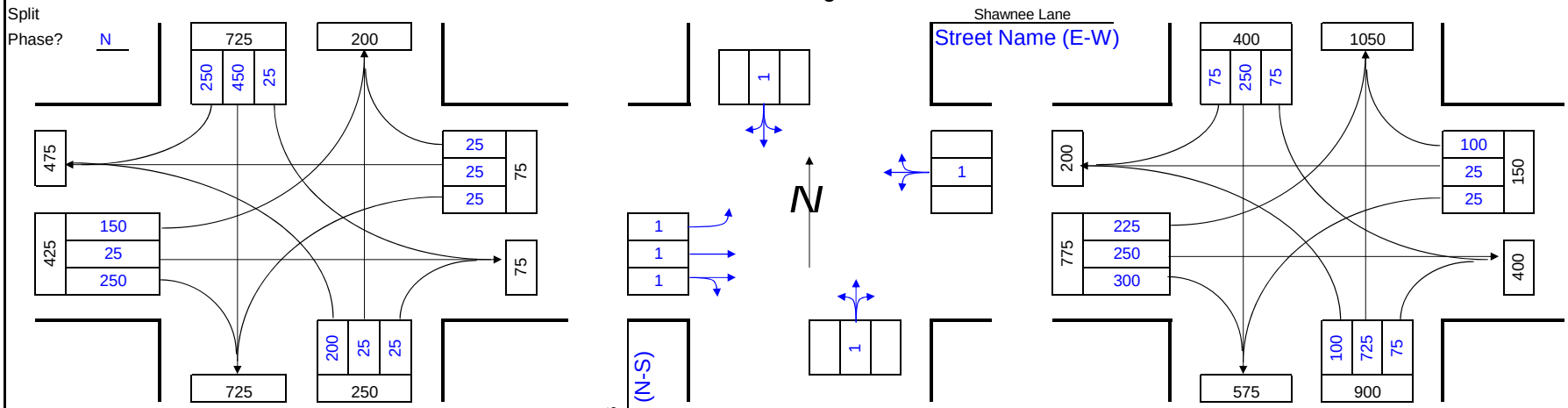
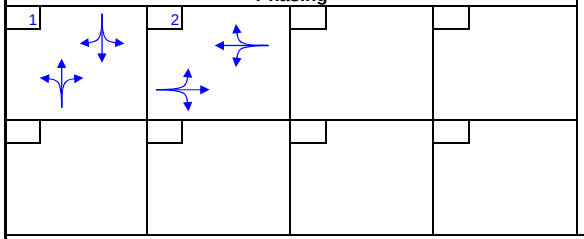
Morning Peak Hour

Lane Configuration

Evening Peak Hour



Phasing



No. of Lanes	Lane Use Factor
1	1.00
2	0.53
3	0.37
4	0.30
Dbl-lft	0.53

LOS	Critical Lane Volume	
A	0	999
B	1000	1149
C	1150	1299
D	1300	1449
E	1450	1600
F	1601	9999

Opposing Volume (vph)	PCE
<= 199	1.1
<= 599	2.0
<= 799	3.0
<= 999	4.0
> 1000	5.0

AM

Phase	Movement	(1) Volume	(2)Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	50	1.00	50	25	1.00	25	75	
1	SB	700	1.00	700	200	1.00	200	900	C
2	EB	275	0.53	146	150	1.00	150	296	C
2	WB	50	1.00	50	25	1.00	25	75	

C: Critical Volume — Total 1196; V/C 0.75; LOS C

PM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	800	1.00	800	75	1.00	75	875	C
1	SB	325	1.00	325	100	1.00	100	425	
2	EB	550	0.53	292	25	1.00	25	317	
2	WB	125	1.00	125	225	1.00	225	350	C

C: Critical Volume — Total 1225; V/C 0.77; LOS C

Critical Lane Volume
Level of Service Worksheet

Intersection	MD 355 & Stringtown Road
Major Approach:	MD 355
Minor Approach:	Stringtown Road
County/State:	Montgomery County/Maryland
Scenario:	2040 HI Build
Analyst:	DSG/VHB

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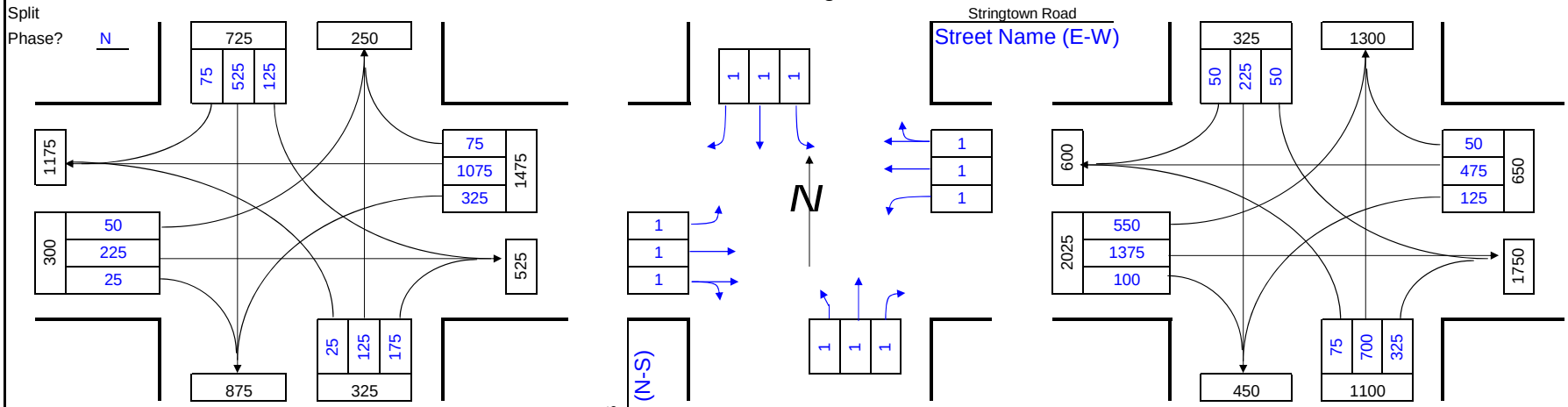
Morning Peak Hour

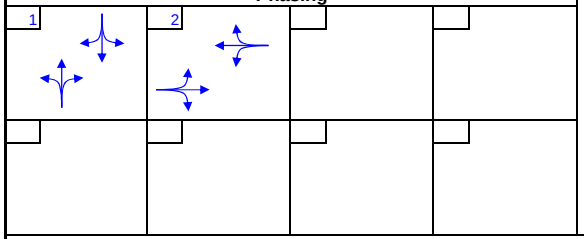
Lane Configuration

Evening Peak Hour

Split Phase? N



Phasing



No. of Lanes	Lane Use Factor
1	1.00
2	0.53
3	0.37
4	0.30
Dbl-lft	0.53

LOS	Critical Lane Volume	
A	0	999
B	1000	1149
C	1150	1299
D	1300	1449
E	1450	1600
F	1601	9999

Opposing Volume (vph)	PCE
<= 199	1.1
<= 599	2.0
<= 799	3.0
<= 999	4.0
> 1000	5.0

AM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	125	1.00	125	125	1.00	125	250	
1	SB	525	1.00	525	25	1.00	25	550	C
2	EB	250	0.53	133	325	1.00	325	458	
2	WB	1150	0.53	610	50	1.00	50	660	C
							Total	1210	
							V/C	0.76	
							LOS	C	

C: Critical Volume

PM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	700	1.00	700	50	1.00	50	750	C
1	SB	225	1.00	225	75	1.00	75	300	
2	EB	1475	0.53	782	125	1.00	125	907	C
2	WB	525	0.53	278	550	1.00	550	828	
							Total	1657	
							V/C	1.04	
							LOS	F	

C: Critical Volume

Critical Lane Volume
Level of Service Worksheet

Intersection	Gateway Center Dr & Stringtown Road
Major Approach:	Gateway Center Dr
Minor Approach:	Stringtown Road
County/State:	Montgomery County/Maryland
Scenario:	2040 HI Build
Analyst:	DSG/VHB

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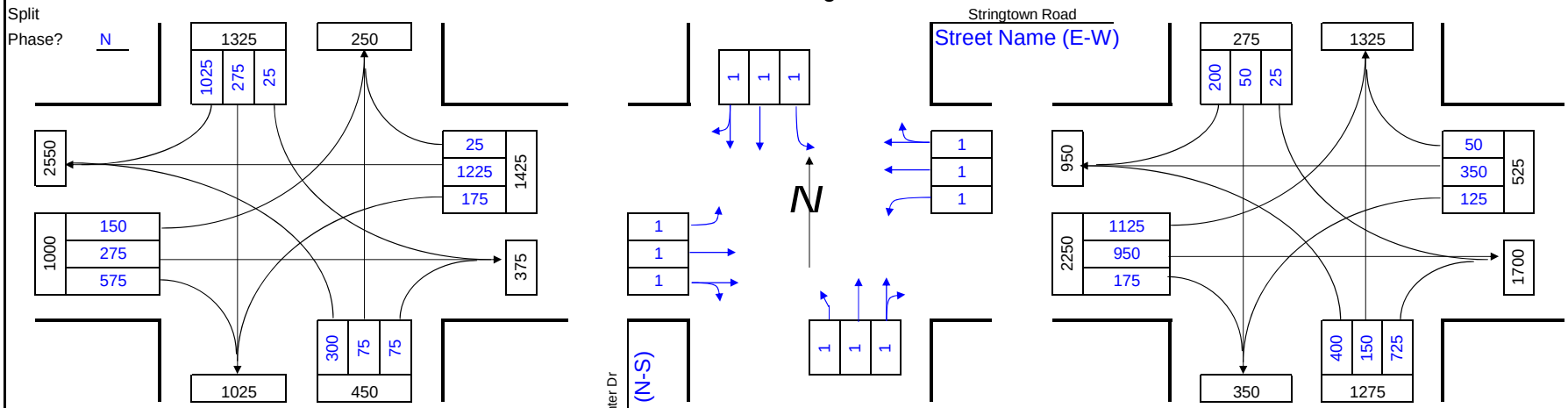
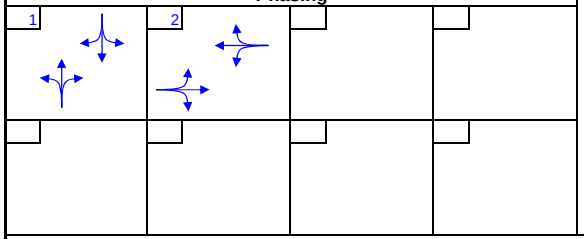
Morning Peak Hour

Lane Configuration

Evening Peak Hour



Phasing



No. of Lanes	Lane Use Factor
1	1.00
2	0.53
3	0.37
4	0.30
Dbl-lft	0.53

LOS	Critical Lane Volume	
A	0	999
B	1000	1149
C	1150	1299
D	1300	1449
E	1450	1600
F	1601	9999

Opposing Volume (vph)	PCE
<= 199	1.1
<= 599	2.0
<= 799	3.0
<= 999	4.0
> 1000	5.0

AM

Phase	Movement	(1) Volume	(2)Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	150	0.53	80	25	1.00	25	105	
1	SB	1300	0.53	689	300	1.00	300	989	C
2	EB	850	0.53	451	175	1.00	175	626	
2	WB	1250	0.53	663	150	1.00	150	813	C

C: Critical Volume — Total 1802; V/C 1.13; LOS F

PM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	875	0.53	464	25	1.00	25	489	
1	SB	250	0.53	133	400	1.00	400	533	C
2	EB	1125	0.53	596	125	1.00	125	721	
2	WB	400	0.53	212	1125	1.00	1125	1337	C

C: Critical Volume — Total 1870; V/C 1.17; LOS F

Critical Lane Volume
Level of Service Worksheet

Intersection	New Road & Stringtown Road
Major Approach:	New Road
Minor Approach:	Stringtown Road
County/State:	Montgomery County/Maryland
Scenario:	2040 HI Build
Analyst:	DSG/VHB

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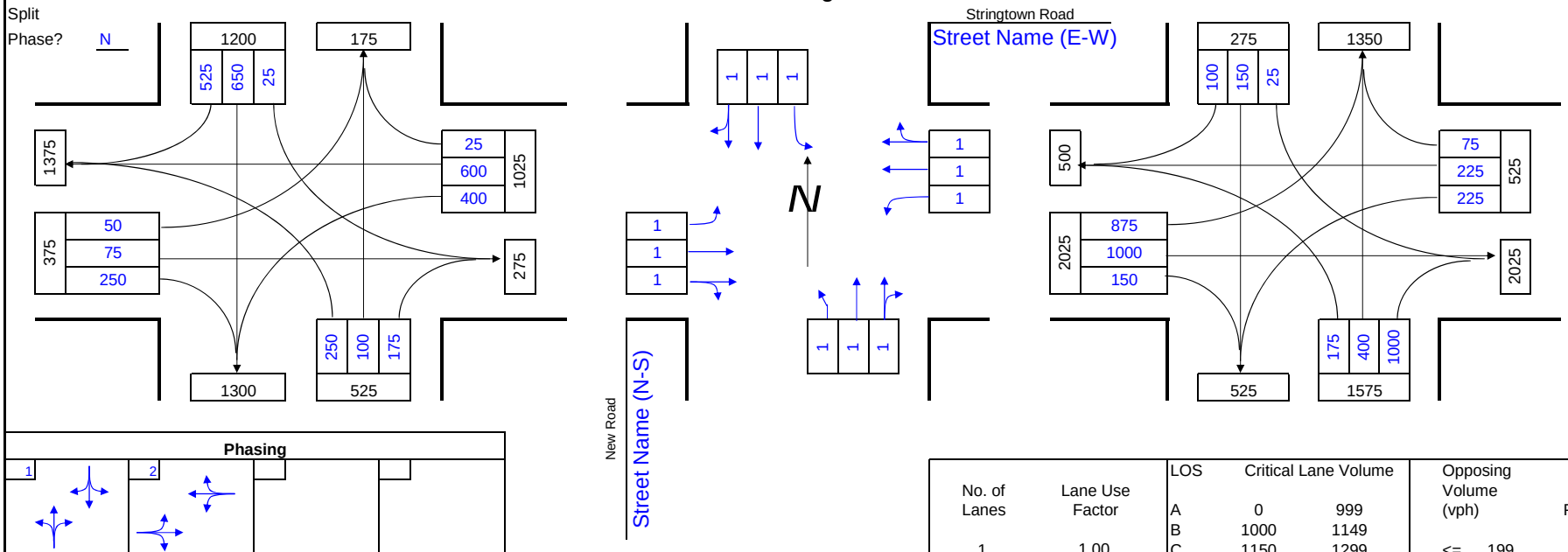
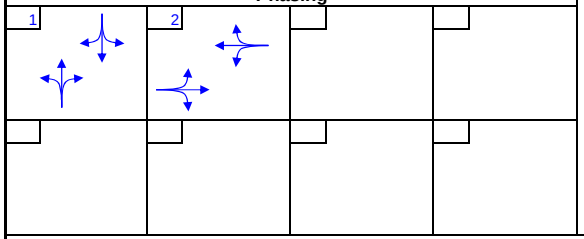
Morning Peak Hour

Lane Configuration

Evening Peak Hour



Phasing



No. of Lanes	Lane Use Factor
1	1.00
2	0.53
3	0.37
4	0.30
Dbl-lft	0.53

LOS	Critical Lane Volume	
A	0	999
B	1000	1149
C	1150	1299
D	1300	1449
E	1450	1600
F	1601	9999

Opposing Volume (vph)	PCE
<= 199	1.1
<= 599	2.0
<= 799	3.0
<= 999	4.0
> 1000	5.0

AM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	275	0.53	146	25	1.00	25	171	
1	SB	1175	0.53	623	250	1.00	250	873	C
2	EB	325	0.53	172	400	1.00	400	572	C
2	WB	625	0.53	331	50	1.00	50	381	
C: Critical Volume						Total		1445	
						V/C		0.90	
						LOS		D	

PM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	1400	0.53	742	25	1.00	25	767	C
1	SB	250	0.53	133	175	1.00	175	308	
2	EB	1150	0.53	610	225	1.00	225	835	
2	WB	300	0.53	159	875	1.00	875	1034	C
C: Critical Volume						Total		1801	
						V/C		1.13	
						LOS		F	

Critical Lane Volume
Level of Service Worksheet

Intersection	MD 121 & I-270 Western Intersection
Major Approach:	I-270
Minor Approach:	MD 121
County/State:	Montgomery County/Maryland
Scenario:	2040 HI No-Build
Analyst:	DSG/VHB

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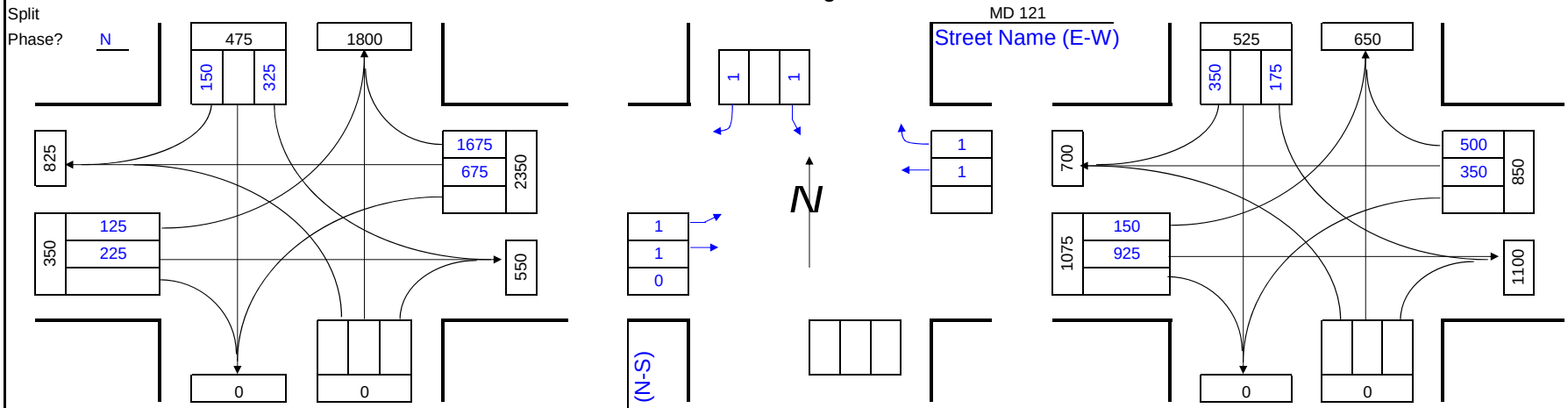
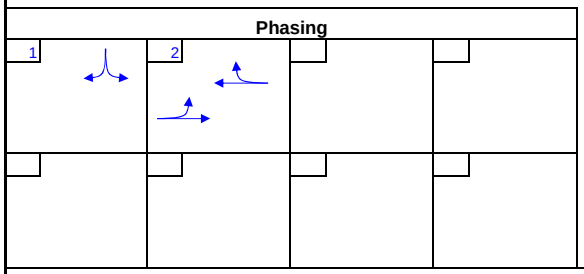
Morning Peak Hour

Lane Configuration

Evening Peak Hour





No. of Lanes	Lane Use Factor
1	1.00
2	0.53
3	0.37
4	0.30
Dbl-lft	0.53

LOS	Critical Lane Volume	
A	0	999
B	1000	1149
C	1150	1299
D	1300	1449
E	1450	1600
F	1601	9999

Opposing Volume (vph)	PCE
<= 199	1.1
<= 599	2.0
<= 799	3.0
<= 999	4.0
> 1000	5.0

AM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	SBL	0	1.00	0	325	1.00	325	325	C
2	EB	225	1.00	225	0	1.00	0	225	
2	WB	675	1.00	675	125	1.00	125	800	C

C: Critical Volume — Total 1125; V/C 0.70; LOS B

PM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	SBL		1.00	0	175	1.00	175	175	C
2	EB	925	1.00	925	0	1.00	0	925	
2	WB	350	1.00	350	150	1.00	150	500	C

C: Critical Volume — Total 675; V/C 0.42; LOS A

Critical Lane Volume
Level of Service Worksheet

Intersection	MD 121 & I-270 Eastern Intersection
Major Approach:	I-270
Minor Approach:	MD 121
County/State:	Montgomery County/Maryland
Scenario:	2040 HI No-Build
Analyst:	DSG/VHB

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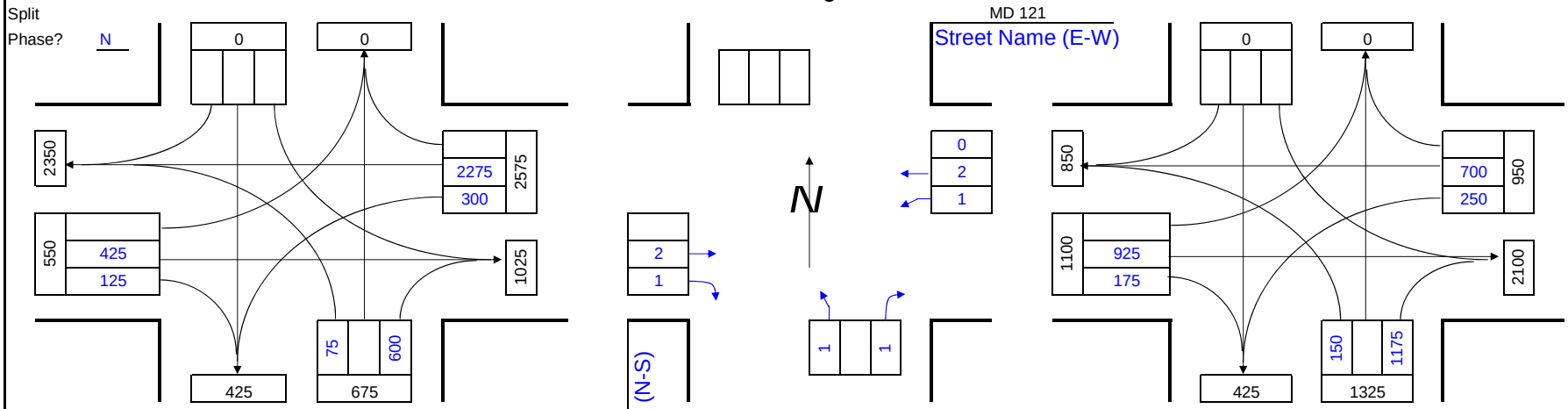
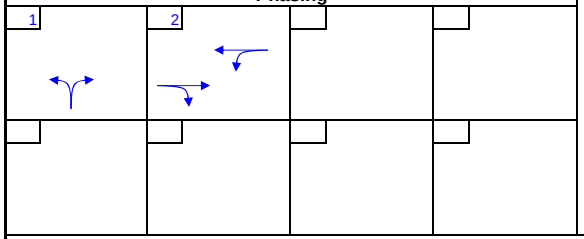
Morning Peak Hour

Lane Configuration

Evening Peak Hour



Phasing



No. of Lanes	Lane Use Factor
1	1.00
2	0.53
3	0.37
4	0.30
Dbl-lft	0.53

LOS	Critical Lane Volume	
A	0	999
B	1000	1149
C	1150	1299
D	1300	1449
E	1450	1600
F	1601	9999

Opposing Volume (vph)	PCE
<= 199	1.1
<= 599	2.0
<= 799	3.0
<= 999	4.0
> 1000	5.0

AM

Phase	Movement	(1) Volume	(2)Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NBL	75	1.00	75	25	1.00	25	100	C
2	EB	425	0.53	225	300	1.00	300	525	
2	WB	2275	0.53	1206		1.00	0	1206	C
		C: Critical Volume				Total		1306	
						V/C		0.82	
						LOS		D	

PM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NBL	150	1.00	150	0	1.00	0	150	C
2	EB	700	1.00	700	0	1.00	0	700	
2	WB	925	1.00	925	250	1.00	250	1175	C
		C: Critical Volume				Total		1325	
						V/C		0.83	
						LOS		D	

Critical Lane Volume
Level of Service Worksheet

Intersection	MD 355 & MD 121
Major Approach:	MD 355
Minor Approach:	Clarksburg Road (MD 121)
County/State:	Montgomery County/Maryland
Scenario:	2040 HI No-Build
Analyst:	DSG/VHB

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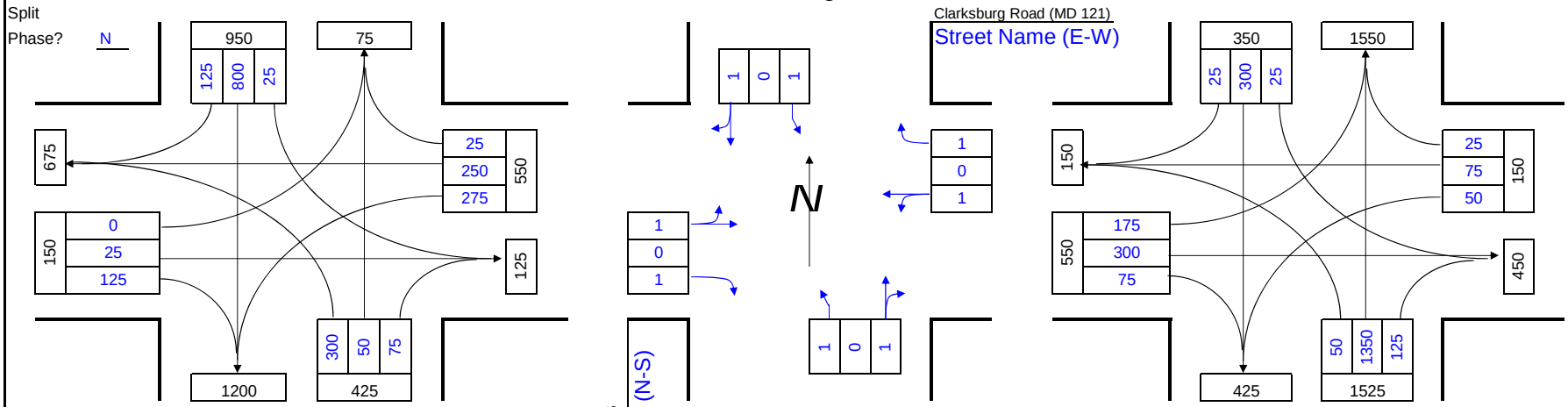
Morning Peak Hour

Lane Configuration

Evening Peak Hour

Split Phase? N



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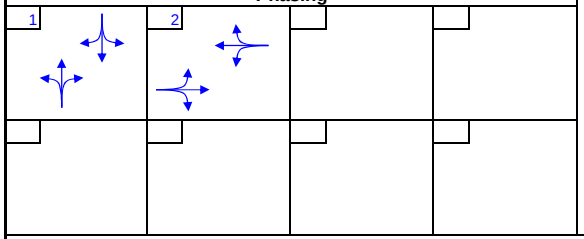

No. of Lanes	Lane Use Factor
1	1.00
2	0.53
3	0.37
4	0.30
Dbl-lft	0.53

LOS	Critical Lane Volume	
A	0	999
B	1000	1149
C	1150	1299
D	1300	1449
E	1450	1600
F	1601	9999

Opposing Volume (vph)	PCE
<= 199	1.1
<= 599	2.0
<= 799	3.0
<= 999	4.0
> 1000	5.0

AM

Phase	Movement	(1) Volume	(2)Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	125	1.00	125	25	1.00	25	150	
1	SB	925	1.00	925	300	1.00	300	1225	C
2	EB	250	1.00	250	0	1.00	0	250	
2	WB	25	1.00	25	275	1.00	275	300	C

C: Critical Volume

Total	1525
V/C	0.95
LOS	E

PM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	1475	1.00	1475	25	1.00	25	1500	C
1	SB	325	1.00	325	50	1.00	50	375	
2	EB	300	1.00	300	50	1.00	50	350	C
2	WB	75	1.00	75	175	1.00	175	250	

C: Critical Volume

Total	1850
V/C	1.16
LOS	F

Critical Lane Volume
Level of Service Worksheet

Intersection	MD 355 & Shawnee Lane
Major Approach:	MD 355
Minor Approach:	Shawnee Lane
County/State:	Montgomery County/Maryland
Scenario:	2040 HI No-Build
Analyst:	DSG/VHB

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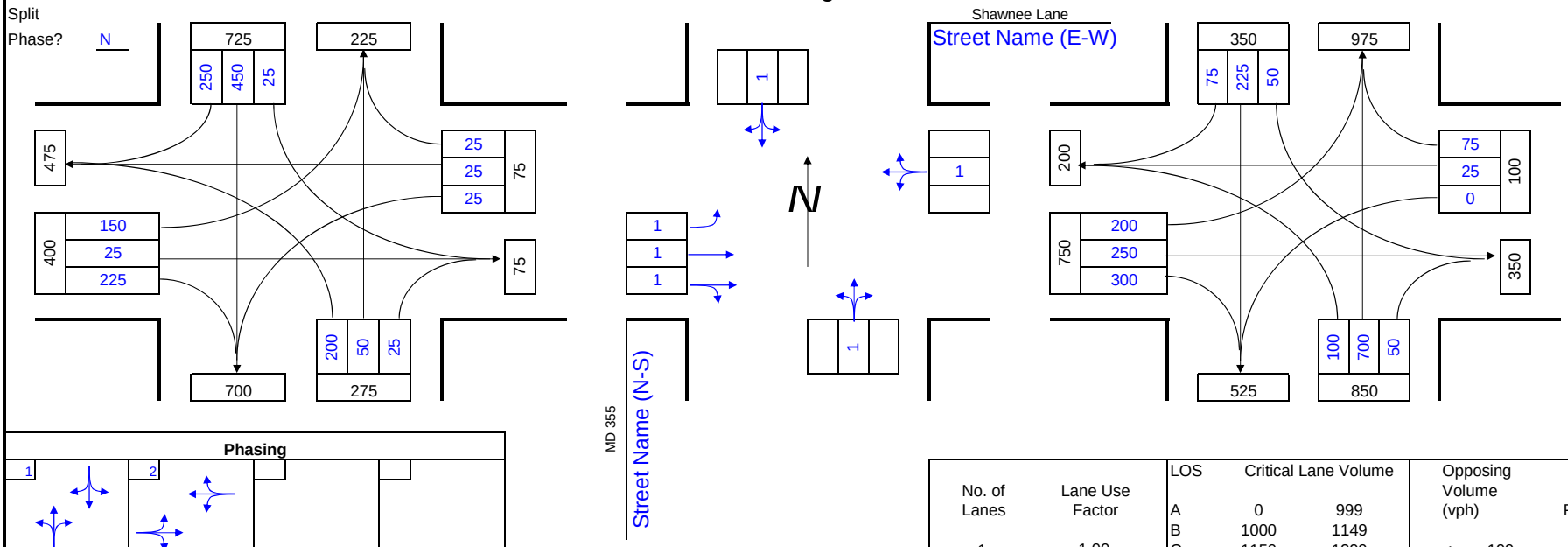
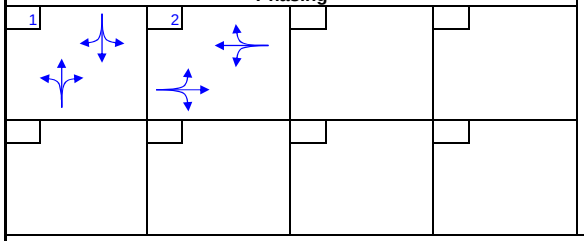
Morning Peak Hour

Lane Configuration

Evening Peak Hour



Phasing



No. of Lanes	Lane Use Factor
1	1.00
2	0.53
3	0.37
4	0.30
Dbl-lft	0.53

LOS	Critical Lane Volume	
A	0	999
B	1000	1149
C	1150	1299
D	1300	1449
E	1450	1600
F	1601	9999

Opposing Volume (vph)	PCE
<= 199	1.1
<= 599	2.0
<= 799	3.0
<= 999	4.0
> 1000	5.0

AM

Phase	Movement	(1) Volume	(2)Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	75	1.00	75	25	1.00	25	100	
1	SB	700	1.00	700	200	1.00	200	900	C
2	EB	250	0.53	133	150	1.00	150	283	C
2	WB	50	1.00	50	25	1.00	25	75	

C: Critical Volume

Total	1183
V/C	0.74
LOS	C

PM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	750	1.00	750	50	1.00	50	800	C
1	SB	300	1.00	300	100	1.00	100	400	
2	EB	550	0.53	292	0	1.00	0	292	
2	WB	100	1.00	100	200	1.00	200	300	C

C: Critical Volume

Total	1100
V/C	0.69
LOS	B

Critical Lane Volume
Level of Service Worksheet

Intersection	MD 355 & Stringtown Road
Major Approach:	MD 355
Minor Approach:	Stringtown Road
County/State:	Montgomery County/Maryland
Scenario:	2040 HI No-Build
Analyst:	DSG/VHB

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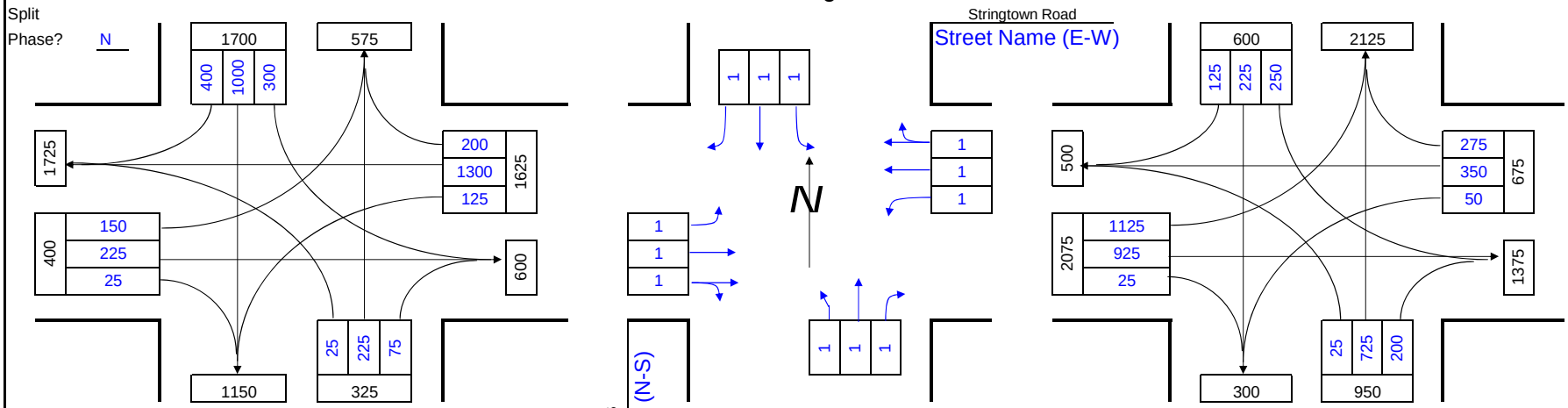
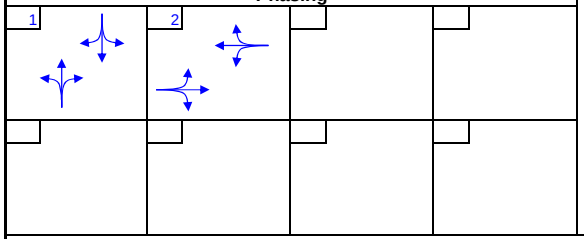
Morning Peak Hour

Lane Configuration

Evening Peak Hour



Phasing



No. of Lanes	Lane Use Factor
1	1.00
2	0.53
3	0.37
4	0.30
Dbl-lft	0.53

LOS	Critical Lane Volume	
A	0	999
B	1000	1149
C	1150	1299
D	1300	1449
E	1450	1600
F	1601	9999

Opposing Volume (vph)	PCE
<= 199	1.1
<= 599	2.0
<= 799	3.0
<= 999	4.0
> 1000	5.0

AM

Phase	Movement	(1) Volume	(2)Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	225	1.00	225	300	1.00	300	525	
1	SB	1000	1.00	1000	25	1.00	25	1025	C
2	EB	250	0.53	133	125	1.00	125	258	
2	WB	1500	0.53	795	150	1.00	150	945	C
C: Critical Volume							Total	1970	
							V/C	1.23	
							LOS	F	

PM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	725	1.00	725	250	1.00	250	975	C
1	SB	225	1.00	225	25	1.00	25	250	
2	EB	950	0.53	504	50	1.00	50	554	
2	WB	625	0.53	331	1125	1.00	1125	1456	C
C: Critical Volume							Total	2431	
							V/C	1.52	
							LOS	F	

Critical Lane Volume
Level of Service Worksheet

Intersection	Gateway Center Dr & Stringtown Road
Major Approach:	Gateway Center Dr
Minor Approach:	Stringtown Road
County/State:	Montgomery County/Maryland
Scenario:	2040 HI No-Build
Analyst:	DSG/VHB

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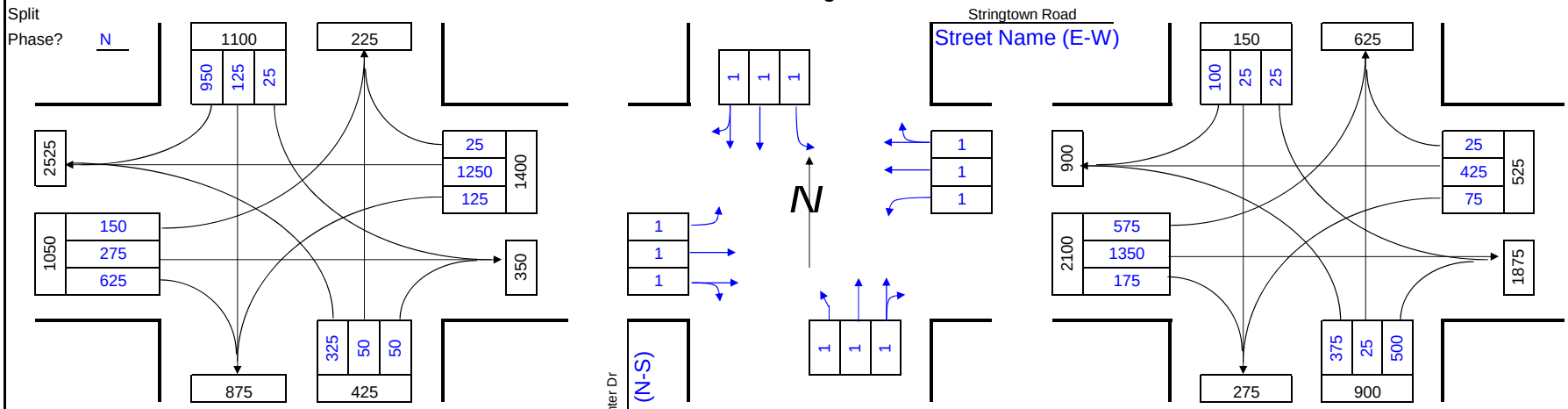
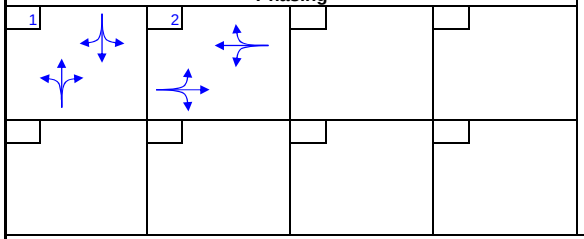
Morning Peak Hour

Lane Configuration

Evening Peak Hour



Phasing



No. of Lanes	Lane Use Factor
1	1.00
2	0.53
3	0.37
4	0.30
Dbl-lft	0.53

LOS	Critical Lane Volume	
A	0	999
B	1000	1149
C	1150	1299
D	1300	1449
E	1450	1600
F	1601	9999

Opposing Volume (vph)	PCE
<= 199	1.1
<= 599	2.0
<= 799	3.0
<= 999	4.0
> 1000	5.0

AM

Phase	Movement	(1) Volume	(2)Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	100	0.53	53	25	1.00	25	78	
1	SB	1075	0.53	570	325	1.00	325	895	C
2	EB	900	0.53	477	125	1.00	125	602	
2	WB	1275	0.53	676	150	1.00	150	826	C

C: Critical Volume — Total 1721; V/C 1.08; LOS F

PM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	525	0.53	278	25	1.00	25	303	
1	SB	125	0.53	66	375	1.00	375	441	C
2	EB	1525	0.53	808	75	1.00	75	883	C
2	WB	450	0.53	239	575	1.00	575	814	

C: Critical Volume — Total 1325; V/C 0.83; LOS D

Critical Lane Volume
Level of Service Worksheet

Intersection	MD 355 & MD 121
Major Approach:	MD 355
Minor Approach:	Clarksburg Road (MD 121)
County/State:	Montgomery County/Maryland
Scenario:	2040 No-Build Mitigation
Analyst:	DSG/VHB

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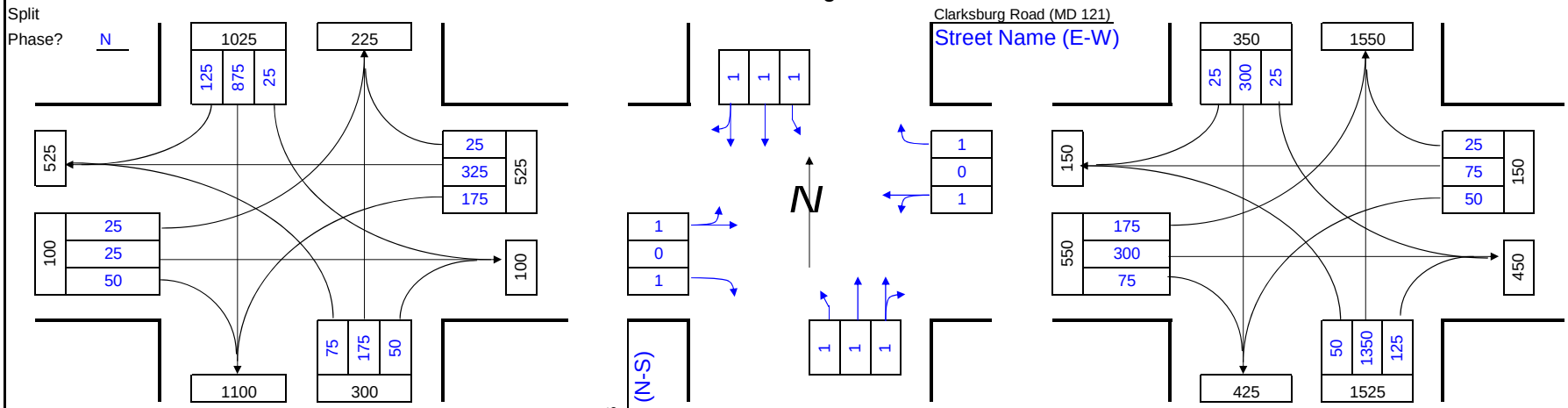
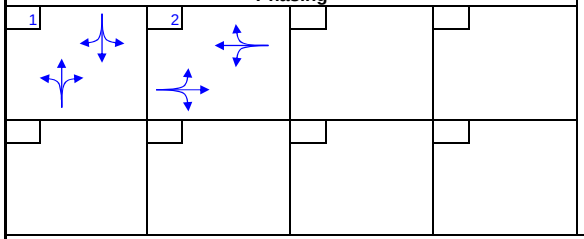
Morning Peak Hour

Lane Configuration

Evening Peak Hour



Phasing



No. of Lanes	Lane Use Factor
1	1.00
2	0.53
3	0.37
4	0.30
Dbl-lft	0.53

LOS	Critical Lane Volume	
A	0	999
B	1000	1149
C	1150	1299
D	1300	1449
E	1450	1600
F	1601	9999

Opposing Volume (vph)	PCE
<= 199	1.1
<= 599	2.0
<= 799	3.0
<= 999	4.0
> 1000	5.0

AM

Phase	Movement	(1) Volume	(2)Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	225	0.53	119	25	1.00	25	144	
1	SB	1000	0.53	530	75	1.00	75	605	C
2	EB	325	1.00	325	25	1.00	25	350	C
2	WB	25	1.00	25	175	1.00	175	200	

C: Critical Volume — Total 955; V/C 0.60; LOS A

PM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	1475	0.53	782	25	1.00	25	807	C
1	SB	325	0.53	172	50	1.00	50	222	
2	EB	300	1.00	300	50	1.00	50	350	C
2	WB	75	1.00	75	175	1.00	175	250	

C: Critical Volume — Total 1157; V/C 0.72; LOS C

Critical Lane Volume
Level of Service Worksheet

Intersection	MD 355 & MD 121
Major Approach:	MD 355
Minor Approach:	Clarksburg Road (MD 121)
County/State:	Montgomery County/Maryland
Scenario:	2040 HI No-Build Mitigation
Analyst:	DSG/VHB

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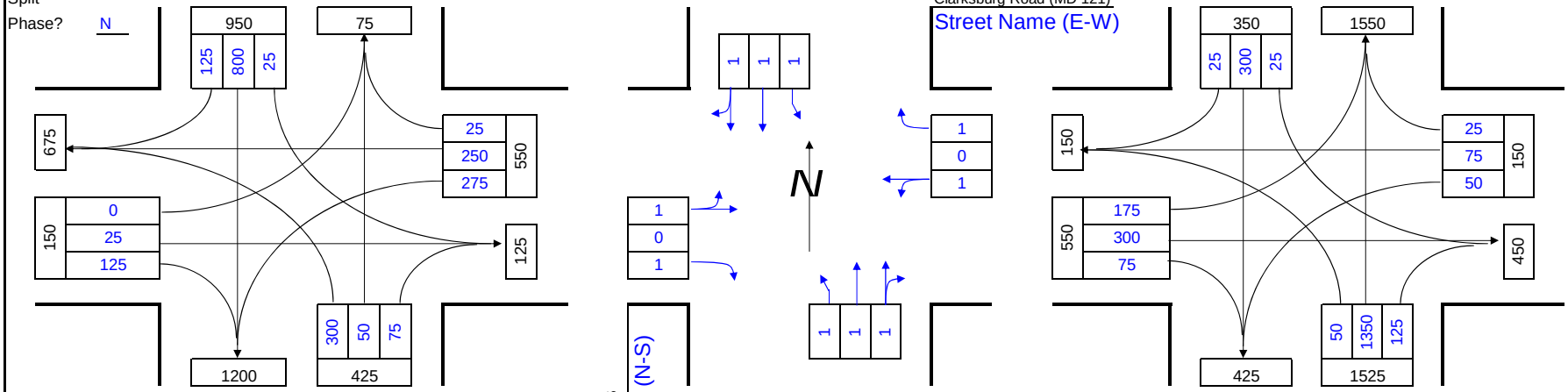
Morning Peak Hour

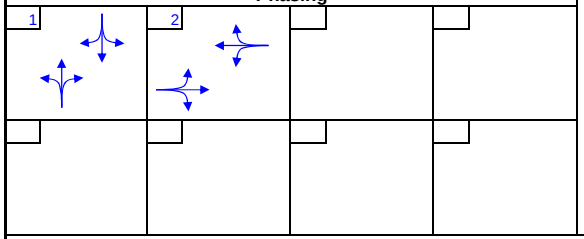
Lane Configuration

Evening Peak Hour

Split Phase? N



Phasing



No. of Lanes	Lane Use Factor
1	1.00
2	0.53
3	0.37
4	0.30
Dbl-lft	0.53

LOS	Critical Lane Volume	
A	0	999
B	1000	1149
C	1150	1299
D	1300	1449
E	1450	1600
F	1601	9999

Opposing Volume (vph)	PCE
<= 199	1.1
<= 599	2.0
<= 799	3.0
<= 999	4.0
> 1000	5.0

AM

Phase	Movement	(1) Volume	(2)Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	125	0.53	66	25	1.00	25	91	
1	SB	925	0.53	490	300	1.00	300	790	C
2	EB	250	1.00	250	0	1.00	0	250	
2	WB	25	1.00	25	275	1.00	275	300	C

C: Critical Volume — Total 1090; V/C 0.68; LOS B

PM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	1475	0.53	782	25	1.00	25	807	C
1	SB	325	0.53	172	50	1.00	50	222	
2	EB	300	1.00	300	50	1.00	50	350	C
2	WB	75	1.00	75	175	1.00	175	250	

C: Critical Volume — Total 1157; V/C 0.72; LOS C

Critical Lane Volume
Level of Service Worksheet

Intersection	MD 355 & Stringtown Road
Major Approach:	MD 355
Minor Approach:	Stringtown Road
County/State:	Montgomery County/Maryland
Scenario:	2040 HI No-Build Mitigation
Analyst:	DSG/VHB

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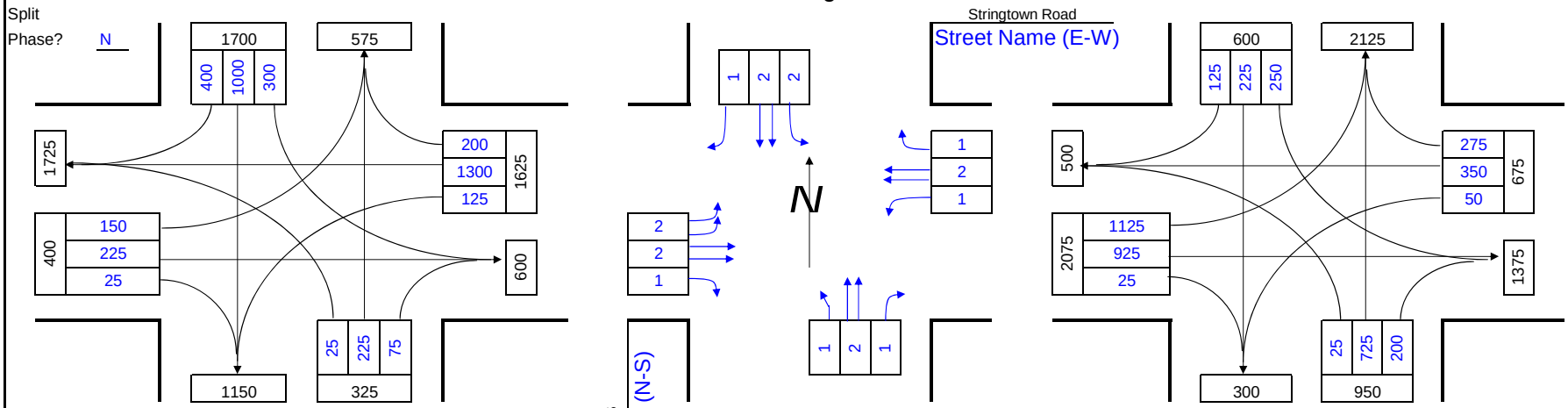
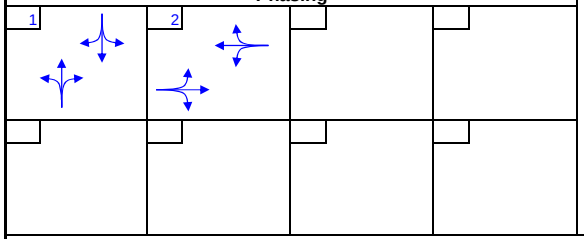
Morning Peak Hour

Lane Configuration

Evening Peak Hour



Phasing



No. of Lanes	Lane Use Factor
1	1.00
2	0.53
3	0.37
4	0.30
Dbl-lft	0.53

LOS	Critical Lane Volume	
A	0	999
B	1000	1149
C	1150	1299
D	1300	1449
E	1450	1600
F	1601	9999

Opposing Volume (vph)	PCE
<= 199	1.1
<= 599	2.0
<= 799	3.0
<= 999	4.0
> 1000	5.0

AM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	225	0.53	119	300	1.00	300	419	
1	SB	1000	0.53	530	25	1.00	25	555	C
2	EB	225	0.53	119	125	1.00	125	244	
2	WB	1300	0.53	689	150	1.00	150	839	C
C: Critical Volume						Total		1394	
						V/C		0.87	
						LOS		D	

PM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	725	0.53	384	250	1.00	250	634	C
1	SB	225	0.53	119	25	1.00	25	144	
2	EB	925	0.53	490	50	1.00	50	540	
2	WB	350	0.53	186	1125	0.53	596	782	C
C: Critical Volume						Total		1416	
						V/C		0.89	
						LOS		D	

Critical Lane Volume
Level of Service Worksheet

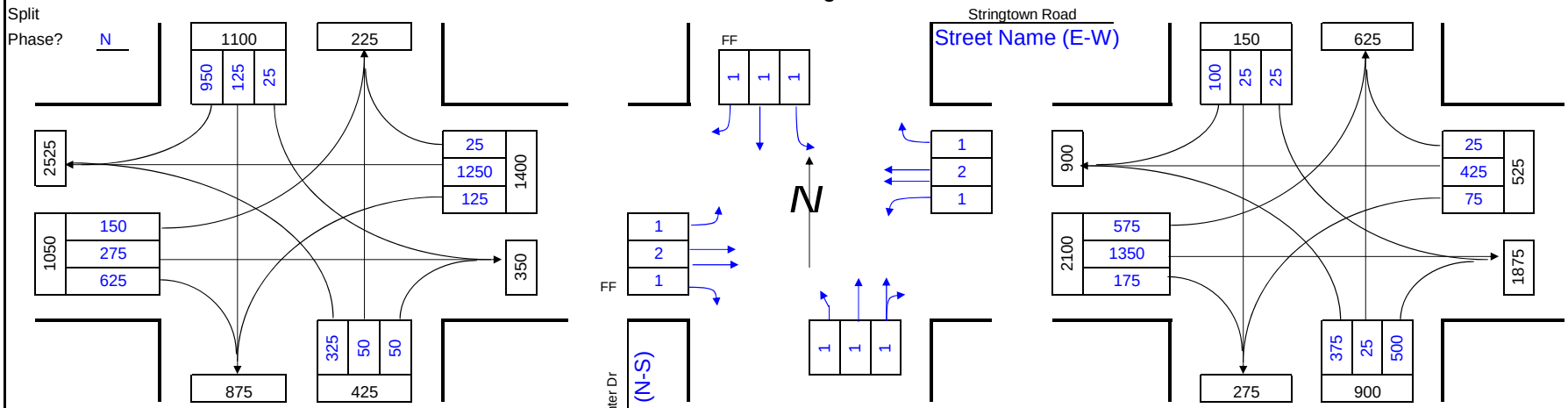
Intersection	Gateway Center Dr & Stringtown Road
Major Approach:	Gateway Center Dr
Minor Approach:	Stringtown Road
County/State:	Montgomery County/Maryland
Scenario:	2040 HI No-Build Mitigation
Analyst:	DSG/VHB

VHB Vanasse Hangen Brustlin, Inc.
8300 Boone Blvd, Suite 700
Vienna, Virginia 22182
Telephone 703.841.3071

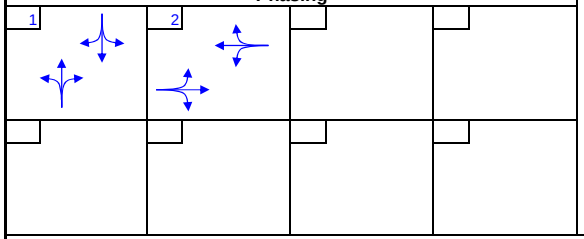
Morning Peak Hour

Lane Configuration

Evening Peak Hour



Phasing



No. of Lanes	Lane Use Factor
1	1.00
2	0.53
3	0.37
4	0.30
Dbl-lft	0.53

LOS	Critical Lane Volume	
A	0	999
B	1000	1149
C	1150	1299
D	1300	1449
E	1450	1600
F	1601	9999

Opposing Volume (vph)	PCE
<= 199	1.1
<= 599	2.0
<= 799	3.0
<= 999	4.0
> 1000	5.0

AM

Phase	Movement	(1) Volume	(2)Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	100	0.53	53	25	1.00	25	78	
1	SB	125	0.53	66	325	1.00	325	391	C
2	EB	275	0.53	146	125	1.00	125	271	
2	WB	1250	0.53	663	150	1.00	150	813	C

C: Critical Volume — Total 1204; V/C 0.75; LOS C

PM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	525	0.53	278	25	1.00	25	303	
1	SB	25	0.53	13	375	1.00	375	388	C
2	EB	1350	0.53	716	75	1.00	75	791	
2	WB	450	0.53	239	575	1.00	575	814	C

C: Critical Volume — Total 1202; V/C 0.75; LOS C

Critical Lane Volume
Level of Service Worksheet

Intersection	MD 355 & MD 121
Major Approach:	MD 355
Minor Approach:	Clarksburg Road (MD 121)
County/State:	Montgomery County/Maryland
Scenario:	2040 Build Mitigation
Analyst:	DSG/VHB

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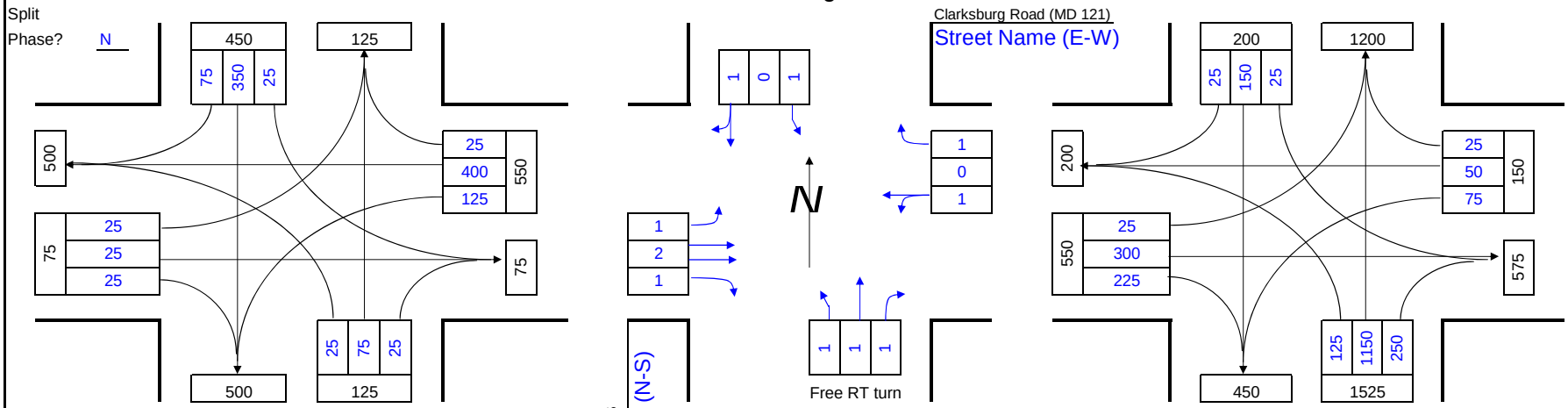
Vienna, Virginia 22182
Telephone 703.841.3071

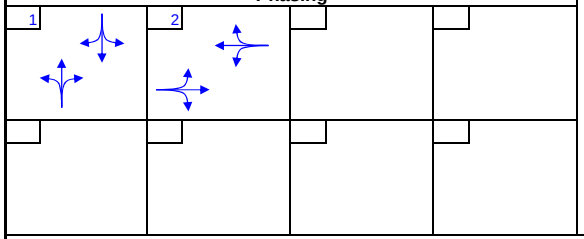
Morning Peak Hour

Lane Configuration

Evening Peak Hour



Phasing



No. of Lanes	Lane Use Factor
1	1.00
2	0.53
3	0.37
4	0.30
Dbl-lft	0.53

LOS	Critical Lane Volume	
A	0	999
B	1000	1149
C	1150	1299
D	1300	1449
E	1450	1600
F	1601	9999

Opposing Volume (vph)	PCE
<= 199	1.1
<= 599	2.0
<= 799	3.0
<= 999	4.0
> 1000	5.0

AM

Phase	Movement	(1) Volume	(2)Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	100	1.00	100	25	1.00	25	125	
1	SB	425	1.00	425	25	1.00	25	450	C
2	EB	400	1.00	400	25	1.00	25	425	C
2	WB	25	1.00	25	125	1.00	125	150	

C: Critical Volume — Total 875; V/C 0.55; LOS A

PM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	1150	1.00	1150	25	1.00	25	1175	C
1	SB	175	1.00	175	125	1.00	125	300	
2	EB	300	0.53	159	75	1.00	75	234	C
2	WB	50	1.00	50	25	1.00	25	75	

C: Critical Volume — Total 1409; V/C 0.88; LOS D

Critical Lane Volume
Level of Service Worksheet

Intersection	New Road & Stringtown Road
Major Approach:	New Road
Minor Approach:	Stringtown Road
County/State:	Montgomery County/Maryland
Scenario:	2040 Build Mitigation
Analyst:	DSG/VHB

VHB Vanasse Hangen Brustlin, Inc.
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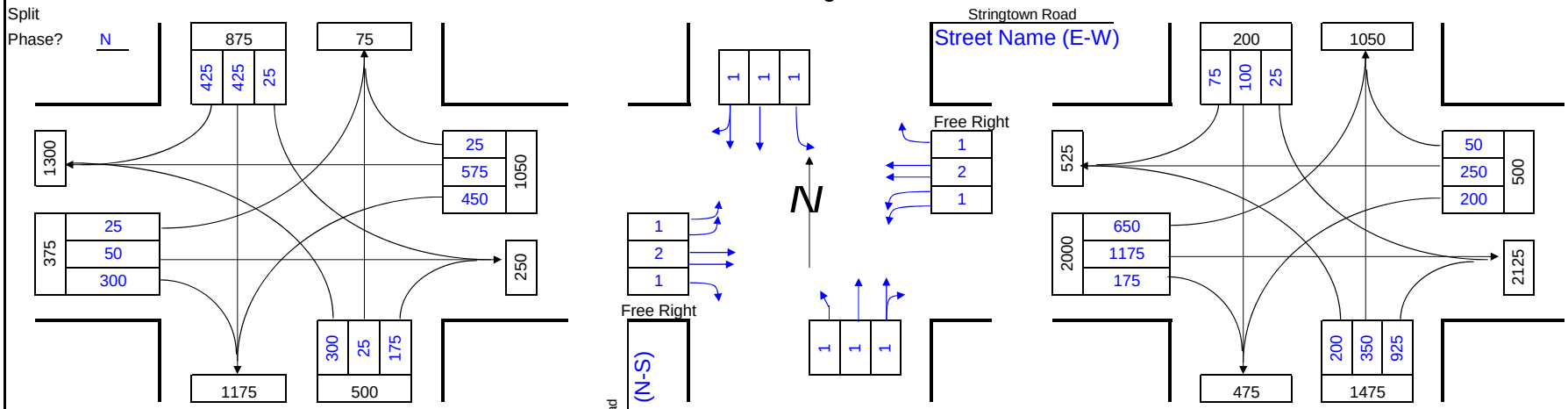
Vienna, Virginia 22182
Telephone 703.841.3071

Morning Peak Hour

Lane Configuration

Evening Peak Hour



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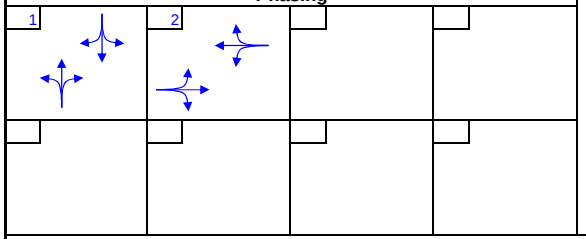


No. of Lanes	Lane Use Factor
1	1.00
2	0.53
3	0.37
4	0.30
Dbl-lft	0.53

LOS	Critical Lane Volume	
A	0	999
B	1000	1149
C	1150	1299
D	1300	1449
E	1450	1600
F	1601	9999

Opposing Volume (vph)	PCE
<= 199	1.1
<= 599	2.0
<= 799	3.0
<= 999	4.0
> 1000	5.0

AM

Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	200	0.53	106	25	1.00	25	131	
1	SB	850	0.53	451	300	1.00	300	751	C
2	EB	350	0.53	186	450	1.00	450	636	C
2	WB	600	0.53	318	25	1.00	25	343	

C: Critical Volume

Total	1386
V/C	0.87
LOS	D

PM

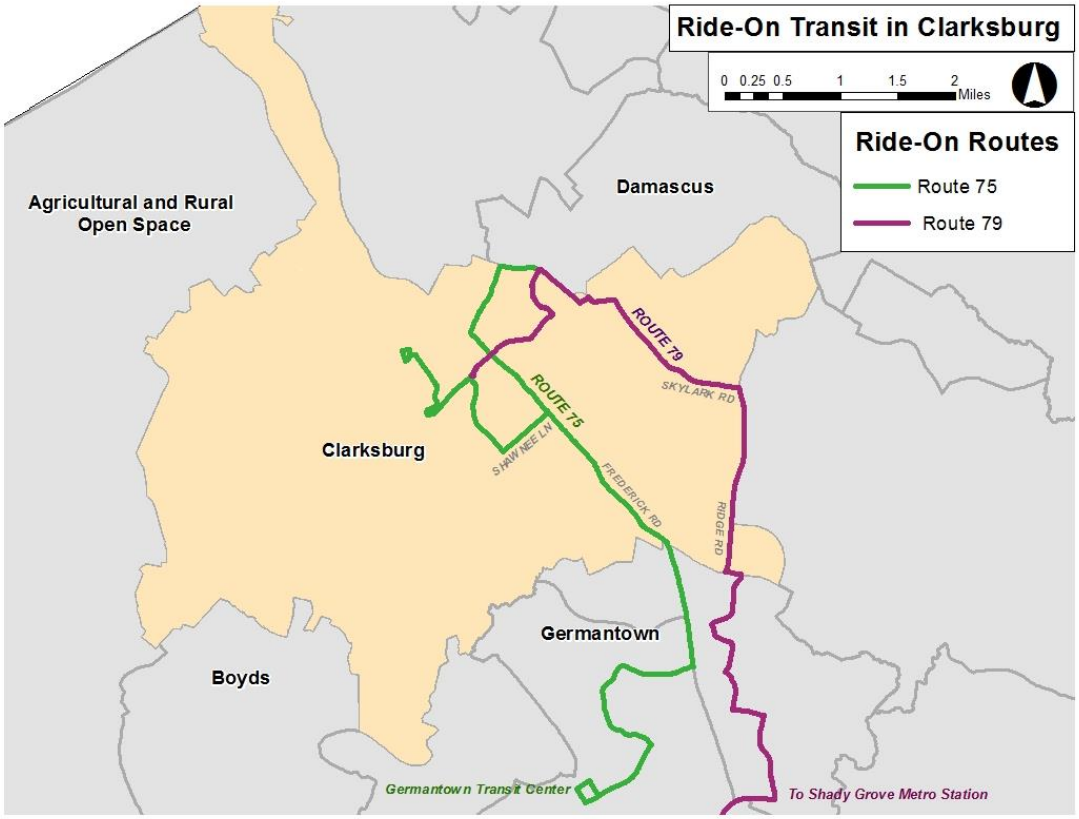
Phase	Movement	(1) Volume	(2) Lane Use Factor	Lane Volume (1) x (2)	(3) Opposing Lefts	(4) Left Turn Lane Use Factor	Lane Volume (3) x (4)	Critical Lane Volume	C
1	NB	1275	0.53	676	25	1.00	25	701	C
1	SB	175	0.53	93	200	1.00	200	293	
2	EB	1175	0.53	623	200	0.53	106	729	C
2	WB	250	0.53	133	650	0.53	345	477	

C: Critical Volume

Total	1430
V/C	0.89
LOS	D

Existing Transit Service

Existing transit service is quite limited as Clarksburg is served by just two Ride-On bus routes (Routes 75 and 79) and no WMATA bus or rail routes. The map below depicts the routes serving Clarksburg:

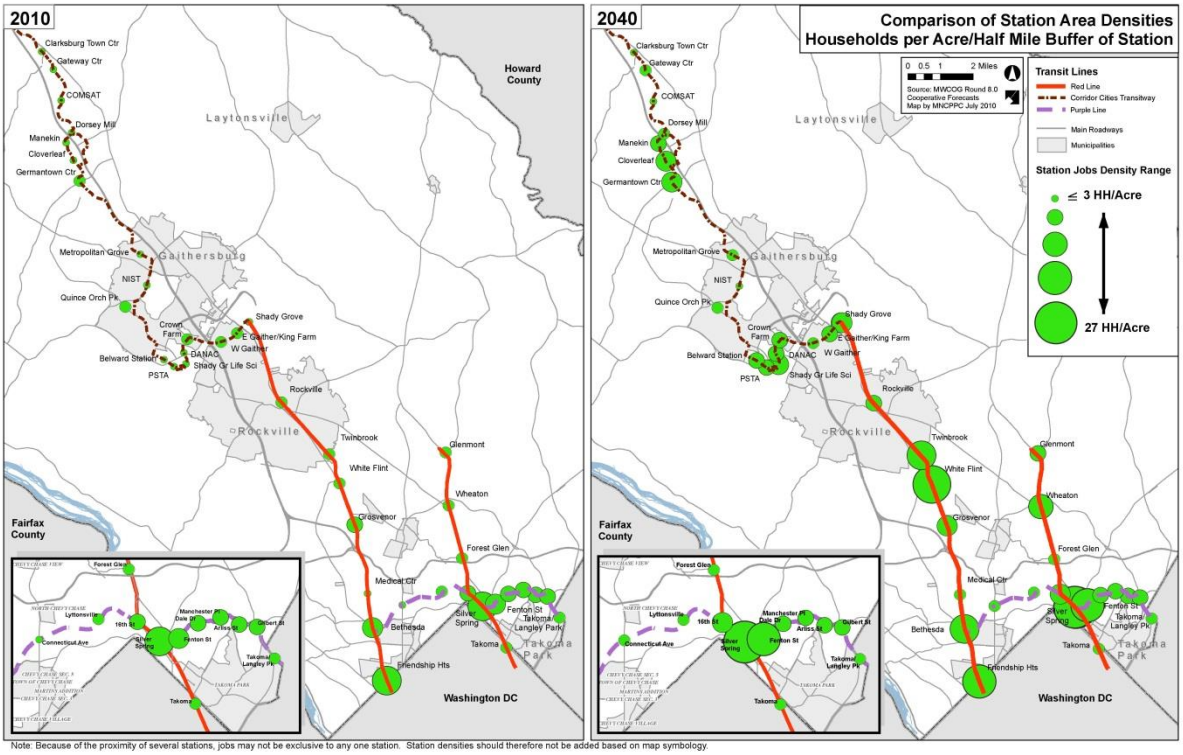


Route 75 runs from the Montgomery County Correctional Facility to Germantown Transit Center via Frederick Road on a 30 minute frequency every weekday. There is no weekend service. Route 79 runs from Gateway Center to Shady Grove Metro Station via Skylark and Ridge Roads on a 30 minute frequency during weekday peak periods. The service is provided in the peak direction only. There is no weekend service.

Analysis of Transit Demand

Planned station area densities north of Father Hurley Boulevard / Ridge Road are generally not at a level considered to be supportive of transit in a dedicated lane (see illustrations below). This is essentially the reason the MTA Corridor Cities Transitway (CCT) concept planning and alternatives analysis work to date assumes a northern terminus at COMSIS where there is a planned park and ride lot. While the year 2040 ridership forecasts developed for the Countywide Transit Corridors Functional Master Plan (CTCFMP) essentially confirmed those earlier findings for this segment the Planning Board Draft CTCFMP does include a recommendation for a MD 355 North Bus Rapid Transit Corridor that would operate in mixed traffic between Milestone and the Clarksburg Town Center Transit Station.

The mean travel time for work trips for Montgomery County residents is about 34 minutes based upon the American Community Survey for the time period 2007-2011. In general, about 40-50 minutes is thought to be the point where travel time begins to influence the selection of the location of the residence and/or job – all other things being equal.



This somewhat theoretical maximum travel time is reflected to some extent in the census data available on weekday residence to work-place county trips (rounded to nearest thousand) for 2006-2010 as noted below.

Residence County to Work Place County Trips 2006 – 2010 – Average Weekday

From/To	Montgomery Co.	D.C.	Prince George's Co.	Arlington Co.	Fairfax Co.
Montgomery Co.	298,000	107,000	29,000	9,000	22,000
Howard Co.	14,000	10,000	14,000	1,000	2,000
Frederick Co.	26,000	4,000	2,000	1,000	3,000
Fairfax Co.	17,000	90,000	10,000	48,200	302,000
Prince George's Co.	44,000	136,000	175,000	16,000	18,000

As noted in the table, travel flows within jurisdictions far exceed flows to adjacent jurisdictions in most instances. Congestion, however, remains an issue (even with the lower volumes) because of the limited

number of corridors available to accommodate the trips between jurisdictions – especially where Metrorail is not available.

The Clarksburg area and its related travel patterns and trip-making are therefore characterized by at least four related conditions in the near and intermediate term (next 10-20 years):

- Residential and employment densities below densities normally thought to be supportive of high quality all day transit service in dedicated lanes
- Travel shed for work trips that extends no more than 40-50 minutes one-way on average for most work trips.
- Limited number of travel corridors with right of way constraints and congested travel conditions.
- Relatively high percentage of peak travel flow in north-south direction.

The origin/destination pairs with highest percentages of an estimated 28,000 work trips originating in Clarksburg and destined for locations in the County, DC, or Frederick County in 2040 – based upon the regional model forecast - include the following:

- Trips to/from City of Gaithersburg – 16%
- Trips Remaining Within Clarksburg – 13%
- Trips to/from Germantown East – 10%
- Trips to/from City of Rockville – 10%
- Trips to/from Germantown West – 8%
- Trips to/from R&D Village – 6%
- Trips to/from DC – 6%
- Trips to/from Frederick County – 6%

The total potential transit market is not large. As an example, a relatively optimistic transit mode share of 15% would translate to 4,200 weekday trips to and from Clarksburg on a typical workday in 2040. A theoretical allocation of those trips to any specific peak hour results in an estimated 300– 500 trips per peak hour - with those trips having dispersed origins and destinations.

These findings suggest that with or without the CCT in Clarksburg Town Center, other components of a (initial) future transit network serving Clarksburg work trips might – at a concept level – consist of the following:

- Peak period frequent (20 minutes or less) express non-stop service from the Clarksburg Town Center to Shady Grove Red Line Metrorail Station via I-270 (estimated 30-35 minute travel time).
- Peak period frequent (20 minutes or less) express non-stop service from the Clarksburg Town Center to Germantown Town Center / Germantown MARC via I-270 (one way travel time an estimated 15-20 minutes).

- Peak period limited stop Ride-On service from the Clarksburg Town Center to Milestone (and ultimate CCT stop) via MD 355 (estimated 15-20 minutes travel time).
- Peak period limited stop Ride-On service from the Clarksburg Town Center to Lakeforest/ Gaithersburg MARC via MD 355 (estimated 30-35 minute travel time).
- Internal Clarksburg circulator service that would connect activity centers east and west of I-270 with the Town Center and the CCT COMSAT station until such time that the CCT was extended to the Town Center. Once the CCT was extended, the need for the circulator service connecting points east and west of I-270 would still likely remain.

The allocation of resources in support of a network similar to the concept described above – given the overall relatively low transit ridership forecast and dispersed trip patterns - is viewed as a better fit for the potential transit market for the foreseeable future. Once the CCT is ultimately extended to the Town Center, the supporting bus network and associated resources would likely be reevaluated. This concept or approach to a developing activity center is similar to what has been successfully implemented by Ride-On in Germantown.

Transportation Policy Area Review Analysis

In support of this Plan, a Countywide Transportation Policy Area Transportation Review (TPAR) analysis was conducted assuming a land use/transportation scenario reflecting the following key elements:

- **Regional Background Conditions:** The year 2040 Round 8.1 Cooperative Forecast is assumed for the region in conjunction with a transportation network generally reflecting the Constrained Long Range Plan. Regional transportation network assumptions also include the extension of HOV lanes on I-270 between MD 121 and MD 15 in Frederick County.

- **Clarksburg Area Conditions:** The proposed "alternative master plan" land use development scenario is assumed within the Ten Mile Creek Area in combination with year 2040 Round 8.1 Cooperative Forecast land use in the remainder of the Clarksburg policy area. The scenario assumed that the employment uses proposed for the Adventist site in Cabin Branch and Miles/Coppala properties located east of I-270 in the vicinity of the Town Center are replaced by retail uses in order to examine worst case traffic conditions. This development scenario is assumed in combination with the adopted Clarksburg Master Plan transportation network.

The results of this analysis are depicted in the graphic shown below as Figure 1. The following notes should be used in support of interpreting the results provided in this graphic:

- The vertical "blue-hatched" bars show the **range** of the average of roadway speeds by direction of travel in relation to the "free flow speed", or LOS, for each Policy Area in the PM peak period.

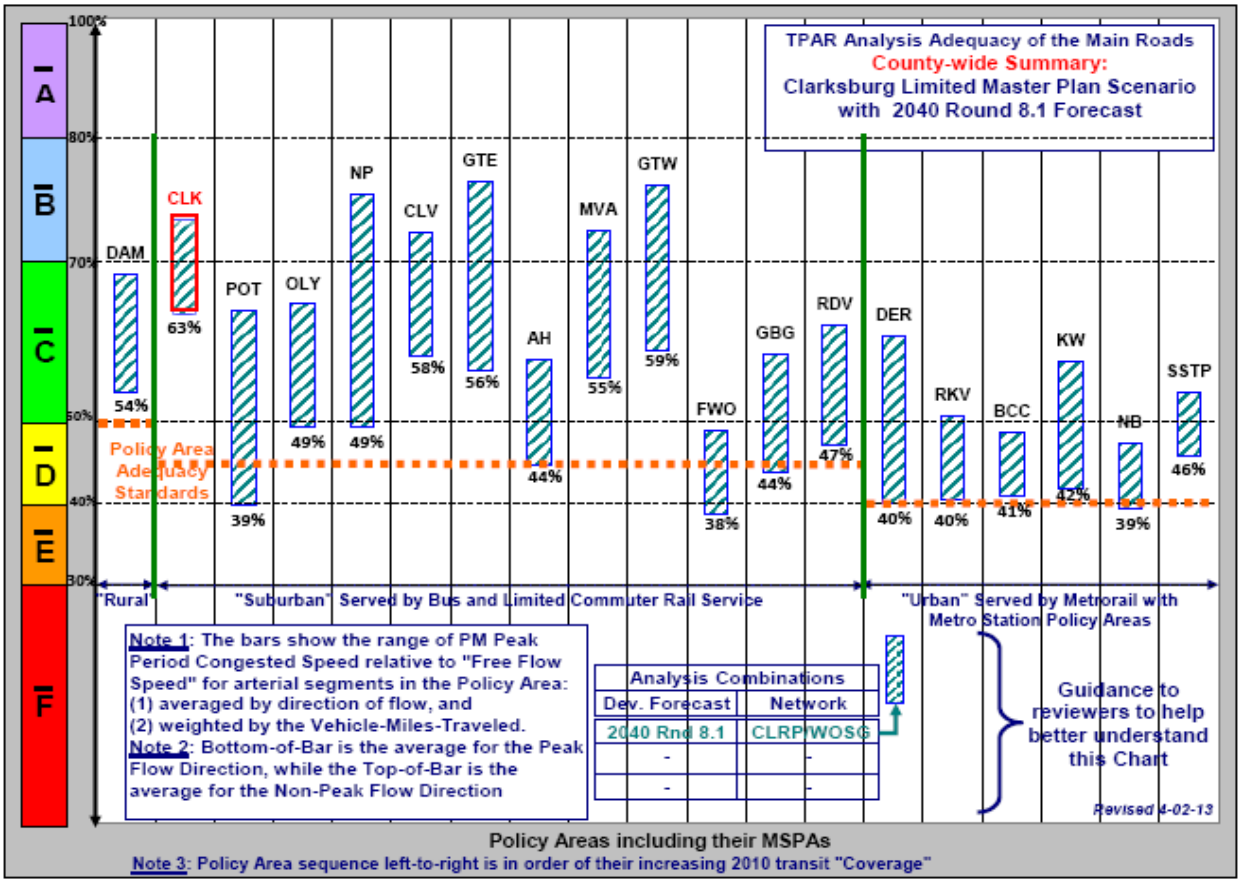
- The bottom of the bar shows the average LOS in the peak direction of travel. The top of the bar shows the average speed (LOS) in the non-peak direction.

- The measurement scale weighted average LOS is shown on the left side of the chart.

- Horizontal dotted orange lines are shown to depict the adequacy standards (LOS) for the Rural, Suburban and Urban (with Metrorail) Policy Areas, from left to right, corresponds to the Standards of Roadway Adequacy as defined the context of TPAR.

The TPAR results depicted in the figure shows that the bottom of the blue-hatched bar for Clarksburg (as noted by the red abbreviation "CLK" and highlighted in the figure below) is projected to achieve a 63% ratio of congested relative to uncongested roadway travel speed. This ratio is well above the 45% policy area standard for suburban policy areas the County as determined by the Subdivision Staging Policy. This result shows that the Clarksburg policy area is forecasted to achieve adequate roadway travel conditions by the year 2040 planning horizon with the proposed alternative master Plan development scenario in the Ten Mile Creek Area.

Figure 1: Year 2040 County-wide TPAR Adequacy Analysis of the Main Roads with the Clarksburg 10 Mile Creek Limited Master Plan Amendment Scenario



For comparison purposes, the summary TPAR results derived from the year 2040 County-wide roadway adequacy analysis performed in support of the 2012- 2016 Subdivision Staging Policy are also provided. These results are depicted in Figure 2 and reflect the build-out of the adopted Clarksburg Master Plan by the year 2040.

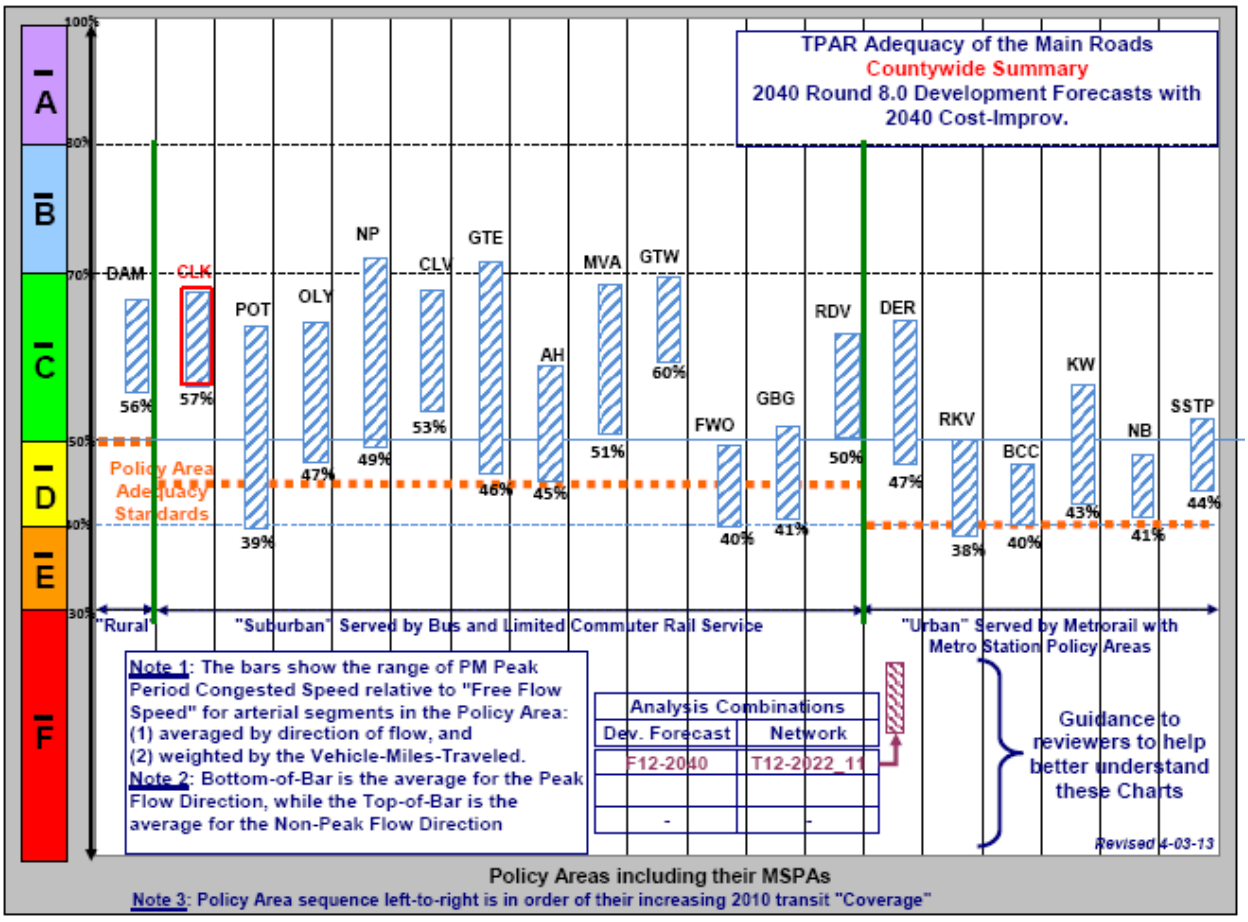
As can be observed, the highlighted results for Clarksburg show that the policy area is projected to achieve a 57% ratio of congested relative to uncongested roadway travel speed. This ratio is well above the 45% policy area standard for suburban policy areas the County as determined by the Subdivision Staging Policy. This result shows that the Clarksburg policy area is forecasted to achieve adequate roadway travel conditions by the year 2040 planning horizon with the land use assumed in the adopted Clarksburg Master Plan.

While the land/use transportation assumptions reflected in Figure 2 are generally comparable to those reflected in Figure 1, there are key differences which particularly impact the TPAR results for Clarksburg, as well as Germantown East. These differences are described below.

- **Demographic Differences:** Figure 1 reflects the year 2040 **Round 8.1** Cooperative Forecast while Figure 2 reflects the year 2040 **Round 8.0** Cooperative Forecast. The year 2040 employment forecast for Frederick County is roughly 35% lower in Round 8.1 relative to Round 8.0. This difference influences the forecast of trip distribution patterns between Frederick County and northern Montgomery County, particularly along the upper I-270 Corridor.

- **Network Differences:** Figure 1 generally reflects the regional Constrained Long Range Plan network, including the full length of Midcounty Highway through Germantown East. Figure 2 reflects those projects needed to achieve TPAR roadway adequacy by 2040 as determined by the TPAR costing analysis performed in support of the 2012-2016 Subdivision Staging Policy. The transportation network assumed in support of the TPAR costing analysis did not reflect the segment Midcounty Highway between Middlebrook Road and Montgomery Village Avenue.

Figure 2: Year 2040 County-wide TPAR Adequacy Analysis of the Main Roads with the Adopted 1994 Clarksburg Master Plan Scenario



Ten Mile Creek Amendment
Appendix 7

Department of Parks Analysis and Recommendations

MONTGOMERY COUNTY DEPARTMENT OF PARKS
MARYLAND-NATIONAL CAPITAL PARK & PLANNING COMMISSION

MEMORANDUM

Date: May 23, 2013

To: Valdis Lazdins, Chief, Area 1
Mary Dolan, Chief, Functional Planning & Policy

Via: Mary Bradford, Director of Parks
Mike Riley, Deputy Director of Administration
John Nissel, Deputy Director of Operations
John Hench, Chief, Park Planning & Stewardship

From: Brenda Sandberg, Legacy Open Space Program Manager
Brooke Farquhar, Master Planner/Supervisor Park and Trail Planning
Jim McMahon, Park Manager, Northern Parks

RE: Park, Trail and Legacy Open Space Recommendations: Clarksburg Limited Master Plan for the Ten Mile Creek Watershed

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Recommendations

The Department of Parks proposes the following recommendations for inclusion in the Clarksburg Limited Master Plan for the Ten Mile Creek Watershed:

Legacy Open Space

- Designate the high quality, critical forest and open habitats that protect the quality of the Ten Mile Creek Headwaters as a Legacy Open Space Natural Resource site (Class II) (Attachment 1).
- Protect the designated Natural Resource on an individual property basis using a variety of tools including easements, dedication through the development review process, and fee simple acquisition.

Park and Trail Recommendations

- Provide a countywide natural surface trail, designed to M-NCPPC Montgomery Parks standards, in the Ten Mile Creek area linking Little Bennett Regional Park and Black Hill Regional Park as per the Countywide Park Trails Plan and the 1994 Clarksburg Master Plan.
- Provide five trailheads, designed to M-NCPPC Montgomery Parks standards, for access to the Ten Mile Creek natural surface trail and nearby natural areas for park users and operations staff.
- Provide a new natural resource-based Neighborhood Park of at least ten acres for close-to-home recreation for the Ten Mile Creek area, designed to M-NCPPC Montgomery Parks standards.

Legacy Open Space Analysis

Existing Legacy Open Space Policy and Site Analysis

The *Legacy Open Space Functional Master Plan* (M-NCPPC, 2001) is designed to protect the best of the best open space resources across the County with a variety of protection tools. The designation of a Legacy Open Space Natural Resource site, as we recommend for the Ten Mile Creek Headwaters, creates a policy rationale for protecting the resource of interest using easement, preservation through development review, and fee simple acquisition into conservation parkland. For this recommended Natural Resource site in the headwaters of the Ten Mile Creek Watershed, Parks recommends using a combination of tools on the varying properties with the Natural Resource designation to protect the forest and watershed.

Background

- Ten Mile Creek watershed was included in Appendix D of the County Council-approved and adopted *Legacy Open Space Functional Master Plan* (M-NCPPC, 2001) as a potential Natural Resource site that needs further evaluation (a Class III site).

- The LOS Master Plan already notes that the area "meets [the] criteria" to be a Natural Resource site, but needs evaluation to determine specific areas to include in the LOS designation.

- The Ten Mile Creek watershed includes over 600 acres of contiguous forest, predominantly a dry and mesic forest on acidic bedrock, comprising mature mixed oak hickory forest predating the 1950s. The geographic positioning of this large forest complex in the headwaters of Ten Mile Creek is an essential reason why documented water quality within Ten Mile Creek is Good to Excellent (*Montgomery County Countywide Stream Protection Strategy*, MCDEP, 2010).

- The large headwater forest area includes large areas of interior forest and has a documented high probability for Forest Interior Dwelling Species (FIDS). Further study is needed to evaluate whether the site may harbor Rare, Threatened or Endangered and Watch-listed plant and animal species (RTES).

- The Ten Mile Creek headwaters forest is one of the few remaining large high quality forest areas not currently afforded protection through easement or public ownership as a Stream Valley or Conservation Park in Montgomery County.

Legacy Criteria Analysis

The Legacy criteria from the Functional Master Plan (p. 17) are listed below. The Ten Mile Creek Headwaters meets six of the eight overall criteria (identified with underlining below), making it a strong candidate for designation under the program.

1. The Resource has particular countywide, regional, or national significance in terms of (a) known or potential habitats for rare, threatened, or endangered species; (b) a "best example" of terrestrial or aquatic community; (c) unique or unusual ecological communities; (d) large, diverse areas with a variety of habitats; or (e) exceptional viewscapes, architectural character, or historic association.

2. The Resource is critical to the successful implementation of public policy such as the protection of the Agricultural Reserve and public water supply.

3. The Resource is part of a "critical mass" of like resources that perform an important environmental or heritage function.

4. The Resource makes a significant contribution to one or more heritage themes.

5. The Resource provides human or ecological connectivity between significant park, natural or historic areas and/or corridors.

6. The Resource helps to buffer and thereby protect other significant resources.

7. The Resource represents an opportunity for broadening interpretation and public understanding of natural and heritage resources.

8. The Resource provides a significant opportunity (a) to increase access to public open space in communities with high population densities, (b) to protect scarce open space in an urbanized community, (c) to improve the character of a green boulevard of countywide or regional significance, or (d) to provide for a new regional park facility.

Analysis of the Ten Mile Creek Headwaters by the specific LOS Natural Resource criteria concludes that:

- The Ten Mile Creek Headwaters is of countywide significance due to:
    - Having high potential to include habitats for rare, threatened, or endangered species in the large areas of undisturbed, high quality forest;
    - Being a "best example" of an aquatic community as documented in the Countywide Stream Protection Strategy and other County research;
    - Including large, diverse areas with a variety of habitats to support biodiversity on land and in the aquatic habitat

- The Ten Mile Creek Headwaters is critical to the successful implementation of public policy, specifically the protection of public water supply in Little Seneca Lake downstream from the headwaters.

- The Ten Mile Creek Headwaters is part of a "critical mass" of like resources across several watersheds that perform an important environmental function – the protection of the high quality aquatic resources in the Ten Mile Creek watershed that drains to a water supply reservoir, Little Seneca Lake.

- The Ten Mile Creek Headwaters provides ecological connectivity between significant natural areas in Bucklodge Forest Conservation Park, Little Bennett Regional Park and Black Hill Regional Park.

- The Ten Mile Creek Headwaters resource helps to buffer and thereby protect other significant resources in the Ten Mile Creek watershed.

In summary, the Ten Mile Creek Headwaters site is a large area of contiguous, high quality forest that protects a significant, high quality watershed, factors that combine to make this an important Natural Resource to the County and one that should clearly be added to the Legacy Open Space program for protection.

Legacy Open Space Recommendations

- *Designate the high quality, critical forest and open habitats that protect the quality of the Ten Mile Creek Headwaters as a Legacy Open Space Natural Resource site (Class II) (Attachment 1).*

    - Staff proposes a Natural Resource designation area that covers approximately 1230 acres within the Limited Master Plan boundary. For comparison, the proposed parkland combined with "private conservation areas" designated for protection in the 1994 Clarksburg Master Plan cover approximately 1340 acres

    - Attachment 1 *(1994 Clarksburg MP Conservation Areas and Proposed Legacy Open Space Natural Resource)* illustrates the proposed Ten Mile Creek Headwaters Natural Resource with an overlay of the 1994 Clarksburg Master Plan Conservation Areas.

        - The indicated Conservation Areas (black cross hatch) include both the "Proposed Parkland" and "Private Conservation Areas" from the 1994 Plan since Parks has decided to exercise the option in the 1994 Plan to require conveyance of all conservation areas as parkland during development (as submitted in comments on the pending pre-application).
        - Some developable areas in the 1994 Plan are being recommended for conservation in this LOS proposal, but some of the 1994 Conservation Areas are being excluded from the Legacy proposal to allow for development. The 1994 Conservation Areas that are being excluded from the proposed Natural Resource are based on detailed environmental analysis conducted by the Planning Department that has identified a proposed development envelope close to Clarksburg Road.

    - Attachment 2 (*Proposed Legacy Open Space Natural Resource, Parks and Trails*) indicates the Natural Resource designation area as the proposed future Ten Mile Creek Conservation Park in relation to the proposed natural surface trail corridor, future neighborhood park (see Park and Trail recommendations below), and the Planning Department's proposed development envelope.

- *Protect the designated Natural Resource on an individual property basis using a variety of tools including easements, dedication through the development review process, and fee simple acquisition. Individual property implementation recommendations are as follows:*

    - **Mattlyn Enterprises, LLC** – Pursue resource protection through acquisition.

    - **Montgomery County parcels** – For County-owned parcels outside the proposed development boundary and not already part of the park system, coordinate with County to transfer key resource areas to Park management.

    - **Clarkwood LC** – Pursue resource protection through acquisition.

    - **Shiloh Farm Investments/John King Jr. properties (Pulte Homes)** –

        - Seek conveyance of identified Natural Resource site outside of the proposed development boundary as the core of the Ten Mile Creek Conservation Park.
        - During development design, ensure that proposed homes fronting mature forest within the LOS Natural Resource site are set back from the forest edge a minimum of 150 feet to minimize edge impact and to reduce the potential for hazardous trees impacts associated

with improved property, according to American Society of Arboriculture recommended setbacks. Adequate access for park maintenance throughout the developed area and along the parkland border should be accommodated as part of this setback.

- Within the Pulte-controlled properties, the proposed LOS Natural Resource covers 352 acres, about 42 acres more than the area shown as Conservation Areas in the 1994 Clarksburg Plan (310 acres).

- **Hancock property** – Seek acquisition of this inholding within the Shiloh Farm Investments portion of the Natural Resource site.
- **Maryland Environmental Trust parcels** – Seek acquisition of these parcels in ownership of MET.
- **Betty Casey Trust** – Protect natural resources and preserve active agriculture at time of subdivision or sale through a combination of easement, reforestation of stream valleys, and/or park acquisition.
- **Rable property** – Pursue resource protection through acquisition.
- **Mease and Beck properties** – Pursue partial acquisition to preserve key resources along two main branches of Ten Mile Creek while preserving open agricultural land.
- **All other properties** – Seek to protect resources on these smaller properties using full variety of tools, such as easements, partial acquisition, or full acquisition, as opportunities arise over time.

Park and Trail Analysis

Policy Background

Clarksburg Master Plan and Hyattstown Special Study Area, adopted June 1994

The *1994 Clarksburg Master Plan and Hyattstown Special Study Area* ("1994 Plan") recommended several parks, trails and greenways for the entire area, with a key "goal to link all parkland via a greenway network" (p.159). The proposed park system was envisioned to provide a range of park and recreation services, from countywide to community use facilities. Over several hundred acres of greenways wide enough to "allow development of a trail system", further development of the two regional parks (Little Bennett and Black Hill), two recreational parks (Ovid Hazen Wells and Damascus), a special park (Clarksburg Road, renamed Linthicum Recreational Park), and five local parks were recommended. In addition to the above parks, the 1994 Plan advocated for neighborhood recreation areas, stating that "each new residential development in a neighborhood should provide adequate private open space and recreational facilities for its residents to enjoy non-structured recreation" (p. 162).

Many of the new and future parks are located on the east side of I-270 in areas of the greatest density of development. The Master Plan areas on the west side of I-270 include the Ten Mile Creek Area and the Cabin Branch Neighborhood. In the Cabin Branch area, the 1994 Plan proposed the local park now named Cabin Branch and a special park now named Linthicum Recreational Park. In the Ten Mile Creek area, the 1994 Plan proposed an interconnected greenway with a major natural surface trail forming the link between the two regional parks in the area, Little Bennett and Black Hill. No other public parks were proposed in the 1994 Plan for the Ten Mile Creek area since the Planning Board's Draft recommended only 100 dwelling units on large lots

and thus envisioned no need for more close-to-home park facilities. When the density was increased to 900 dwelling units by Council, there was insufficient time to re-examine park needs in the area.

Issues and Opportunities

To determine issues, opportunities, and preliminary recommendations the Department of Parks re-examined the 1994 Plan recommendations, as well as park and trail planning guidance for natural-resource based recreation and facility-based recreation needs, including the 1998 *Countywide Park Trails Plan*, the 2010 *Vision 2030 Strategic Plan*, the *2012 Park, Recreation, and Open Space (PROS) Plan*, and the *2005 PROS Plan*.

Clarksburg Master Plan

The 1994 Plan generally laid out a well-distributed system of park platforms and trails to serve densities and land uses in Clarksburg. Due to its proximity to local parks, recreational parks, and regional parks, the Ten Mile Creek area is well served nearby by drive-to facilities such as athletic fields, picnic areas, courts and playgrounds. Every residence in the Ten Mile Creek Area will be within a mile of future adult rectangular fields, playgrounds, and basketball courts, as well as hard surface and natural surface trails at Clarksburg Local Park, Linthicum Recreational Park, and Clarksburg Elementary School.

The addition of significant potential density in Ten Mile Creek area at the time of Council approval raises concern as to whether sufficient neighborhood park and recreation amenities were recommended in 1994. If the Limited Master Plan under review now continues to recommend these densities, an important issue will be how to achieve an adequate supply of close-to-home park facilities typically found in a neighborhood park.

Natural Resource-based Recreation: Natural Areas and Trails

Recommendations for the Ten Mile Creek Area in the 1994 Plan focused on the importance of conservation and stewardship in the Ten Mile Creek Area. The character of the land presents both an issue and an opportunity. With its steep wooded stream valleys and high knolls and ridges, some of them with views into the forest, the area lends itself to natural resource-based recreation, accessed by trails within the proposed park system.

Countywide Park Trails Plan

The *1998 Countywide Park Trails Plan (CWPTP)* (updated in 2008) recommended a major regional natural surface trail along the east side of the Ten Mile Creek to connect Black Hill Regional Park with Little Bennett Regional Park. The Preliminary Service Delivery Recommendations of the *CWPTP Amendment* reconfirmed this segment of trail as a critical route in the County's regional trail system, and recognized its importance as part of the MoCo Epic route. To support the trail and public and maintenance access to it, trailheads, road crossings, bridges, and maintenance access will need to be appropriately sited.

Vision 2030 and 2012 Park, Recreation, and Open Space (PROS) Plan

In the *Vision 2030* survey, Natural Areas and Trails used to access them were rated as the top two most important park and recreation components. The *2012 PROS Plan* showcases how Natural Areas are important not only for conservation of ecosystems, but for a form of recreation referred to as natural resource-based recreation. Natural resource-based recreation is defined in *PROS* as:

> *…any leisure activity conducted outdoors that is dependent on a particular element or combination of elements in the natural environment. These elements cannot be easily duplicated by human effort. In contrast, facility-based recreation (any leisure activity dependent on a built facility) can generally be provided anywhere, assuming the availability of space and funds for development. Natural resource-based*

recreation includes a vast range of pursuits including bicycling, hiking, running, and horseback riding on trails, bird watching, nature photography, wildlife viewing, and fishing….

The *2012 PROS Plan* explains the importance of Natural Areas and Trails to access them to existing and future populations:

Quality of life in Montgomery County is significantly enhanced when adults have easy access to natural areas where they can de-stress and unplug from fast-paced lives. As our population grows older, the importance of access to natural areas increases. In addition, natural resource-based recreation forms the backbone of the meaningful experiences children and youth have in nature outside of school….

Finally, the *2012 PROS Plan* describes the type of parkland needed to support natural resource-based recreation:

Natural resource-based recreation requires land and resource preservation far beyond the actual space for trails, wildlife viewing and other activities. Water quality capable of sustaining a diversity of fish and amphibian species, forests large enough to harbor forest interior dwelling birds, geological and soil conditions diverse enough to provide habitat for rare, threatened and endangered species - all are dependent on large tracts of land. The best resources will attract the greater numbers of visitors and the quality of a natural recreational experience is directly related to the quality of the environment within which the activity is taking place. High quality natural environments are characterized by a diversity of animals and plants, an absence of invasive plants, a general absence of manmade features and often include varied topography and hydrologic features, and the necessary quiet and solitude to enjoy nature. Large natural areas are needed to insure ecological function and sustainability, be it preserving watersheds or limiting fragmentation and edge effects to forested areas. (2012 PROS Plan, pp. 44-46)

Based on the importance of preserving natural areas and creating trails for access to resource-based recreation, the Ten-Mile Creek area offers a valuable opportunity to serve not only the Clarksburg population, but residents countywide.

Facility-Based Recreation

The *2012 PROS Plan* estimates future needs for facilities in the Clarksburg Planning Area to the year 2022 as 3 playgrounds, 5 tennis courts, and 3 basketball courts. *PROS* demonstrates that needs will be met at a minimum at the following parks and schools: Cabin Branch Local Park, Piedmont Woods Neighborhood Park, Clarksburg Village South Local Park, and Damascus/Clarksburg Middle School #2.

The *2005 LPPRP/PROS Plan* estimated a need for nineteen adult-sized rectangular fields throughout the entire I-270 Corridor area. According to *PROS*, by the year 2021, thirteen of these will have been constructed. The balance of the future need will be constructed beyond the Year 2022. In addition, immediately north of the area, the portion of Little Bennett Regional Park located between MD 355 and I-270 could accommodate at least five more rectangular fields in the future.

Staff agrees with the 1994 Plan that in areas of residential density, close-to-home recreational facilities are needed. In the Ten Mile Creek area, it makes sense to provide those types of facilities that will provide access to and will enhance the natural resource areas. Facilities with minimal impervious surfaces such as open grassy areas for a variety of activities (described in PROS as Community Open Space), natural play areas, and community gathering areas were highly rated by the *Vision 2030* survey. *PROS* identified several new facility types that are needed in neighborhoods such as such as dog parks, community open space and community gardens.

Park and Trail Recommendations

- *Provide a countywide natural surface trail, designed to M-NCPPC Montgomery Parks standards, in the Ten Mile Creek area linking Little Bennett Regional Park and Black Hill Regional Park as per the Countywide Park Trails Plan and the 1994 Clarksburg Master Plan.*
    - The countywide trail segment to link Little Bennett Regional Park with Black Hill Regional Park should be located within the proposed Legacy Open Space Natural Resource and existing conservation parkland, per the CWPTP and the 1994 Plan.
    - Trails should be built using sustainable standards. Sufficient access to build and maintain the trails and the natural areas around them may require areas outside the environmental buffers in upland areas. Trails should be built using sustainable standards, which could include environmentally sensitive crossings such as bridges or boardwalks. Trails should include signage that meets Department standards.
    - Trail connections to Little Bennett and Black Hill Regional Parks will require stream and road crossings in the safest manner possible.
- *Provide five trailheads, designed to M-NCPPC Montgomery Parks standards, for access to the Ten Mile Creek natural surface trail and nearby natural areas for park users and operations staff.*
    - Five trailheads should be strategically located to access the Ten Mile Creek Trail and the natural resource areas. These trailheads should provide safe and logical public access as well as access for maintenance and policing, and should be built to Parks standards. Trailheads should include:
        - Gravel parking lot with 6-8 parking spaces
        - Kiosks with wayfinding and interpretive signage
- *Provide a new natural resource-based Neighborhood Park of at least ten acres for close-to-home recreation for the Ten Mile Creek area, designed to M-NCPPC Montgomery Parks standards.*
    - A natural resource-based Neighborhood Park of at least ten acres, located outside of environmentally sensitive areas, is recommended as a platform for walkable, close-to-home facilities and to serve as a trailhead for the Ten Mile Creek natural surface trail. The park should have a natural resource theme and should be located adjacent to conservation parkland.
    - The proposed Preliminary Program of Requirements for the Neighborhood Park is as follows:
        - Access to the Conservation Park to the west for trail users and operations, maintenance and police functions from the development
        - Trailhead with small gravel parking area (6-8 spaces), with access through the development
        - Picnic Area
        - Natural Play Area
        - Community Garden
        - Community Open Space large enough for community festivals and pickup sports, at least 15,000 square feet
        - Adequate space to provide for Environmental Site Design, Stormwater Management, Forest Conservation, and other regulatory requirements

Attachments:

1) Clarksburg Master Plan (1994) Conservation Areas and Current Proposed Legacy Open Space Natural Resource, Ten Mile Creek Area
2) Proposed Legacy Open Space Natural Resource and Parks and Trails, Ten Mile Creek Area

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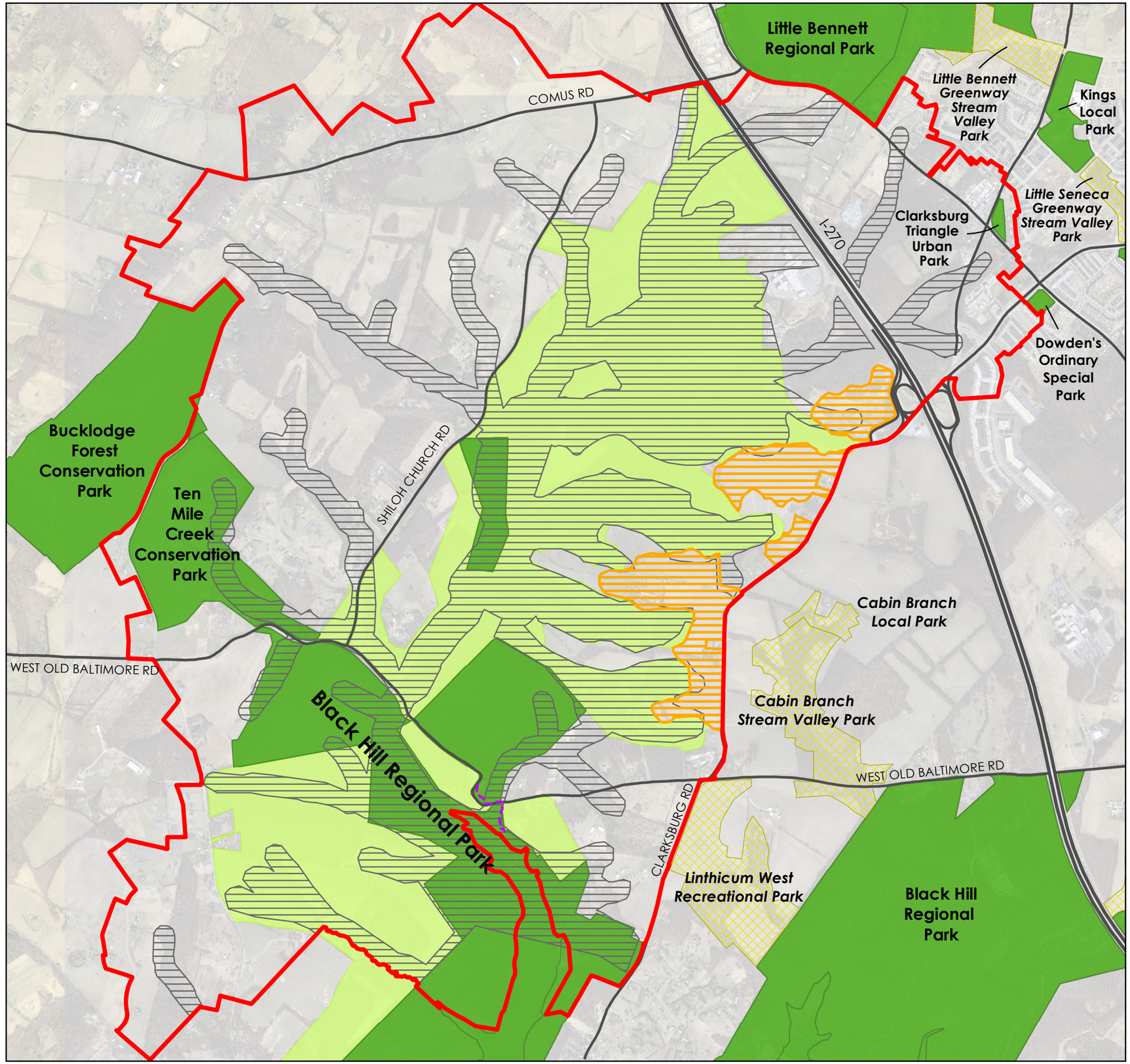
Wendy Hanley
Susanne Paul
Geoffrey Mason
Fred Boyd

Attachment 1:

Clarksburg Master Plan (1994) Conservation Areas and Current Proposed Legacy Open Space Natural Resource, Ten Mile Creek Area



Clarksburg Master Plan (1994) Conservation Areas

Proposed Legacy Open Space Natural Resource

Clarksburg Ten Mile Creek Limited Amendment

M-NCPPC Parks proposed by 1994 Clarksburg Master Plan

Planning Department Proposed Development Areas

Existing M-NCPPC Parkland

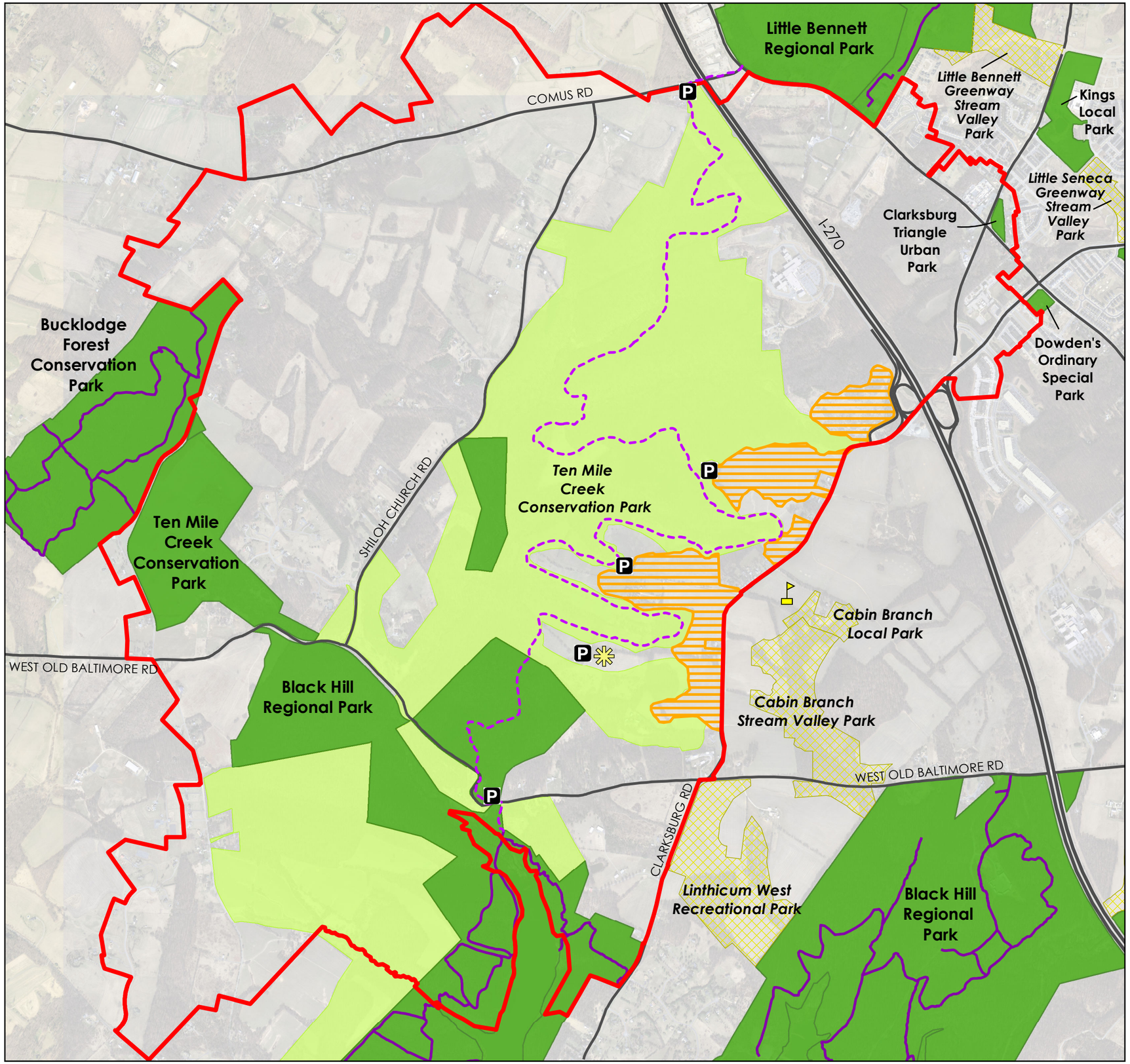
0 0.25 0.5 1 Miles

N

May 2013

Attachment 2:

Proposed Legacy Open Space Natural Resource and Parks and Trails, Ten Mile Creek Area



Proposed Legacy Open Space Natural Resource

Proposed Natural Surface Trail

Proposed Trailhead

Proposed M-NCPPC Neighborhood Park

Elementary School proposed by 1994 Clarksburg Master Plan

M-NCPPC Parks proposed by 1994 Clarksburg Master Plan

Planning Department Proposed Development Areas

Clarksburg Ten Mile Creek Limited Amendment

Existing Natural Surface Trail

Existing M-NCPPC Parkland

0 0.25 0.5 1 Miles

N

May 2013

Appendix July 2013

10 Mile Creek Area Limited Amendment

Clarksburg Master Plan and Hyattstown Special Study Area

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