**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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# 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).

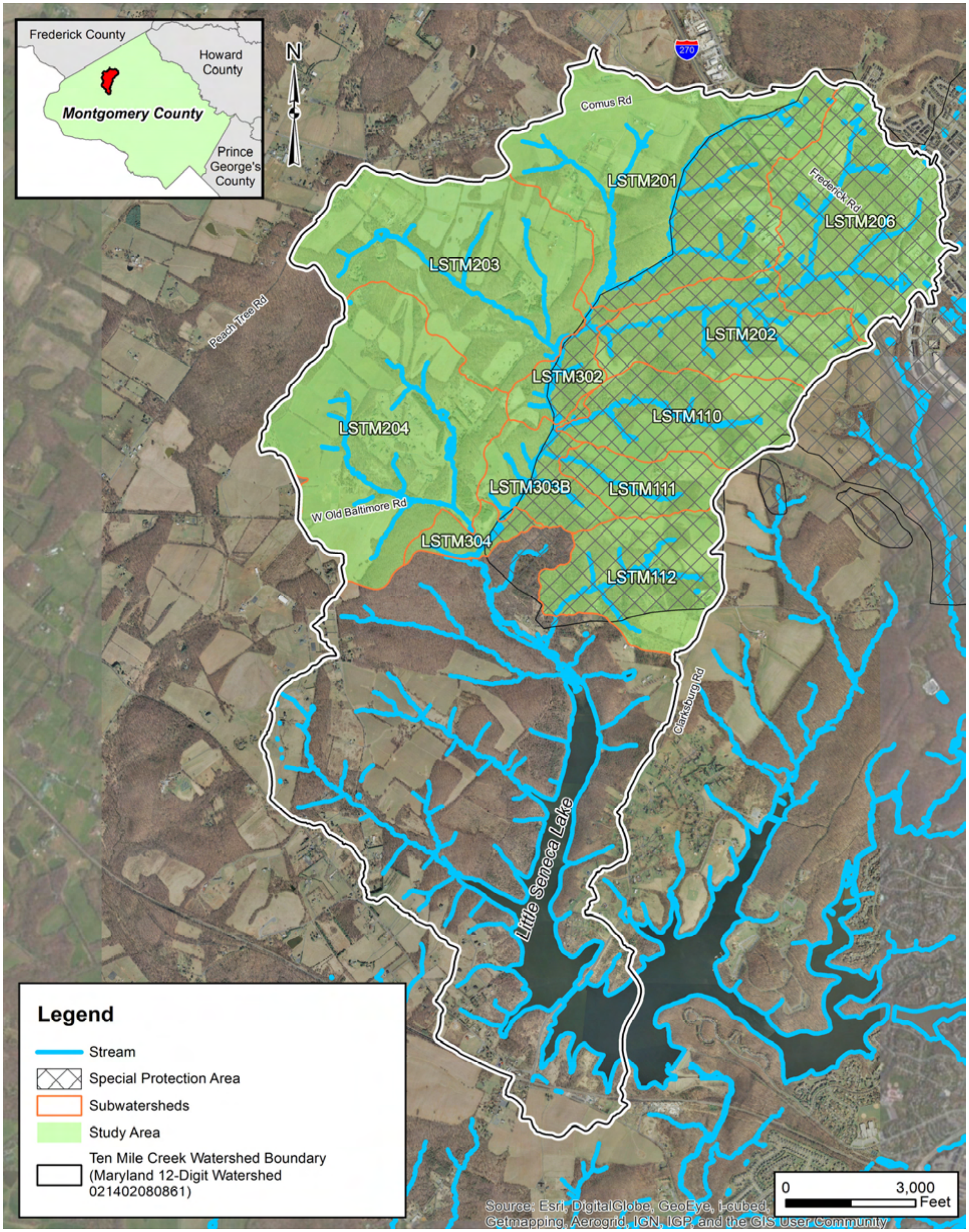
The purpose of this study is to document existing conditions and to evaluate potential watershed response to development within the Ten Mile Creek watershed. As such, analyses focus only on subwatersheds upstream of the existing USGS gage station and those that have the potential to be directly affected 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<br>• 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<br>• (Clarksburg School, Moneysworth Farm, and Cephas Summers House<br>• 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.

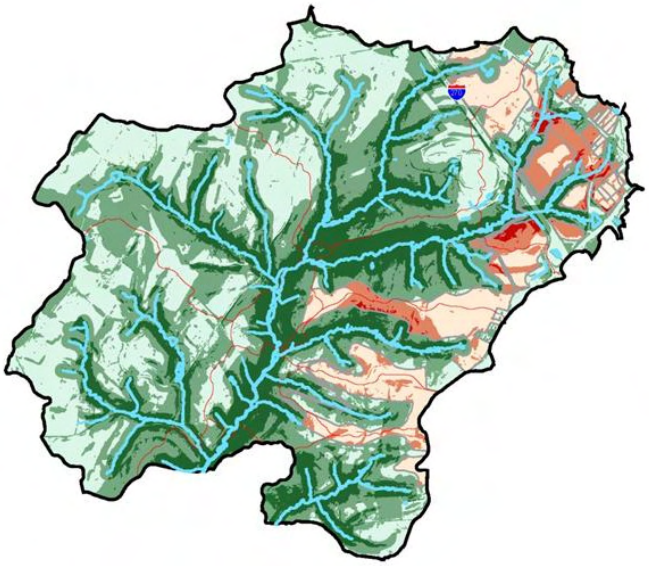
Areas of high resource value within the watershed are generally concentrated near the streams, particularly the mainstem, where wetlands, floodplains, forest, springs, seeps and the streams themselves provide critical watershed functions such as rainfall capture and runoff reduction, pollutant filtering,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

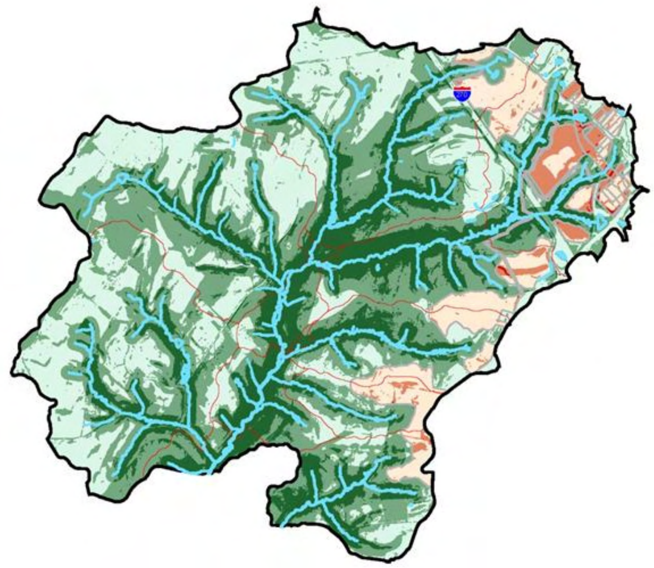
The projected limits of disturbance for Scenario 2 and Scenarios 3&4 were overlaid on the existing conditions Spatial Watershed Analysis to identify the extent of potential impacts to natural resources. Scenarios 3&4 have the same projected limits of disturbance, so this analysis applies to both. The 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.

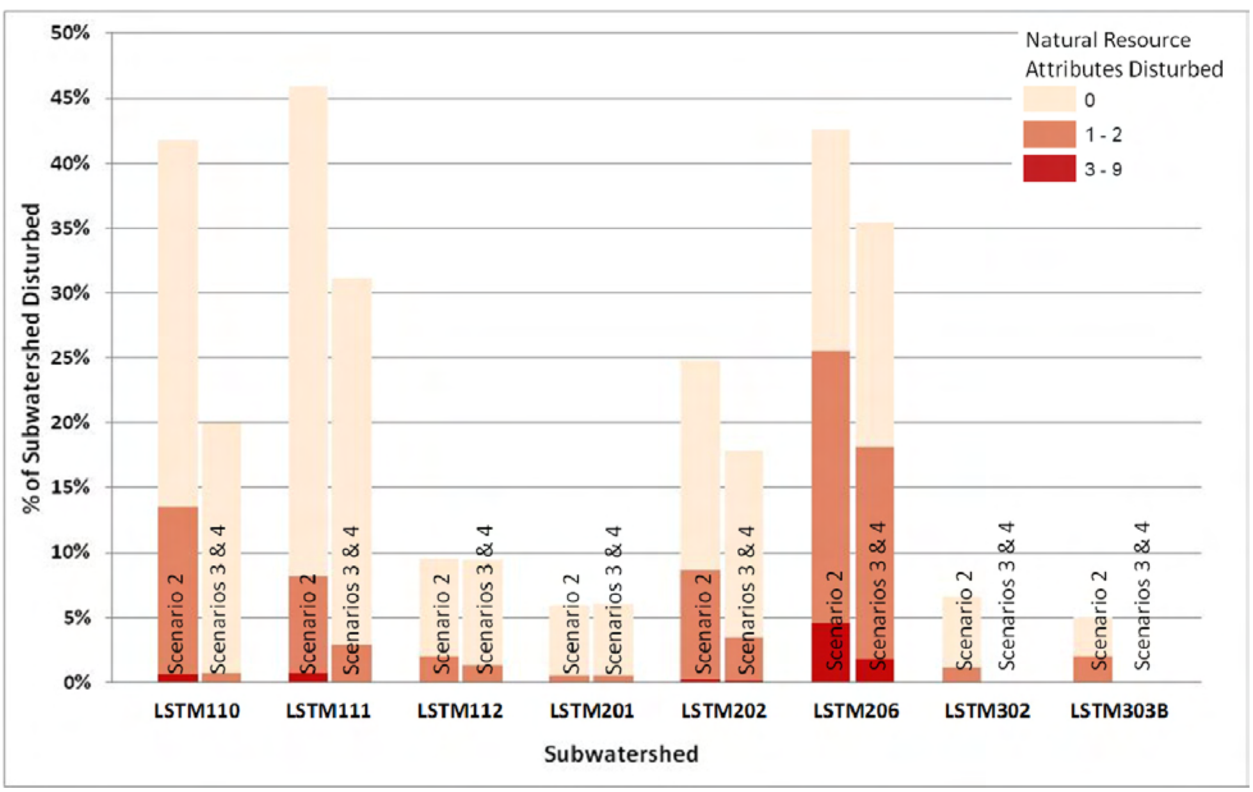
***Natural resource attributes overlain with development scenarios within the Ten Mile Creek study area.***
*Dark green indicates areas with the highest natural resource value, and are generally associated with the presence of the stream system and its buffer areas, forested areas, and wetlands. Medium 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***



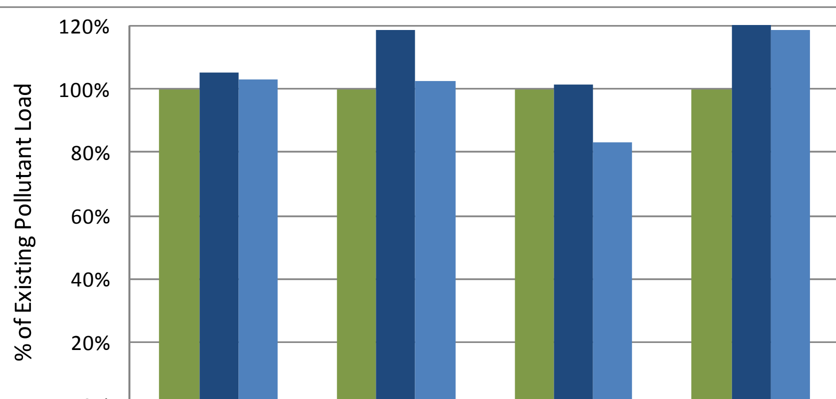
***Scenarios 3&4***



## *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.

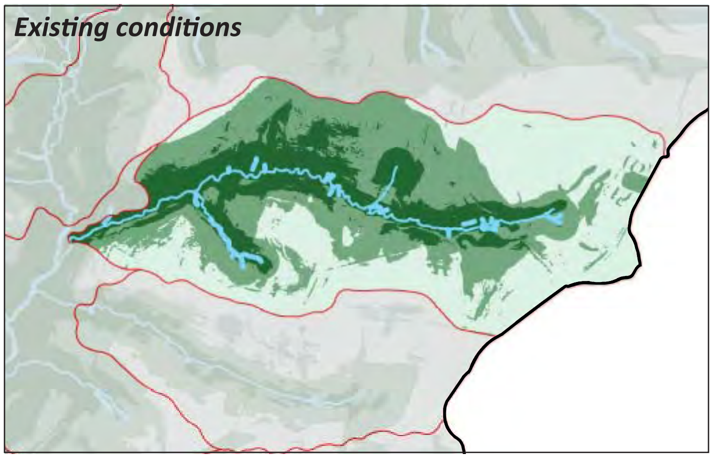
Additional development within the Ten Mile Creek watershed will have a negative impact on watershed health and stream quality. Minimizing impact to Ten Mile Creek will require the following measures:

- 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).

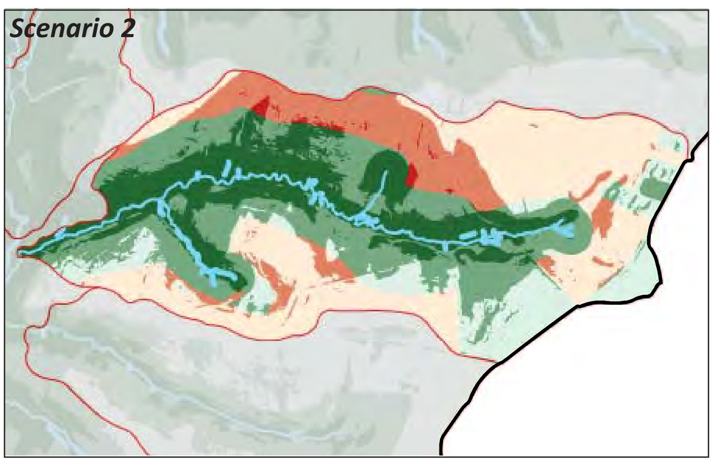
# Attachment A.  Ten Mile Creek Subwatershed Profiles

# TEN MILE CREEK

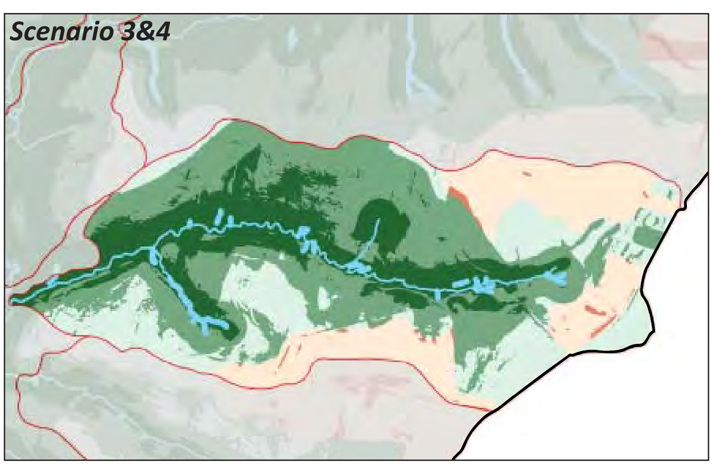
## Contributing Subwatersheds: LSTM110



*Existing conditions*



*Scenario 2*

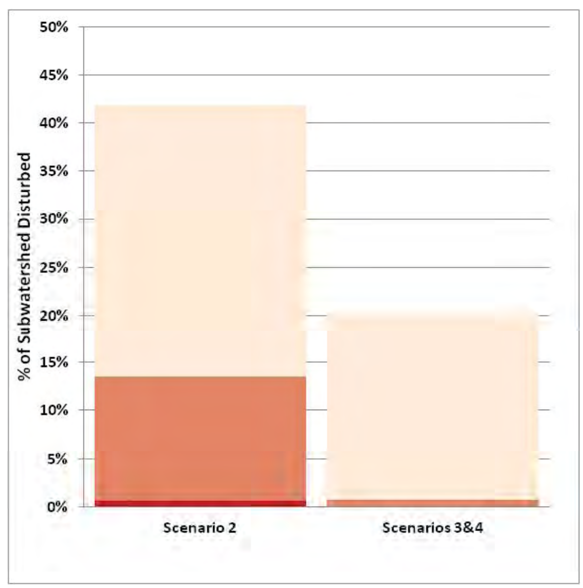


*Scenario 3&4*

## EXISTING CONDITIONS

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

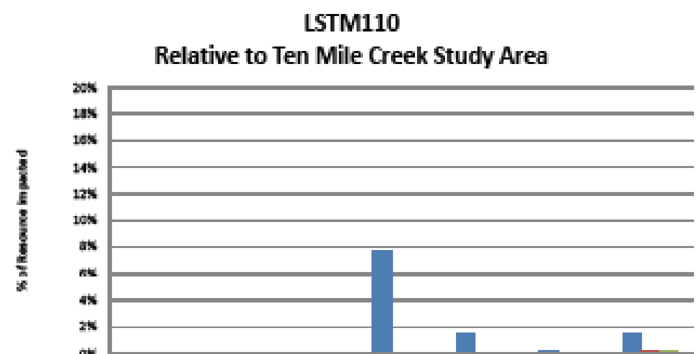
**LSTM101**
**Subwatershed Disturbance**



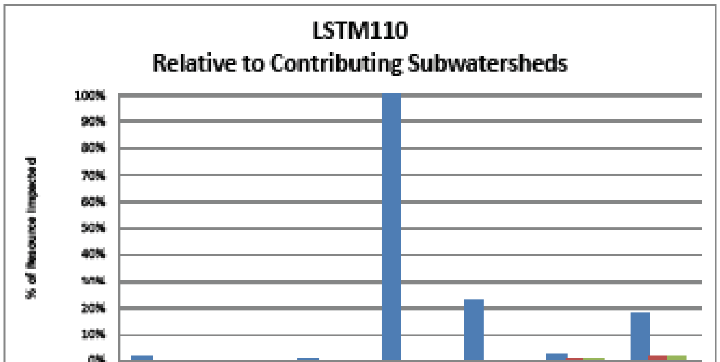

## LEGEND

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

## IMPACTS ON RESOURCES

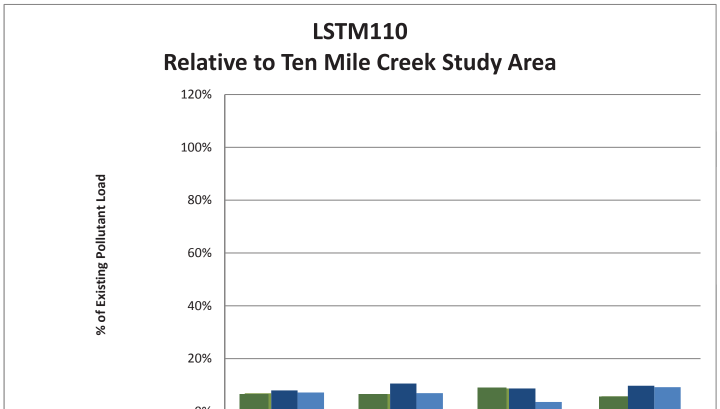



| | Wetlands (acres) | Stream (feet) | Perennial Stream Buffer (acres) | Forest Interior (acres) | Forest (acres) | Areas with Slopes >25% | Areas with Slopes >15% |
|---|---|---|---|---|---|---|---|
| Scenario 2 | 0.0% | 0.0% | 0.0% | 7.7% | 1.6% | 0.1% | 1.5% |
| Scenario 3-4 | 0.0% | 0.0% | 0.0% |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

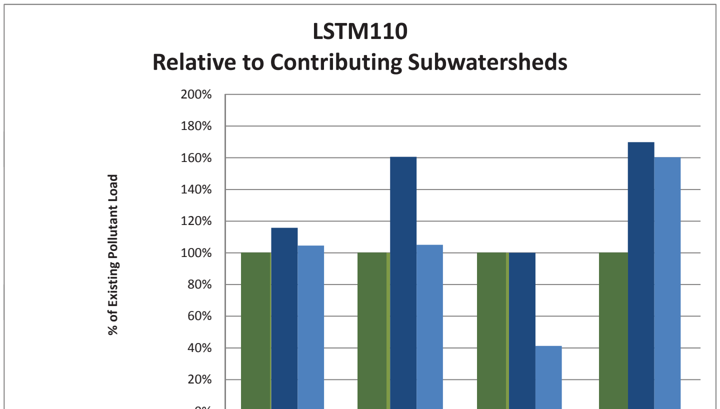



| | Wetlands (acres) | Stream (feet) | Perennial Stream Buffer (acres) | Forest Interior (acres) | Forest (acres) | Areas with Slopes >25% | Areas with Slopes >15% |
|---|---|---|---|---|---|---|---|
| Scenario 2 | 1.8% | 0.0% | 0.7% | 100.0% | 22.8% | 2.5% | 18.0% |
| Scenario 3-4 | 0.0% | 0.0% | 0.0%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

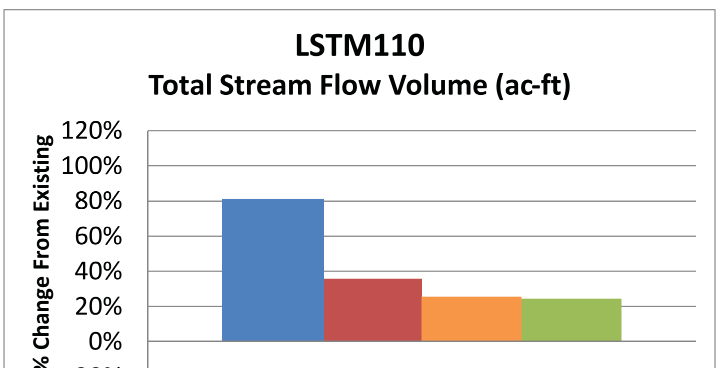



| | TN | TP | TSS | Runoff Volume |
|---|---|---|---|---|
| Existing | 6.9% | 6.6% | 8.7% | 5.7% |
| Scenario 2 During Construction | 7.9% | 10.6% | 8.7% | 9.7% |
| Scenario 2 Post Construction | 7.2% | 6.9% | 3.6% | 9.2% |

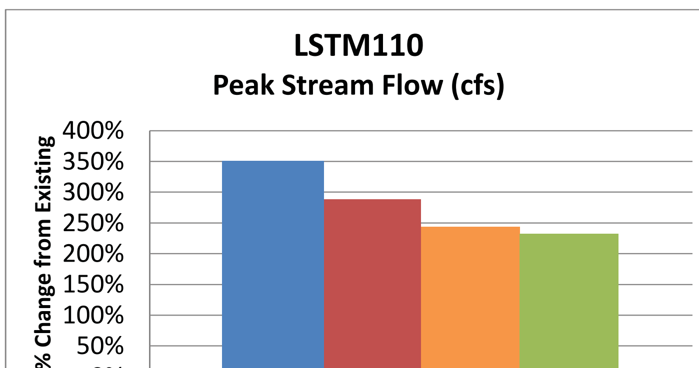



| | TN | TP | TSS | Runoff Volume |
|---|---|---|---|---|
| Existing | 100.0% | 100.0% | 100.0% | 100.0% |
| Scenario 2 During Construction | 115.8% | 160.6% | 100.1% | 169.8% |
| Scenario 2 Post Construction | 104.6% | 105.1% | 41.3% | 160.3% |

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

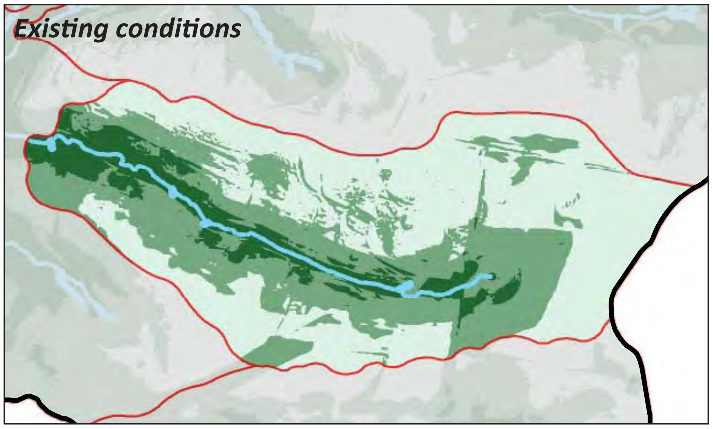


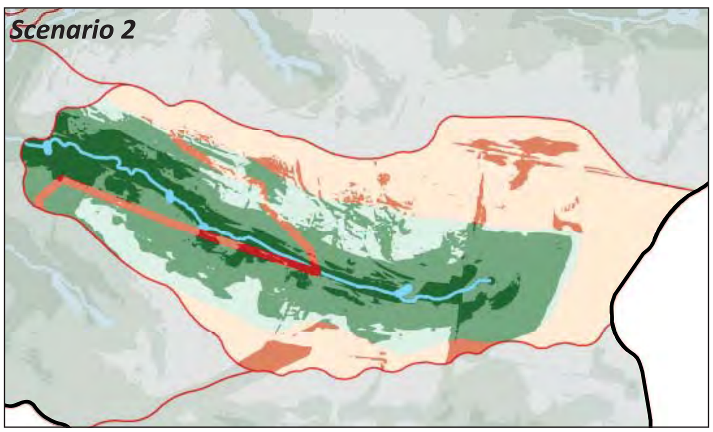

| | Model Scenarios |
|---|---|
| Scenario 2 | 80% |
| Scenario 3 | 36% |
| Scenario 4 | 25% |
| Scenario 5 | 24% |

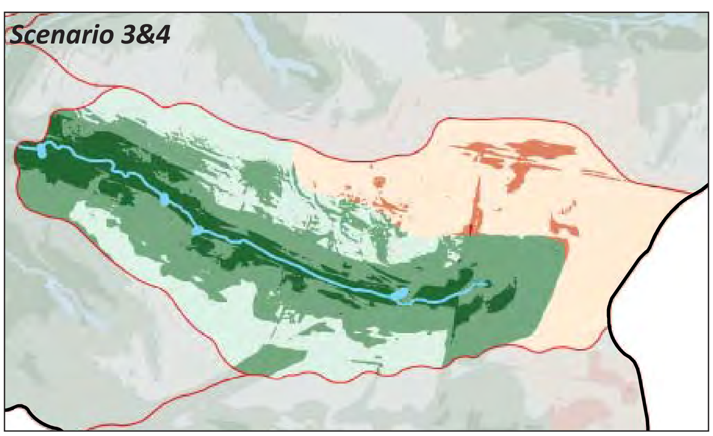



| | Model Scenarios |
|---|---|
| Scenario 2 | 350% |
| Scenario 3 | 289% |
| Scenario 4 | 244% |
| Scenario 5 | 232% |

# TEN MILE CREEK
## Contributing Subwatersheds: LSTM111



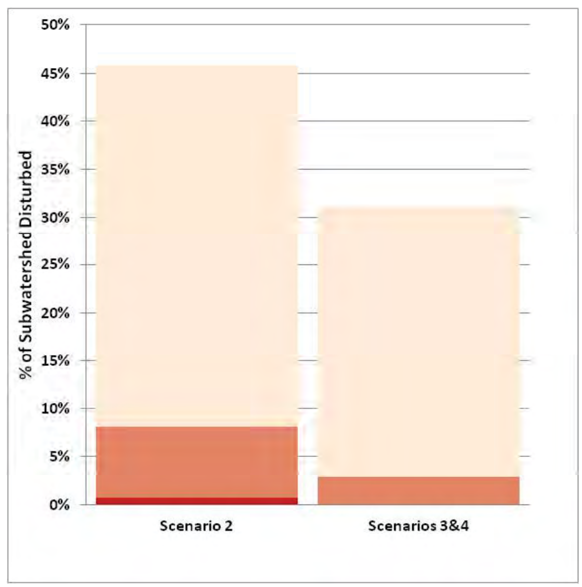




### EXISTING CONDITIONS

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

**LSTM111**
**Subwatershed Disturbance**

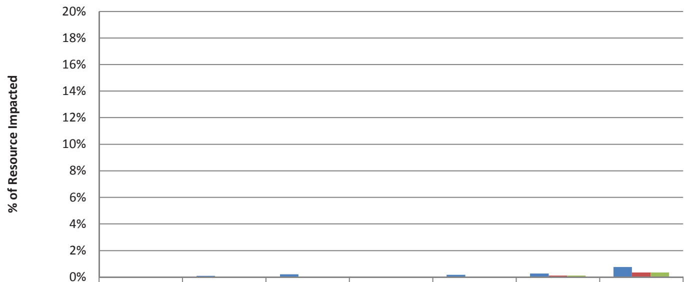



### LEGEND

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

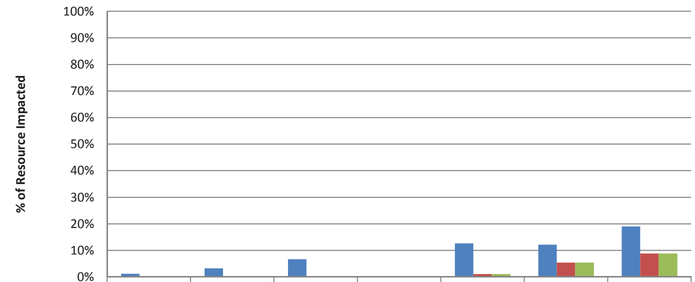
## IMPACTS ON RESOURCES

### LSTM111
### 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 | 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% |

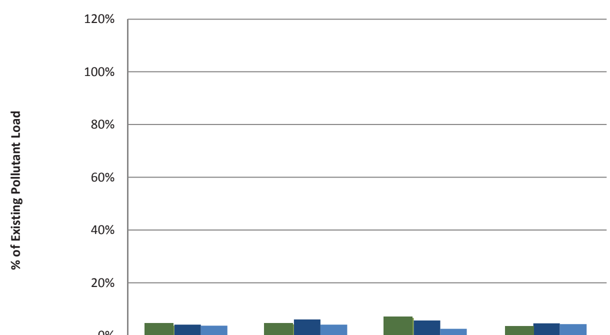
### LSTM111
### Relative to Contributing Subwatersheds




| | Wetlands (acres) | Stream (feet) | Perennial Stream Buffer (acres) | Forest Interior (acres) | Forest (acres) | Areas with Slopes >25% | Areas with Slopes >15% |
|---|---|---|---|---|---|---|---|
| Scenario 2 | 1.2% | 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% |

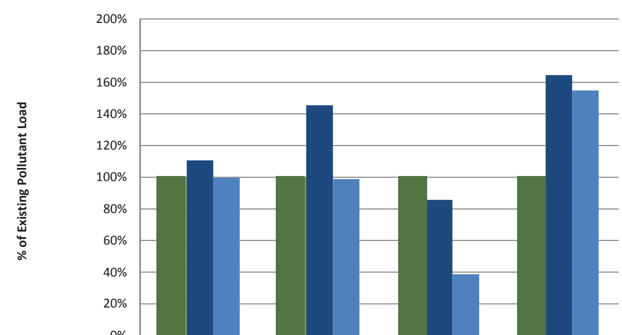
## POLLUTANT LOAD ANALYSIS

### LSTM111
### Relative to Ten Mile Creek Study Area




| | 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% |

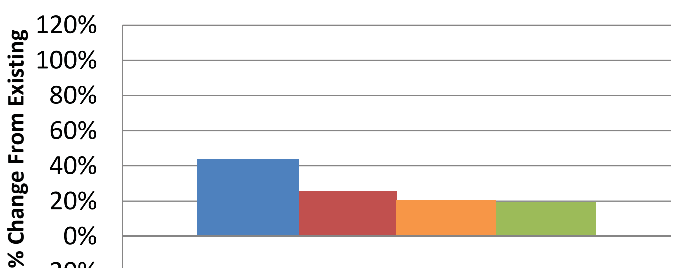
### LSTM111
### Relative to Contributing Subwatersheds




| | 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% |

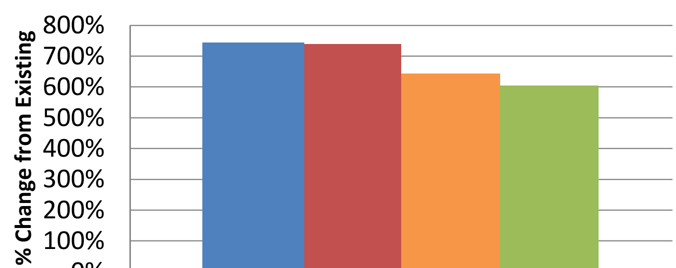
## HYDROLOGY (1-YEAR, 24-HOUR STORM) Note: Scale of Peak Stream flow is 0%-800%

### LSTM111
### Total Stream Flow Volume (ac-ft)



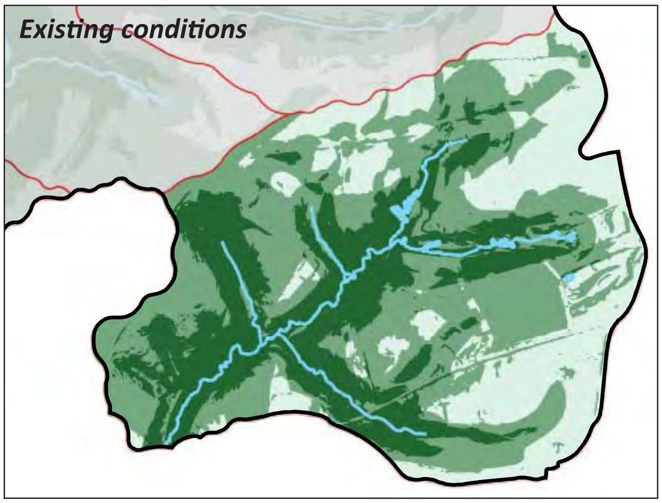

| | Model Scenarios |
|---|---|
| Scenario 2 | 43% |
| Scenario 3 | 26% |
| Scenario 4 | 21% |
| Scenario 5 | 19% |

### LSTM111
### Peak Stream Flow (cfs)



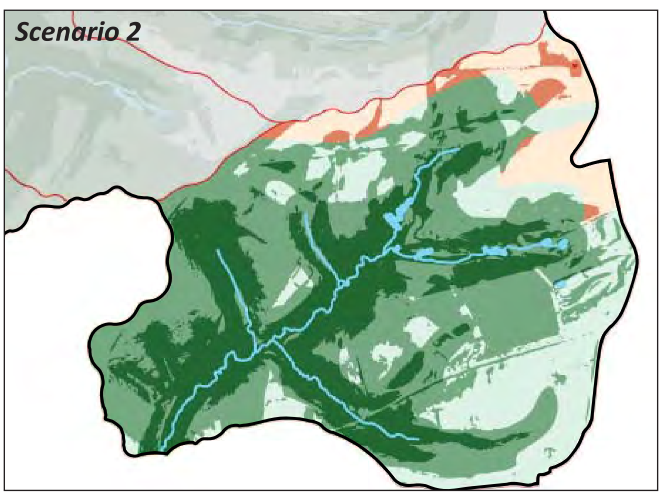

| | Model Scenarios |
|---|---|
| Scenario 2 | 741% |
| Scenario 3 | 739% |
| Scenario 4 | 644% |
| Scenario 5 | 605% |

# TEN MILE CREEK
## Contributing Subwatersheds: LSTM112

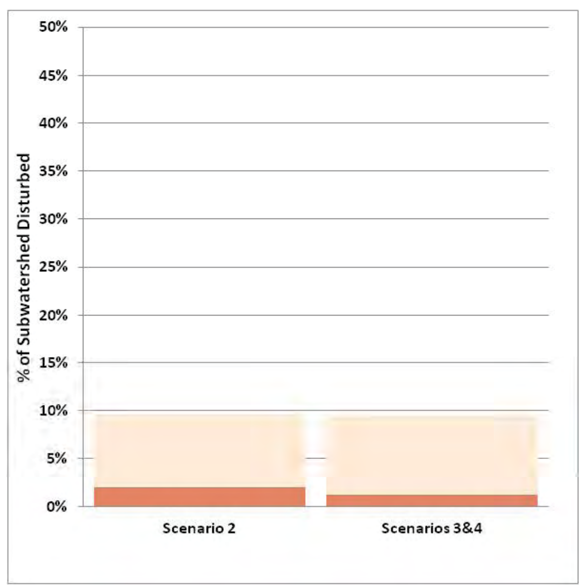


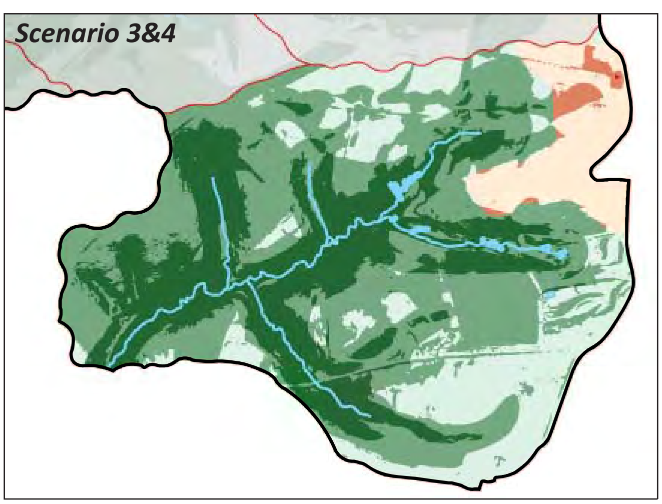

### EXISTING CONDITIONS

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




### LSTM112
### Subwatershed Disturbance

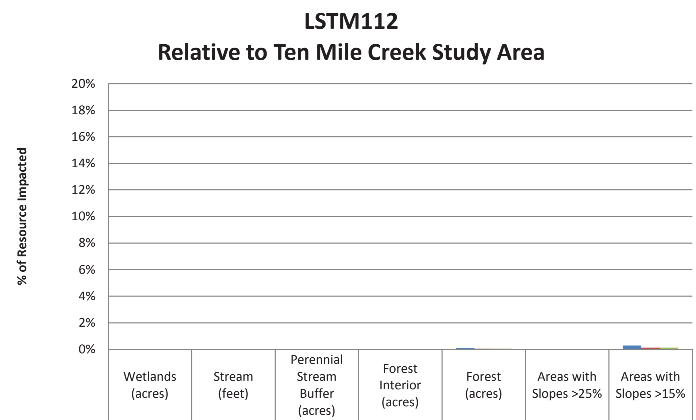


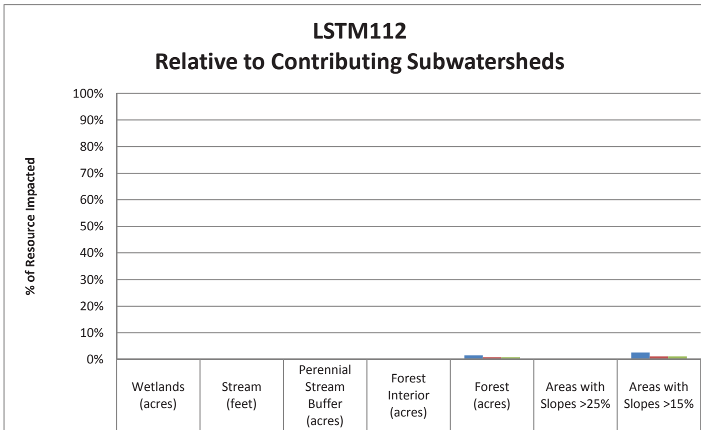

### LEGEND

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

## IMPACTS ON RESOURCES

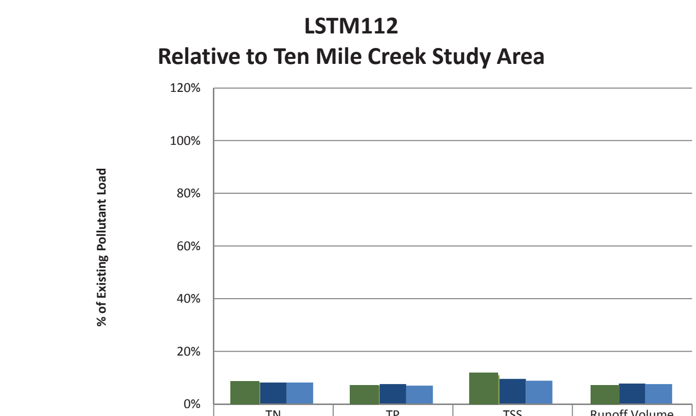



| | Wetlands (acres) | Stream (feet) | Perennial Stream Buffer (acres) | Forest Interior (acres) | Forest (acres) | Areas with Slopes >25% | Areas with Slopes >15% |
|---|---|---|---|---|---|---|---|
| Scenario 2 | 0.0% | 0.0% | 0.0% | 0.0% | 0.1% | 0.0% | 0.3% |
| Scenario 3-4 | 0.0% | 0.0% | 0.0% |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

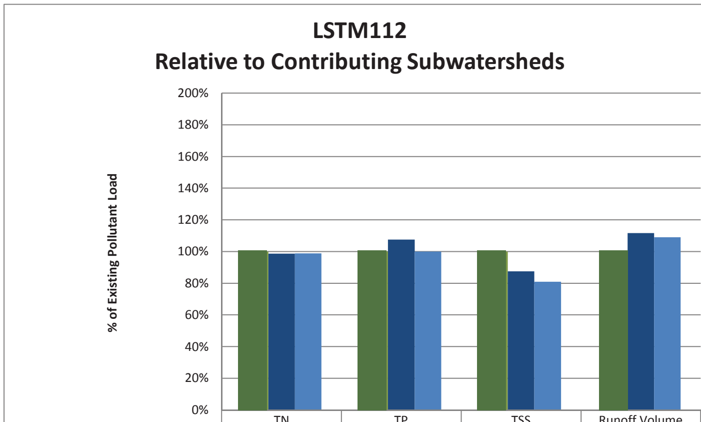



| | Wetlands (acres) | Stream (feet) | Perennial Stream Buffer (acres) | Forest Interior (acres) | Forest (acres) | Areas with Slopes >25% | Areas with Slopes >15% |
|---|---|---|---|---|---|---|---|
| Scenario 2 | 0.0% | 0.0% | 0.0% | 0.0% | 1.5% | 0.2% | 2.5% |
| Scenario 3-4 | 0.0% | 0.0% | 0.0% |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

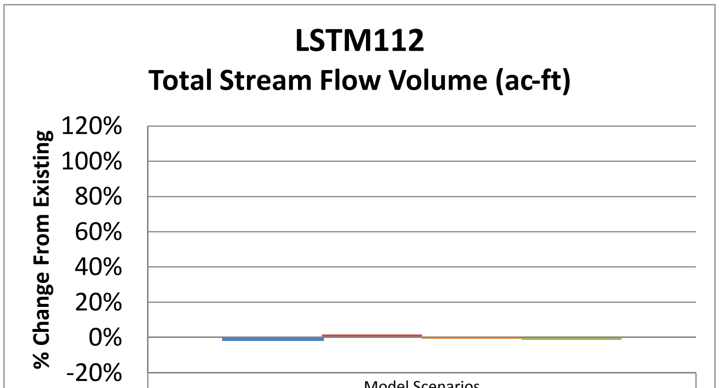



| | TN | TP | TSS | Runoff Volume |
|---|---|---|---|---|
| Existing | 8.3% | 7.1% | 11.0% | 7.0% |
| Scenario 2 During Construction | 8.2% | 7.6% | 9.6% | 7.8% |
| Scenario 2 Post Construction | 8.2% | 7.1% | 8.9% | 7.6% |

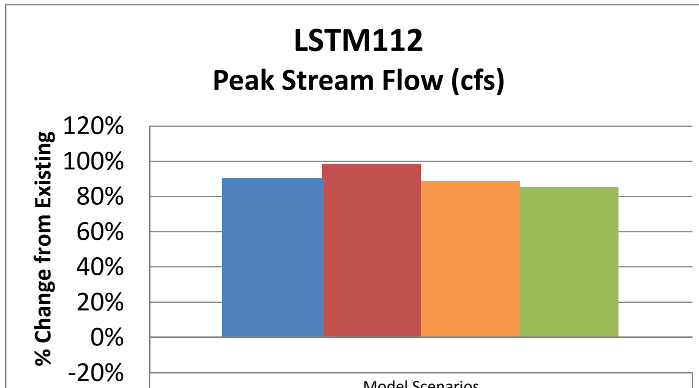



| | TN | TP | TSS | Runoff Volume |
|---|---|---|---|---|
| Existing | 100.0% | 100.0% | 100.0% | 100.0% |
| Scenario 2 During Construction | 98.6% | 107.5% | 87.4% | 111.7% |
| Scenario 2 Post Construction | 98.8% | 100.0% | 80.9% | 109.1% |

## HYDROLOGY (1-YEAR, 24-HOUR STORM)

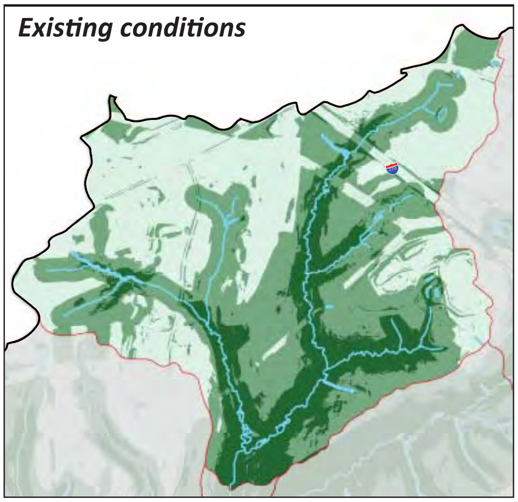



| | Model Scenarios |
|---|---|
| Scenario 2 | -1% |
| Scenario 3 | 2% |
| Scenario 4 | -1% |
| Scenario 5 | -1% |




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

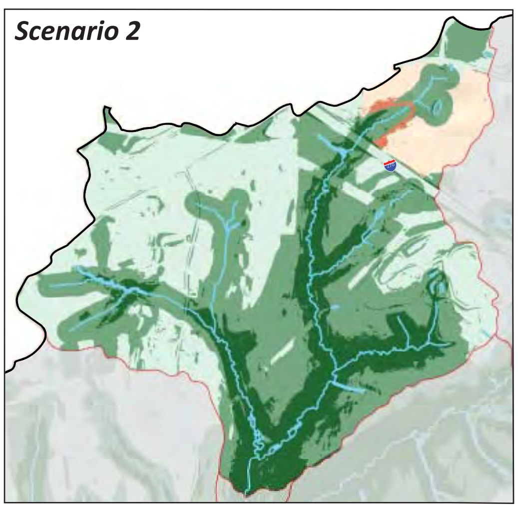
# TEN MILE CREEK
## Contributing Subwatersheds: LSTM201



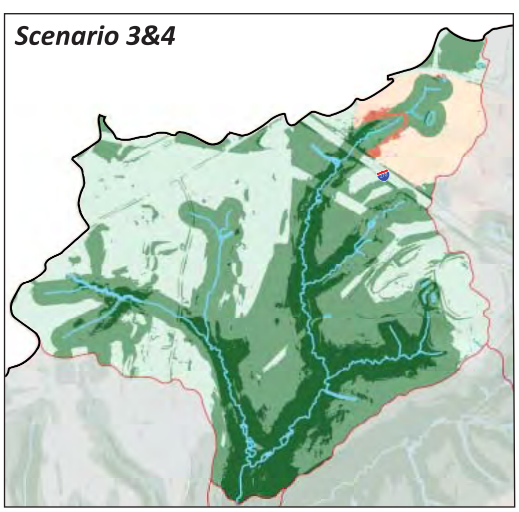
*Existing conditions*

### EXISTING CONDITIONS

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

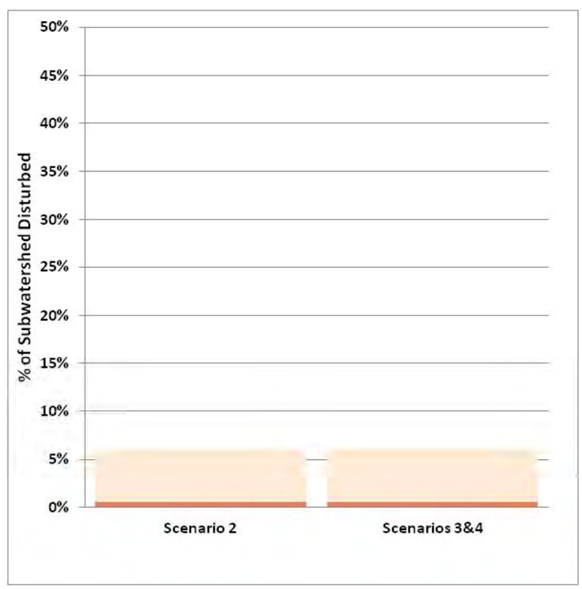


*Scenario 2*



*Scenario 3&4*

### LSTM201
### Subwatershed Disturbance

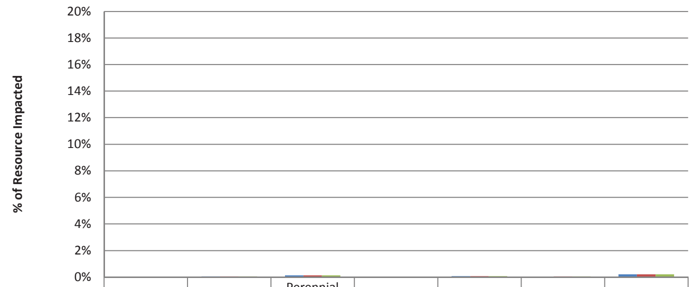



### LEGEND

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

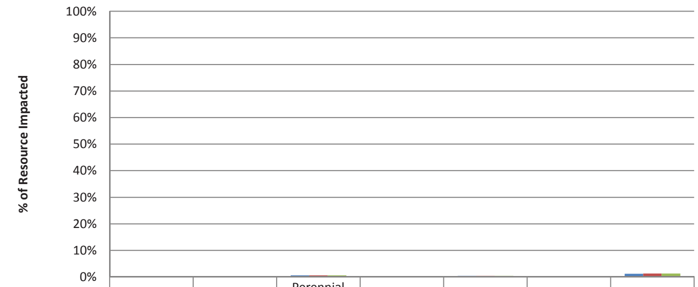
## IMPACTS ON RESOURCES

**LSTM201**
**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 | 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% |

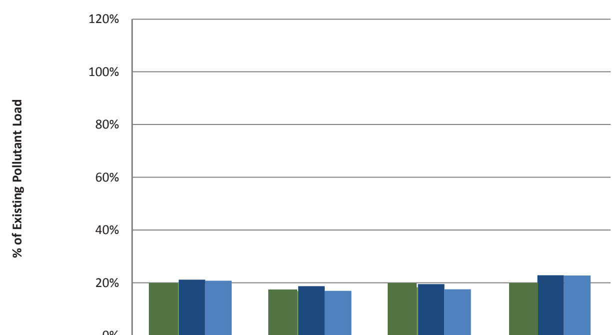
**LSTM201**
**Relative to Contributing Subwatersheds**




| | Wetlands (acres) | Stream (feet) | Perennial Stream Buffer (acres) | Forest Interior (acres) | Forest (acres) | Areas with Slopes >25% | Areas with Slopes >15% |
|---|---|---|---|---|---|---|---|
| Scenario 2 | 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% |

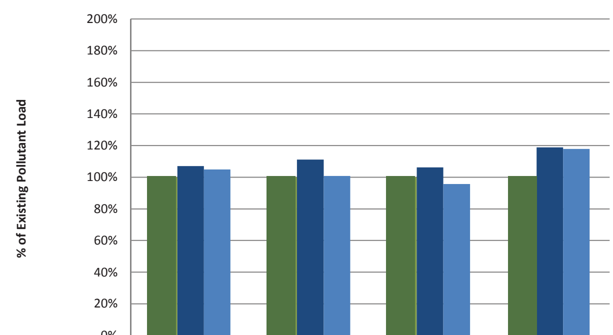
## POLLUTANT LOAD ANALYSIS

**LSTM201**
**Relative to Ten Mile Creek Study Area**




| | 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% |

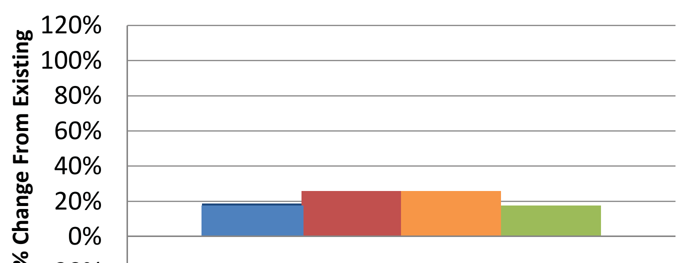
**LSTM201**
**Relative to Contributing Subwatersheds**




| | 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% |

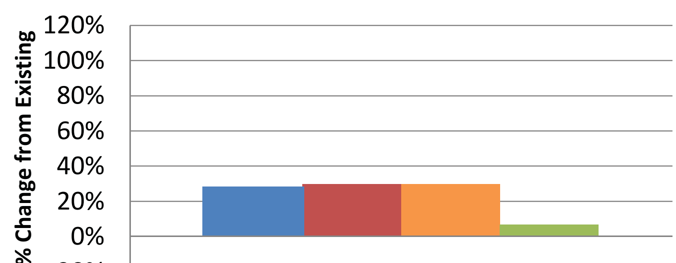
## HYDROLOGY (1-YEAR, 24-HOUR STORM)

**LSTM201**
**Total Stream Flow Volume (ac-ft)**



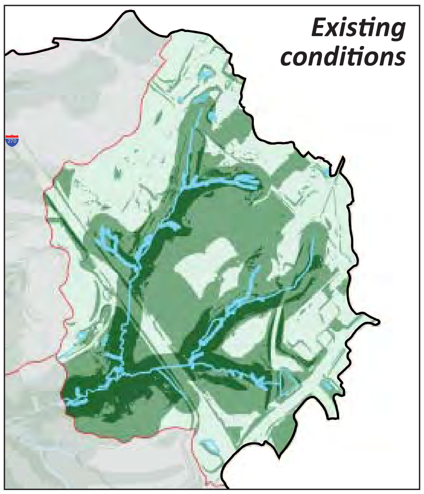

| | Model Scenarios |
|---|---|
| Scenario 2 | 19% |
| Scenario 3 | 26% |
| Scenario 4 | 26% |
| Scenario 5 | 18% |

**LSTM201**
**Peak Stream Flow (cfs)**



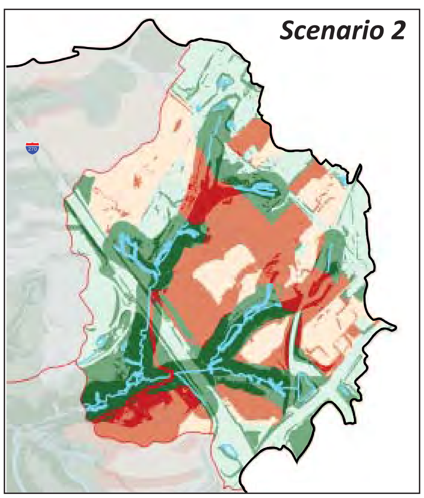

| | Model Scenarios |
|---|---|
| Scenario 2 | 28% |
| Scenario 3 | 30% |
| Scenario 4 | 30% |
| Scenario 5 | 7% |

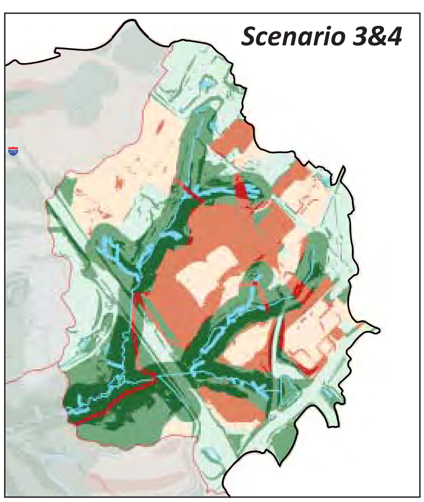
# TEN MILE CREEK
Contributing Subwatersheds:
LSTM206



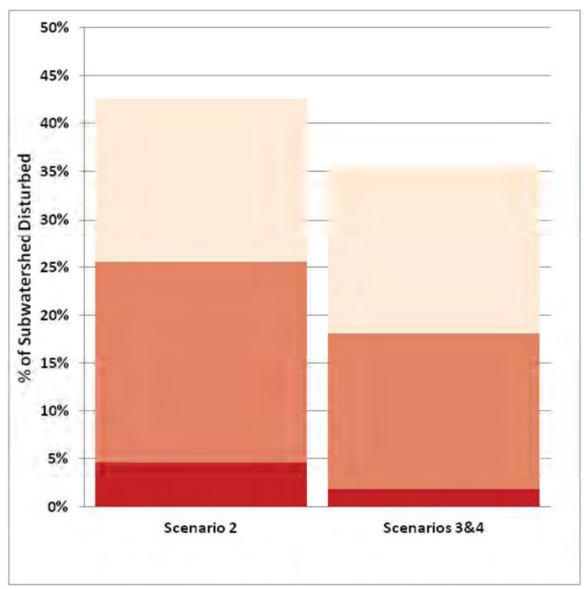

## EXISTING CONDITIONS

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




**LSTM206**
**Subwatershed Disturbance**



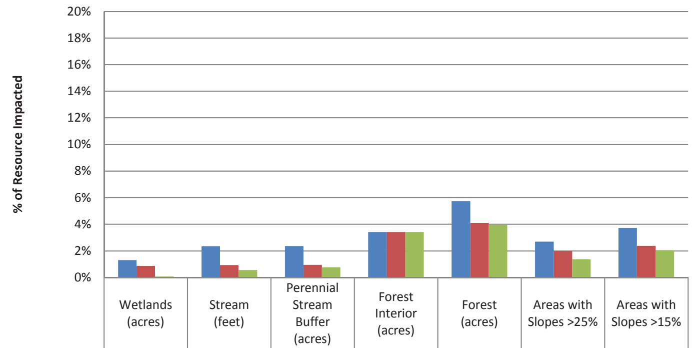

## LEGEND

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

## LSTM206

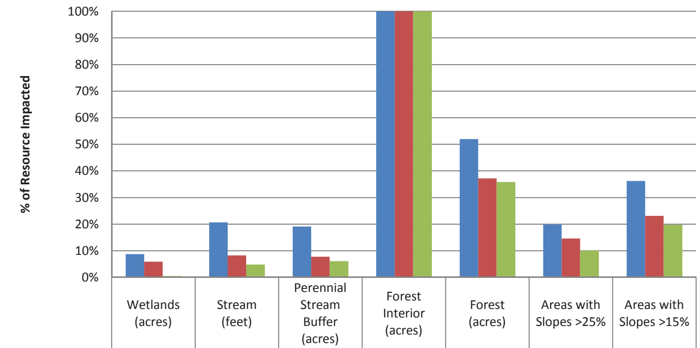
## IMPACTS ON RESOURCES

### LSTM206
### 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% | 2.3% | 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% |

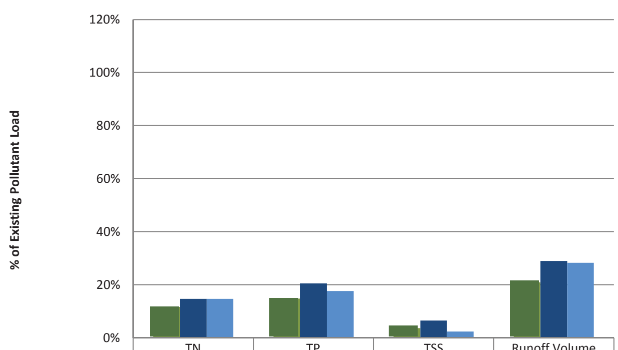
### LSTM206
### Relative to Contributing Subwatersheds




| | Wetlands (acres) | Stream (feet) | Perennial Stream Buffer (acres) | Forest Interior (acres) | Forest (acres) | Areas with Slopes >25% | Areas with Slopes >15% |
|---|---|---|---|---|---|---|---|
| Scenario 2 | 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% |

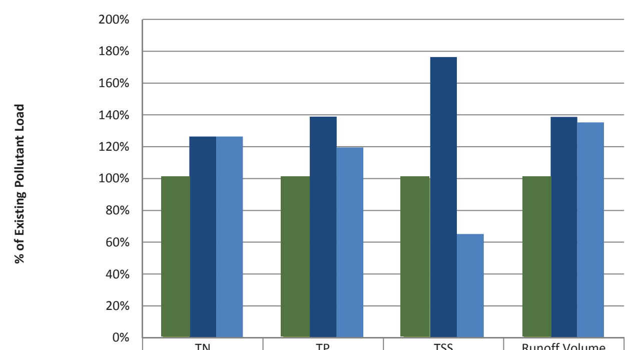
## POLLUTANT LOAD ANALYSIS

### LSTM206
### Relative to Ten Mile Creek Study Area




| | 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% |

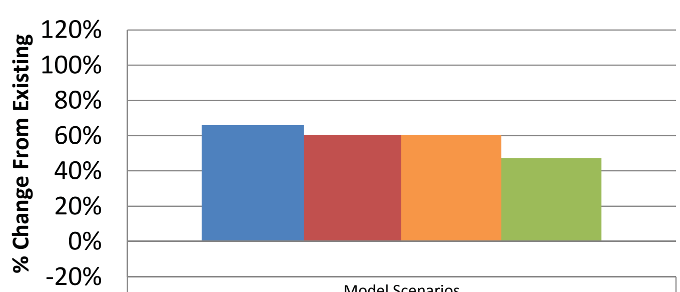
### LSTM206
### Relative to Contributing Subwatersheds




| | 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% |

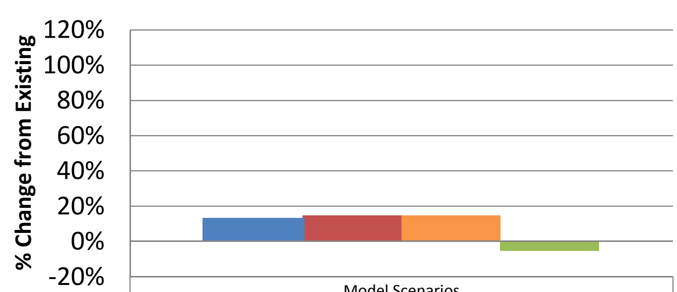
## HYDROLOGY (1-YEAR, 24-HOUR STORM)

### LSTM206
### Total Stream Flow Volume (ac-ft)



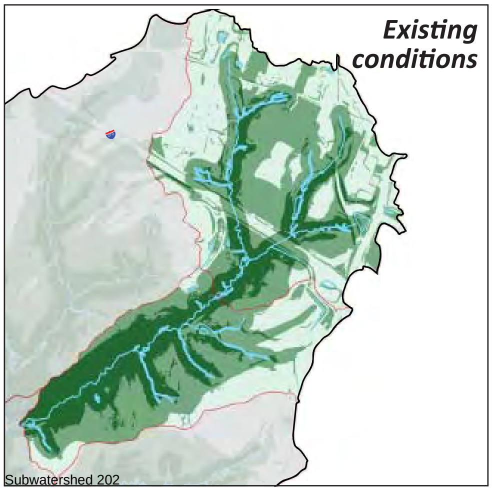

| | Model Scenarios |
|---|---|
| Scenario 2 | 66% |
| Scenario 3 | 60% |
| Scenario 4 | 60% |
| Scenario 5 | 47% |

### LSTM206
### Peak Stream Flow (cfs)



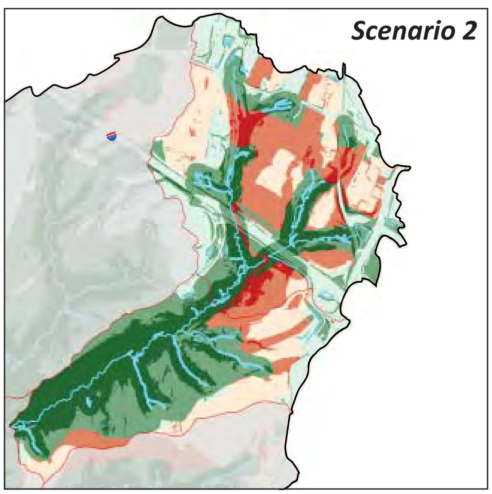

| | Model Scenarios |
|---|---|
| Scenario 2 | 13% |
| Scenario 3 | 15% |
| Scenario 4 | 15% |
| Scenario 5 | -5% |

# TEN MILE CREEK
## Contributing Subwatersheds: LSTM206 & LSTM202

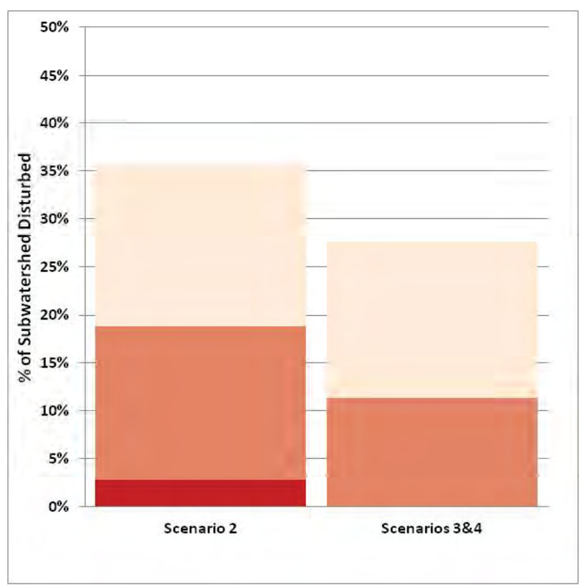


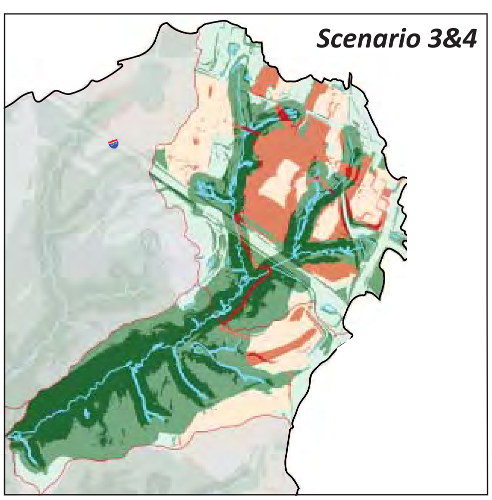

**EXISTING CONDITIONS**

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




**LSTM206 & LSTM202**
**Subwatershed Disturbance**



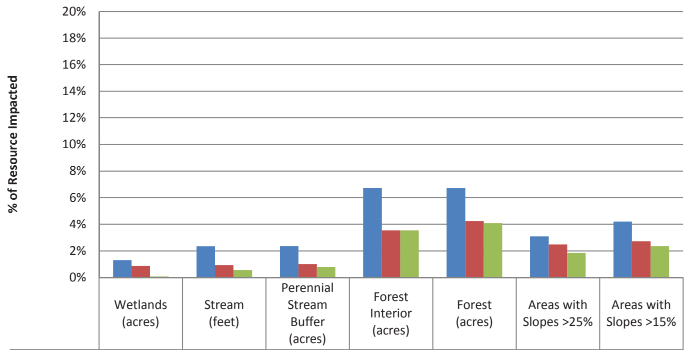




**LEGEND**

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

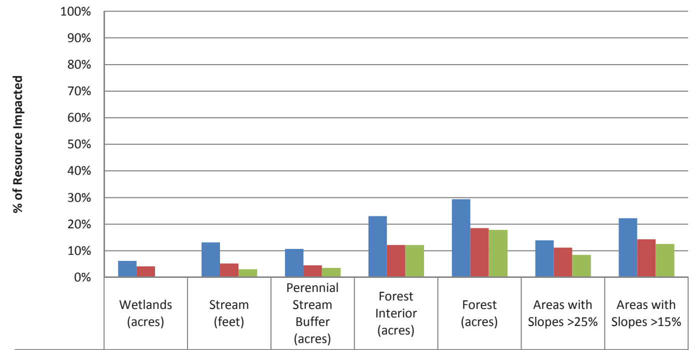
## IMPACTS ON RESOURCES

### LSTM206 & LSTM202
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% | 2.3% | 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% |

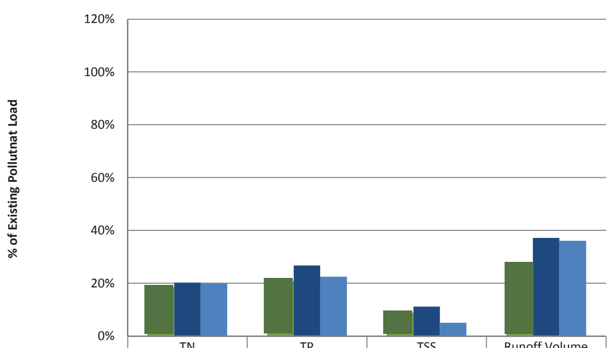
### LSTM206 & LSTM202
Relative to Contributing Subwatersheds




| | Wetlands (acres) | Stream (feet) | Perennial Stream Buffer (acres) | Forest Interior (acres) | Forest (acres) | Areas with Slopes >25% | Areas with Slopes >15% |
|---|---|---|---|---|---|---|---|
| Scenario 2 | 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% |

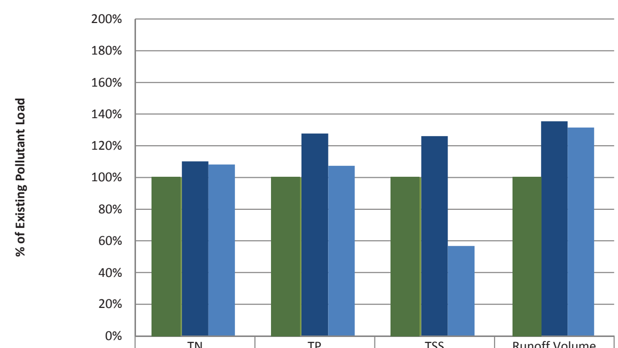
## POLLUTANT LOAD ANALYSIS

### LSTM206 & LSTM202
Relative to Ten Mile Creek Study Area




| | 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% |

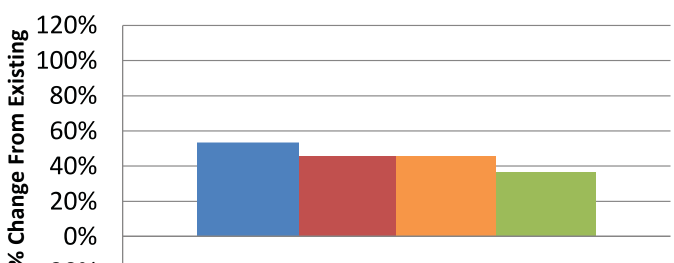
### LSTM206 & LSTM202
Relative to Contributing Subwatersheds




| | 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% |

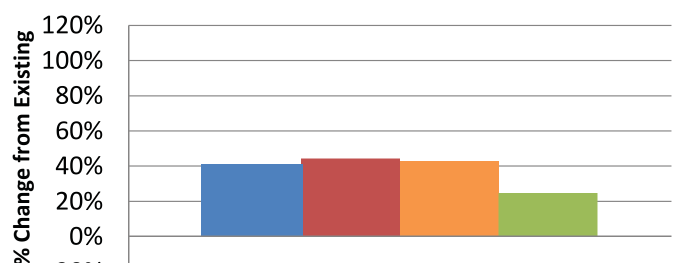
## HYDROLOGY (1-YEAR, 24-HOUR STORM)

### LSTM206 & LSTM202
Total Stream Flow Volume (ac-ft)



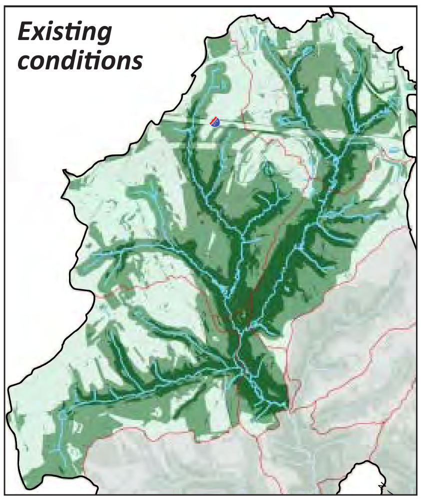

| | Model Scenarios |
|---|---|
| Scenario 2 | 53% |
| Scenario 3 | 46% |
| Scenario 4 | 46% |
| Scenario 5 | 37% |

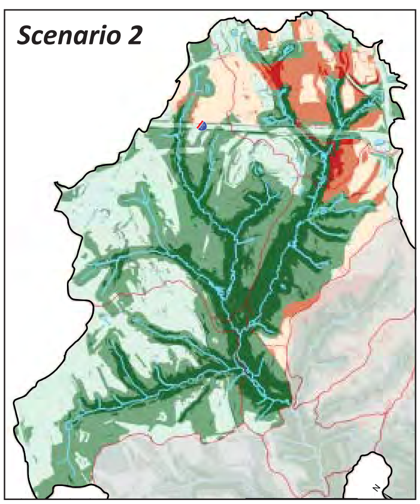
### LSTM206 & LSTM202
Peak Stream Flow (cfs)

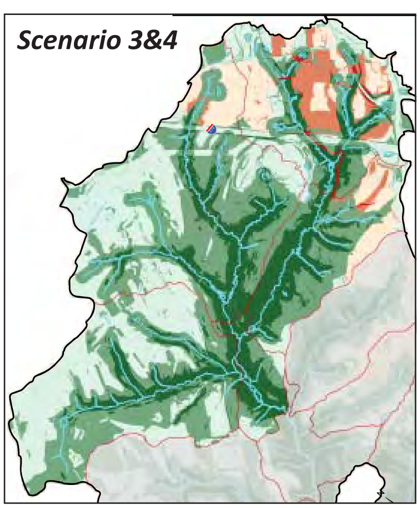



| | Model Scenarios |
|---|---|
| Scenario 2 | 40% |
| Scenario 3 | 44% |
| Scenario 4 | 43% |
| Scenario 5 | 25% |

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



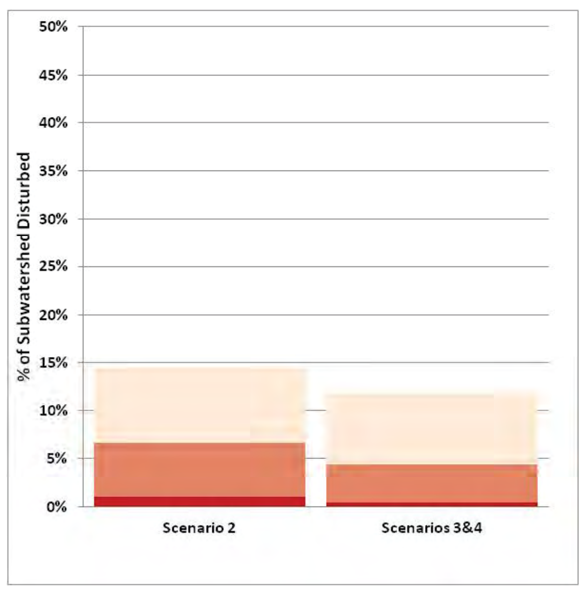




### EXISTING CONDITIONS

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

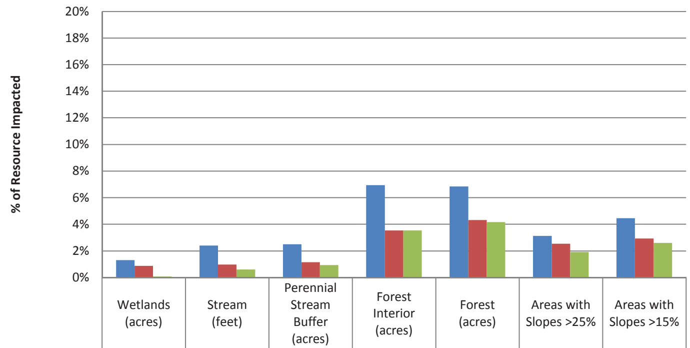



### LEGEND

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

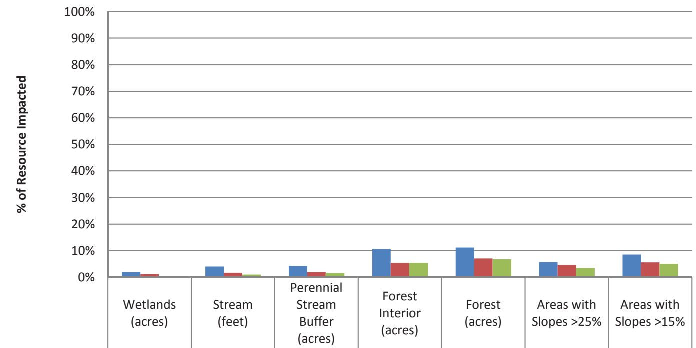
## IMPACTS ON RESOURCES

### 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% |

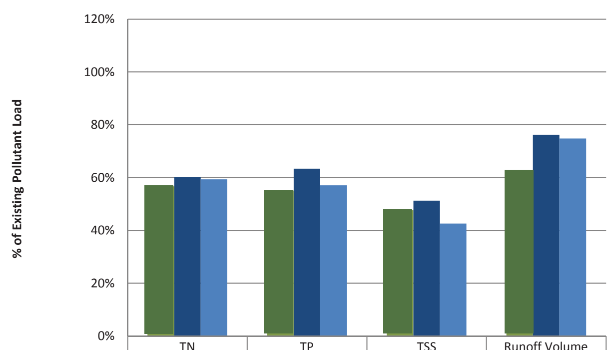
### LSTM206, LSTM202, LSTM201, LSTM203, & LSTM302
Relative to Contributing Subwatersheds




| | 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% |

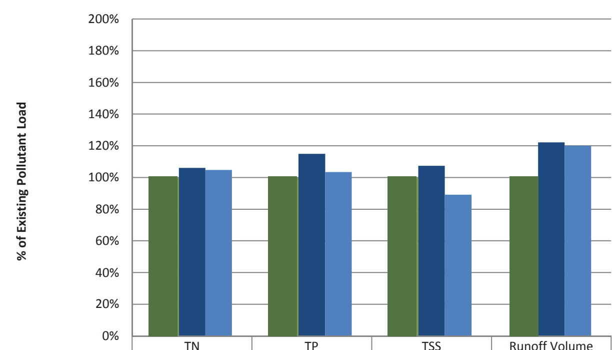
## POLLUTANT LOAD ANALYSIS

### 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% |

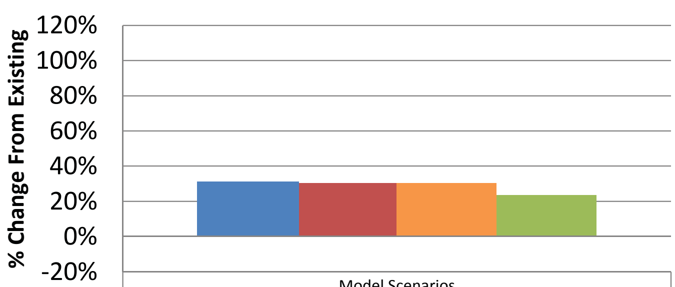
### LSTM206, LSTM202, LSTM201, LSTM203, & LSTM302
Relative to Contributing Subwatersheds




| | 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% |

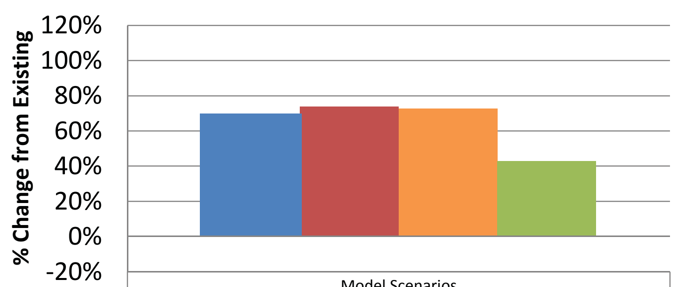
## HYDROLOGY (1-YEAR, 24-HOUR STORM)

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



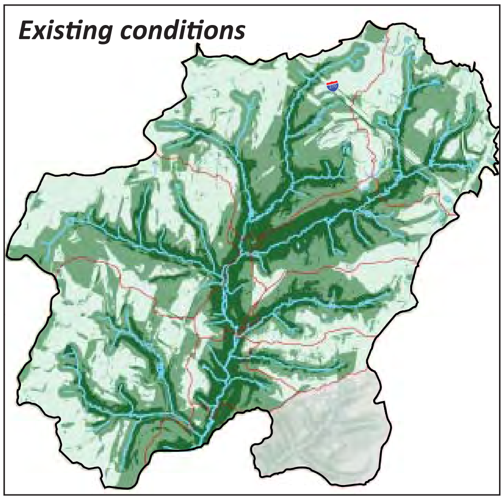

| | Model Scenarios |
|---|---|
| Scenario 2 | 30% |
| Scenario 3 | 30% |
| Scenario 4 | 30% |
| Scenario 5 | 24% |

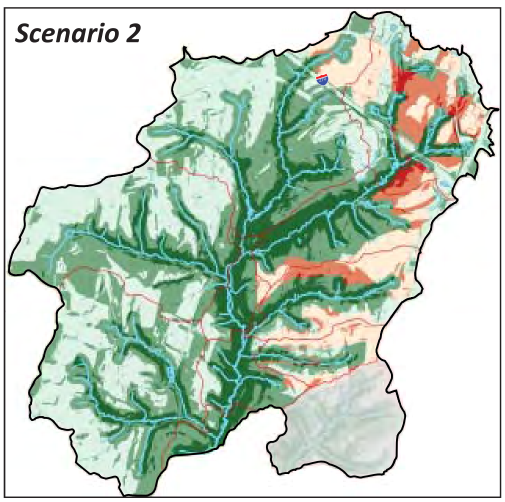
### LSTM206, LSTM202, LSTM201, LSTM203, & LSTM302
Peak Stream Flow (cfs)

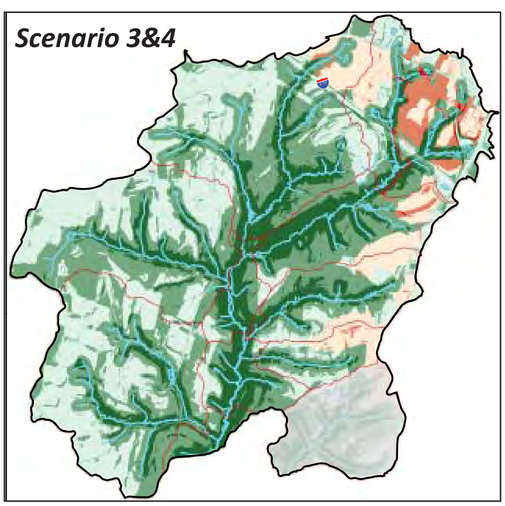



| | Model Scenarios |
|---|---|
| Scenario 2 | 69% |
| Scenario 3 | 74% |
| Scenario 4 | 73% |
| Scenario 5 | 43% |

# TEN MILE CREEK
## Contributing Subwatersheds: LSTM206, LSTM202, LSTM201, LSTM203, LSTM204, LSTM110, LSTM111, LSTM302, LSTM303B, & LSTM304


*Existing conditions*

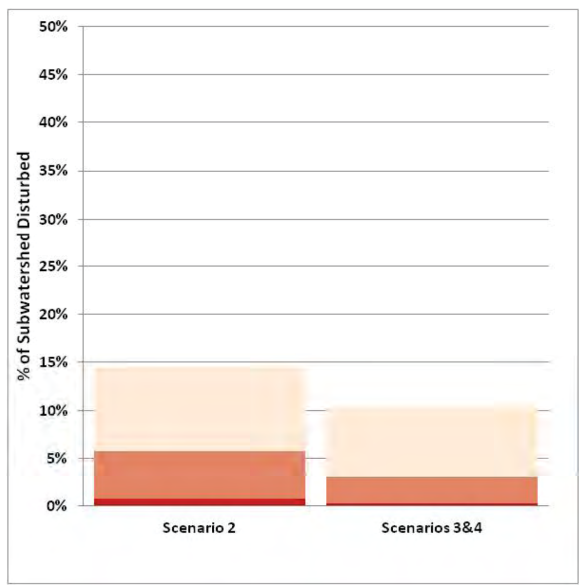

*Scenario 2*


*Scenario 3&4*

### 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**

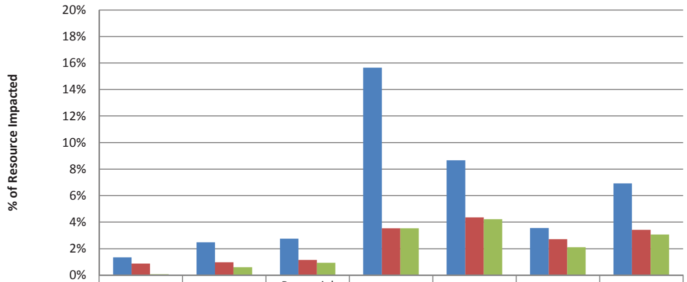



### LEGEND

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

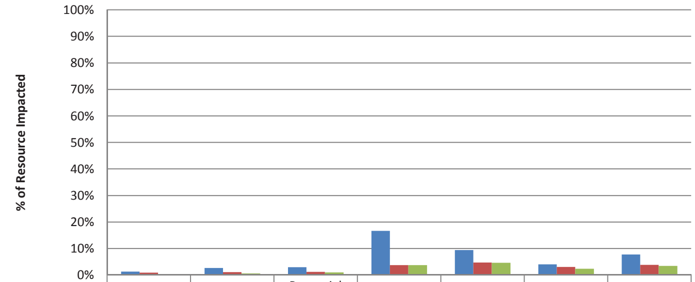
## IMPACTS ON RESOURCES

**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% |

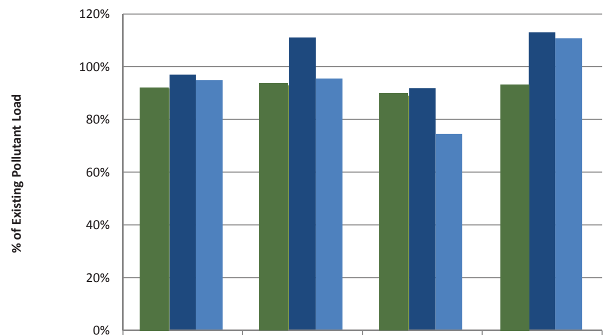
**LSTM206, LSTM202, LSTM201, LSTM203, LSTM204, LSTM110, LSTM111, LSTM302, LSTM303B, & LSTM304**
**Relative to Contributing Subwatersheds**




| | 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% |

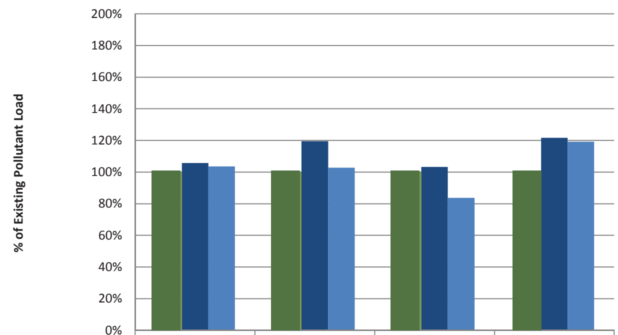
## POLLUTANT LOAD ANALYSIS

**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% |

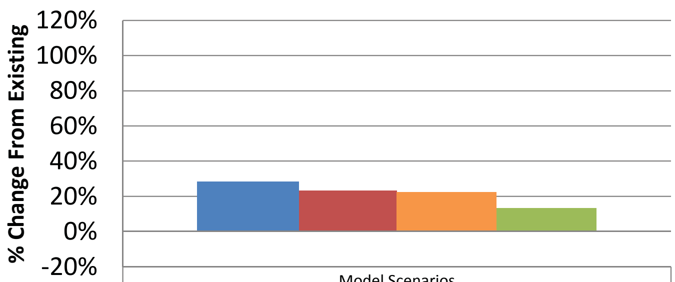
**LSTM206, LSTM202, LSTM201, LSTM203, LSTM204, LSTM110, LSTM111, LSTM302, LSTM303B, & LSTM304**
**Relative to Contributing Subwatersheds**




| | 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% |

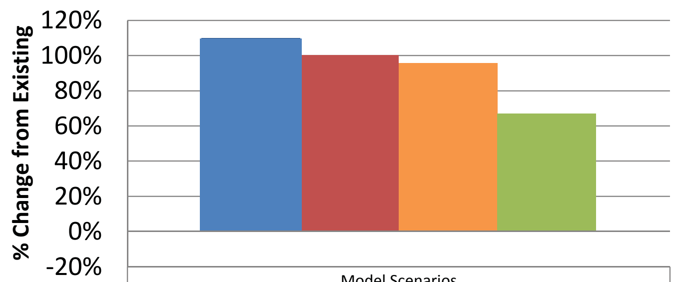
## HYDROLOGY (1-YEAR, 24-HOUR STORM)

**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)

# 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.

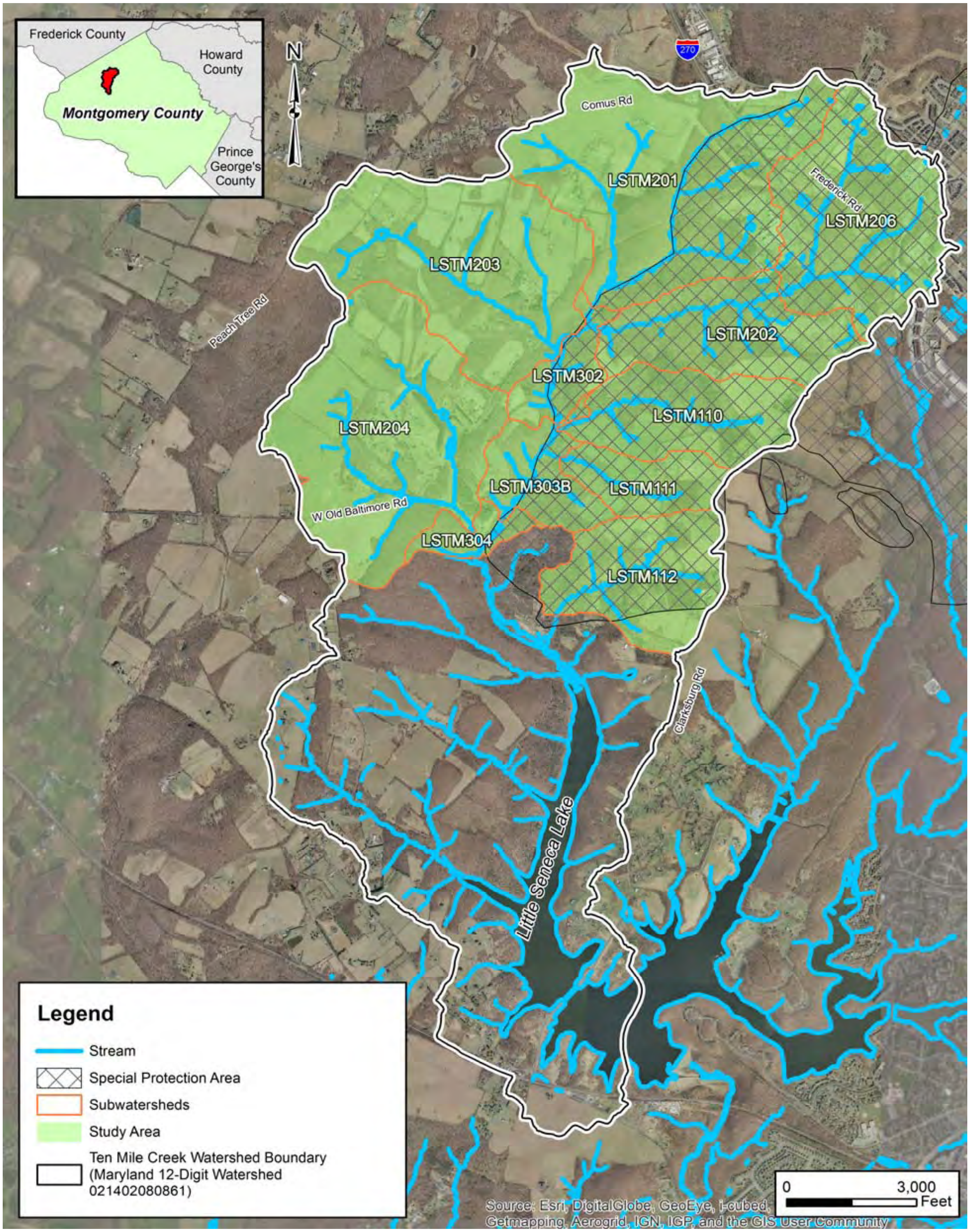


**Figure E.1. Ten Mile Creek Watershed and Subwatersheds**

# 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<br>• 38% Rural<br>• 7% Low Density Residential |
| **Land Cover** | • 4% Impervious Cover<br>• 46% Forest Cover<br>• 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)<br>• Frederick Road (MD 355) |
| **Significant Natural and Historical Features** | • Rustic roads<br>• Old Baltimore Road stream ford<br>• Cemeteries<br>• 1994 Clarksburg Master Plan Individual Sites (Clarksburg School, Moneysworth Farm, and Cephas Summers House)<br>• 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)

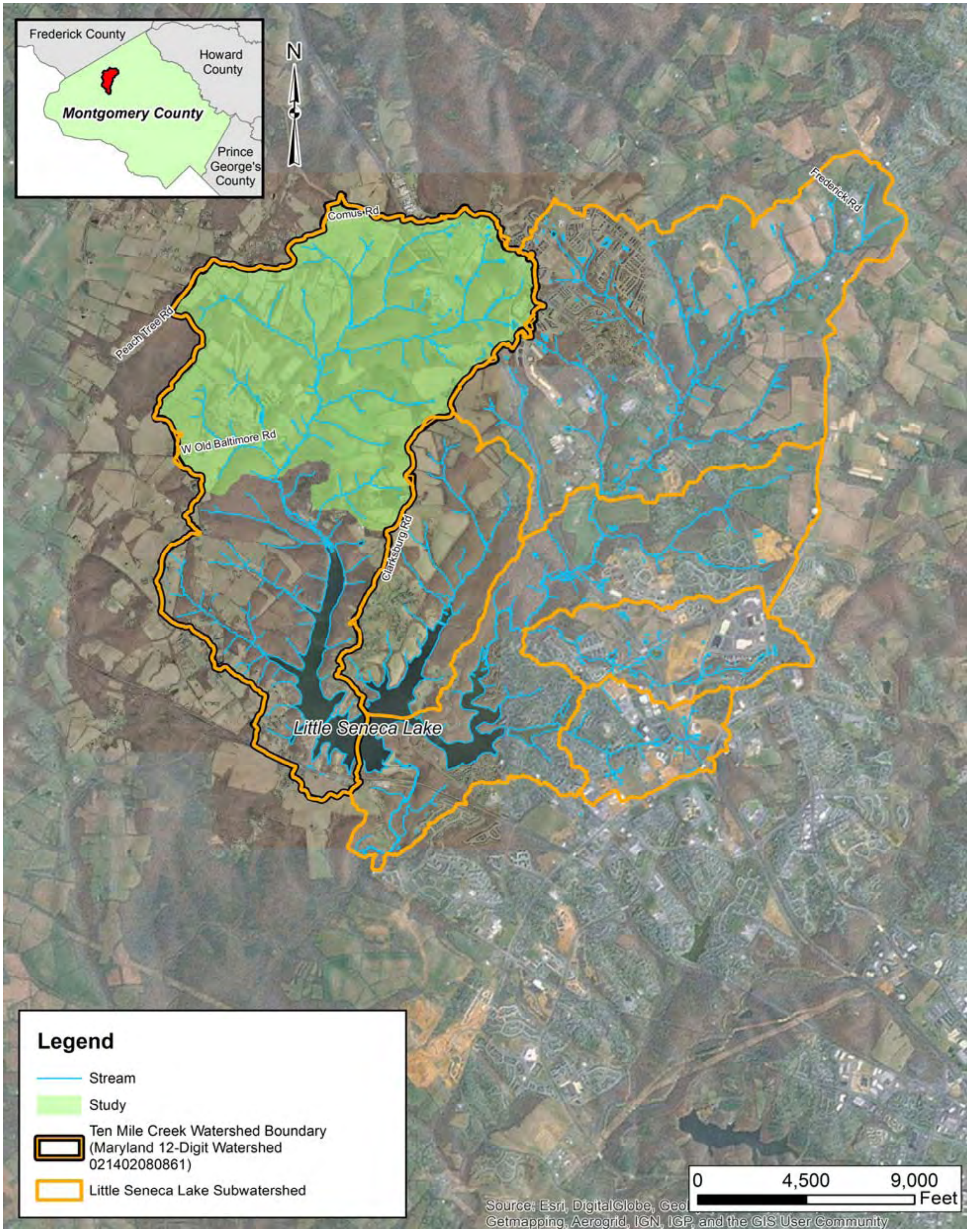


**Figure 1.1. Little Seneca Lake Watershed**

# 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<br>• Construction Completed in 2002<br>• Stormwater Conversion in April 2003 |
| Stringtown Road Extension | LSTM206 | 17 acres, Roadway | • Under Construction 2004<br>• Construction Completed in November 2006 |
| Gateway Commons | LSTM206 | | • March 2008, <30% under construction<br>• November 2008, 30 to 60% constructed<br>• 2010, >60% completed, and 30 to 60% permanently stabilized |
| Gateway 270 Corporations | LSTM206 | | • Construction Completed in 2010 |

Data source: DEP SPA Reports, 1994-2010

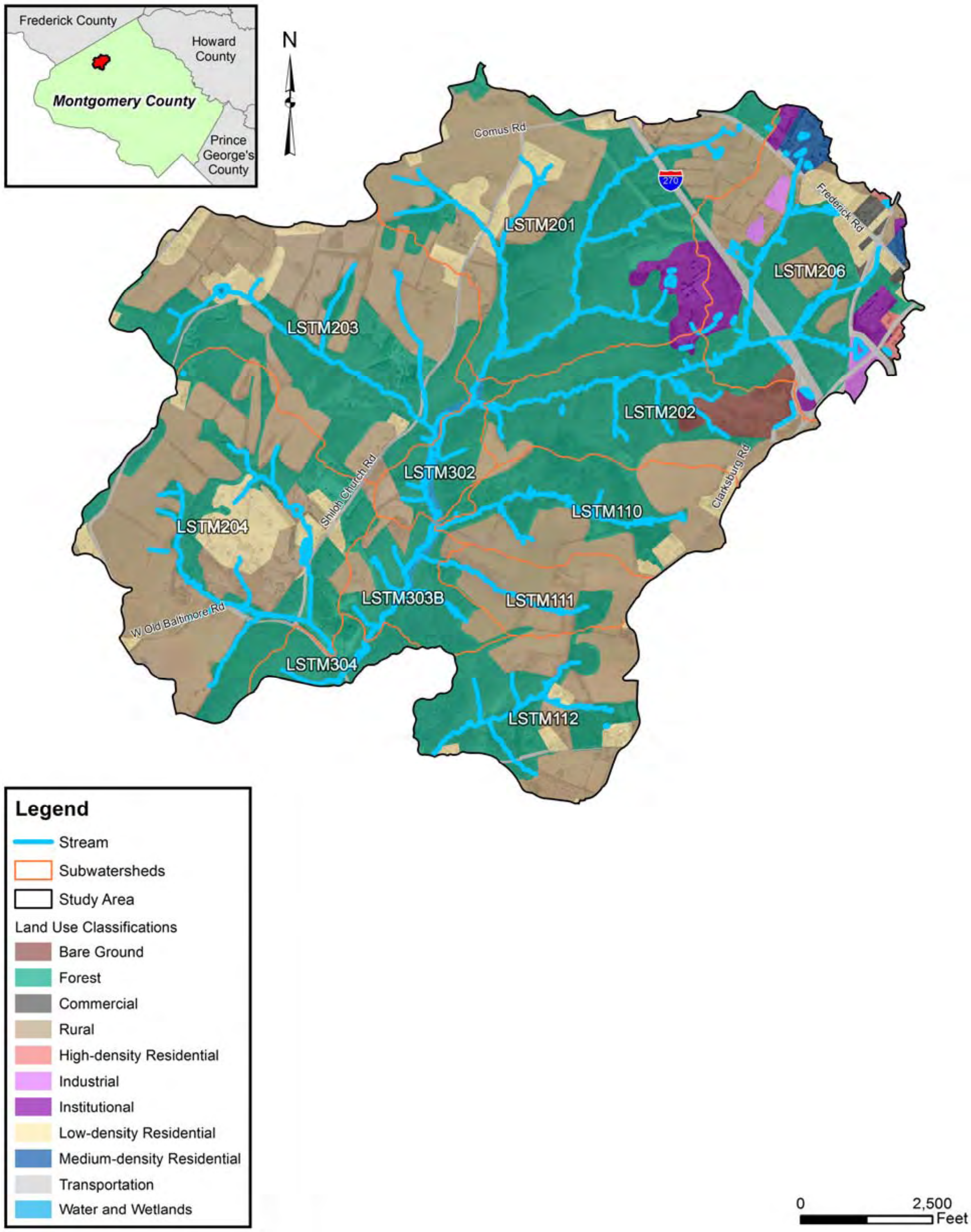


**Figure 2.1. Land Use in the Ten Mile Creek Study Area**

## 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)

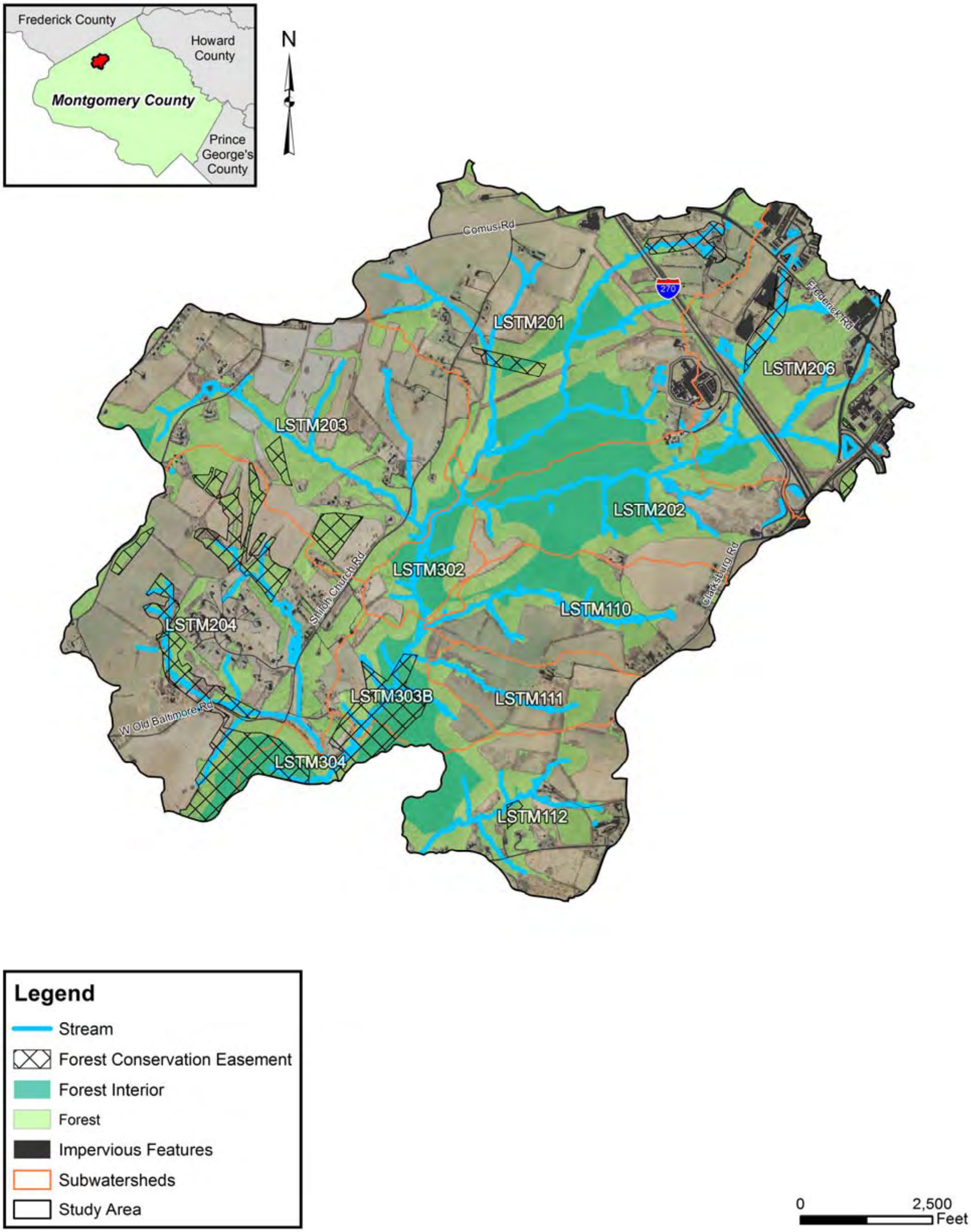


**Figure 2.2. Land Cover in the Ten Mile Creek Study Area**

## 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).

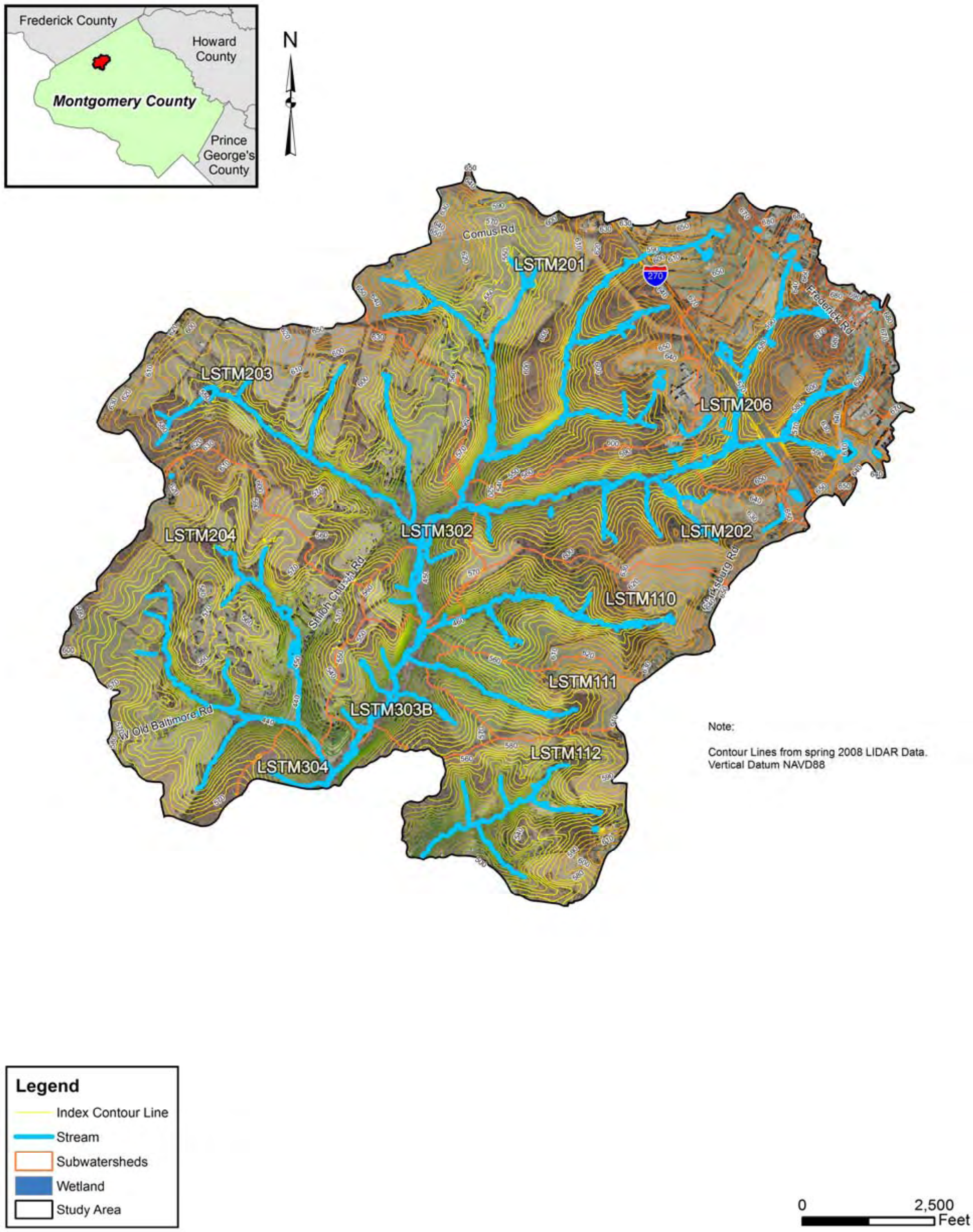


**Figure 3.1. Ten Mile Creek Study Area Topography**

## 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.

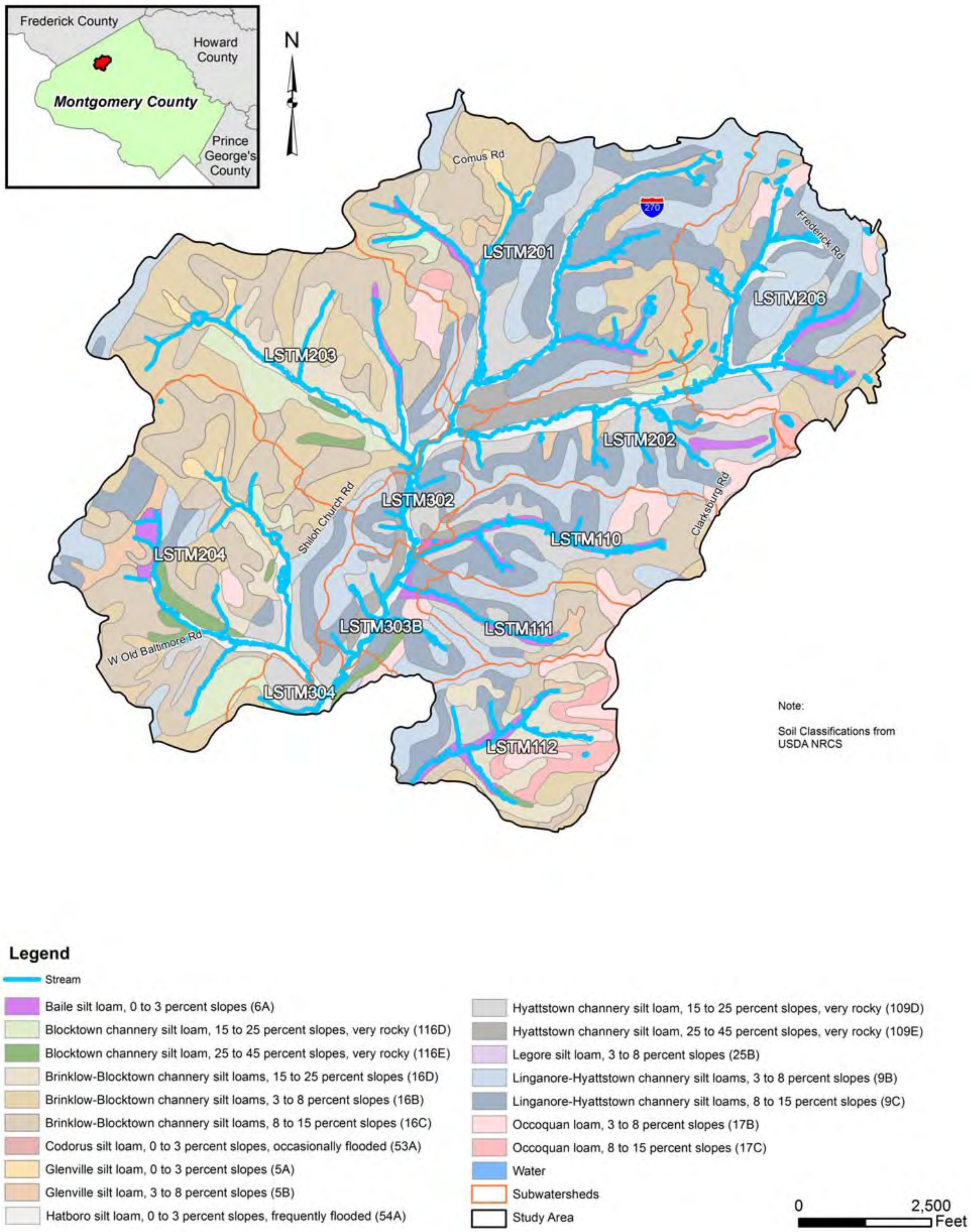


**Figure 3.2. Ten Mile Creek Study Area Soils**

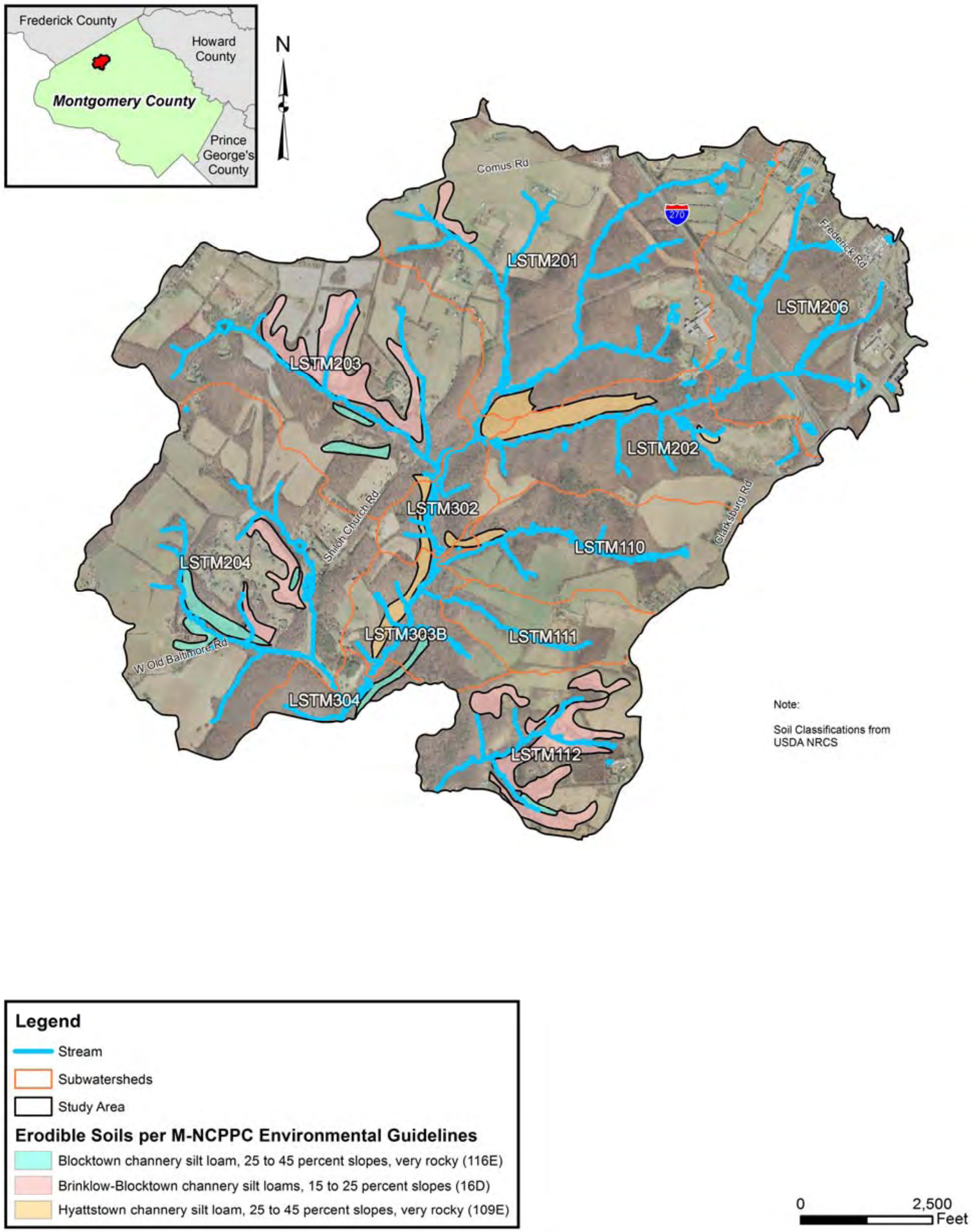


**Figure 3.3. Ten Mile Creek Study Area Erodible Soils**

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.

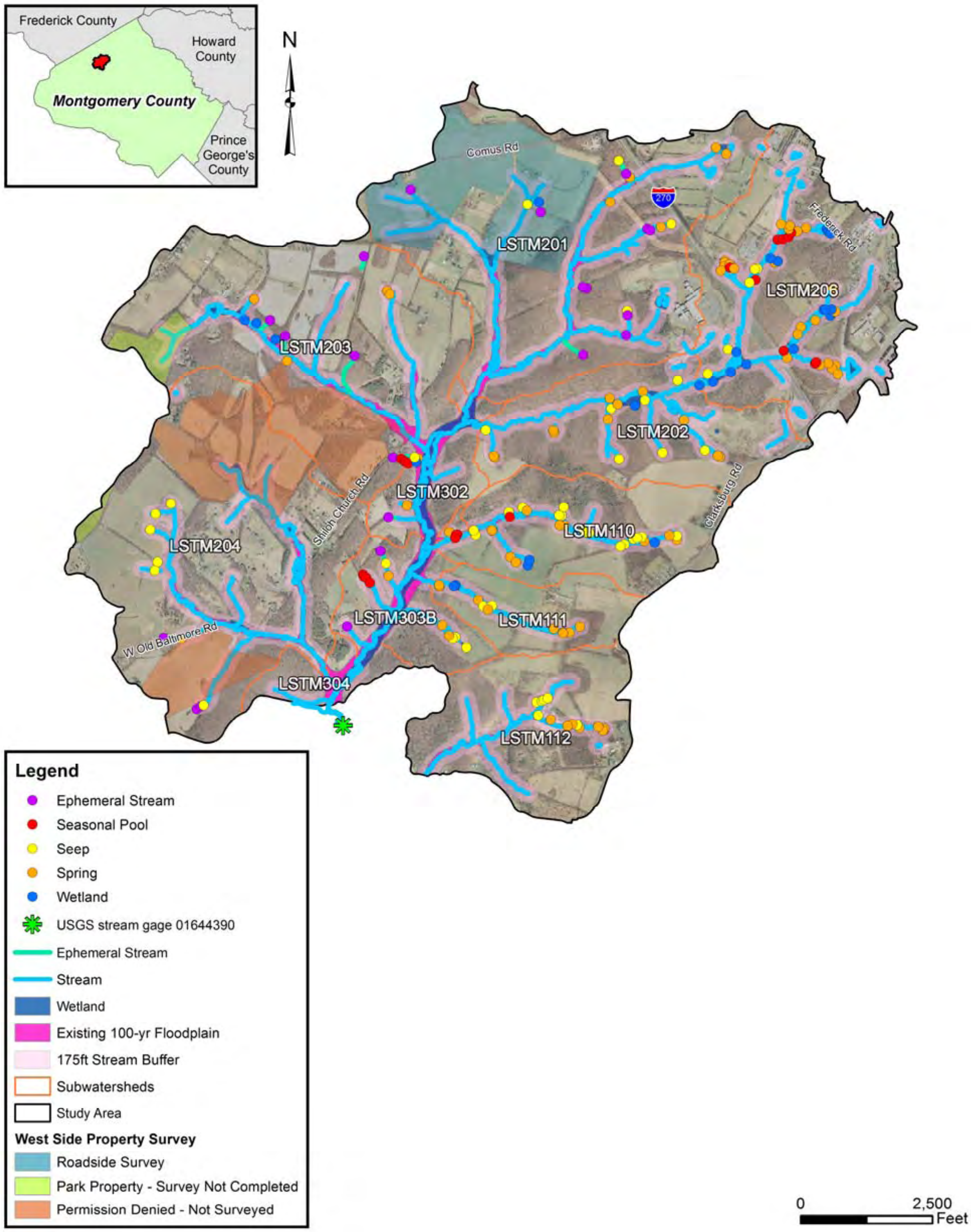


**Figure 3.4. Key Hydrologic Features in the Ten Mile Creek Study Area**

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.

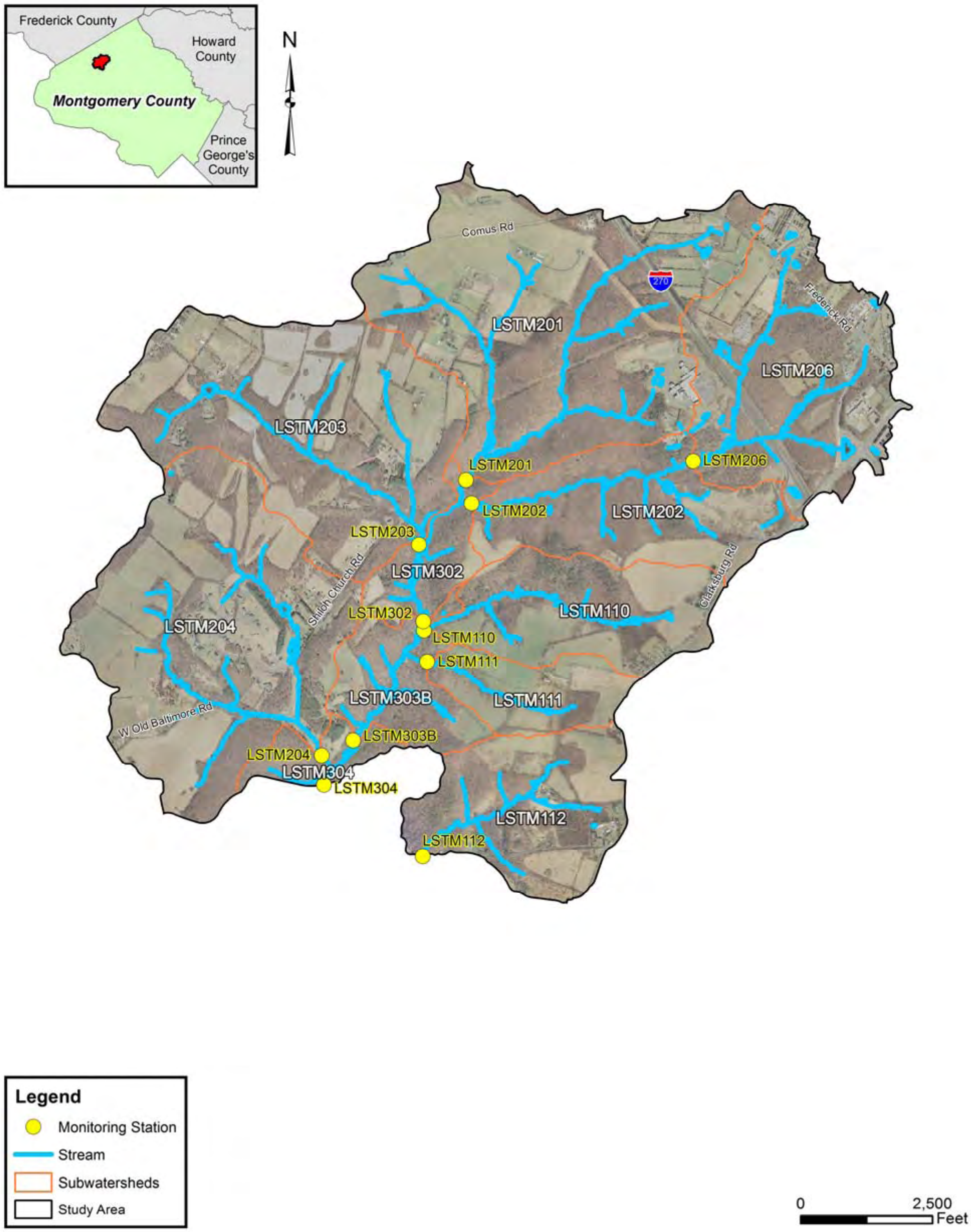


**Figure 3.9. Habitat, Biological, and Geomorphic Stream Monitoring Sites in the Ten Mile Creek Study Area**

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.

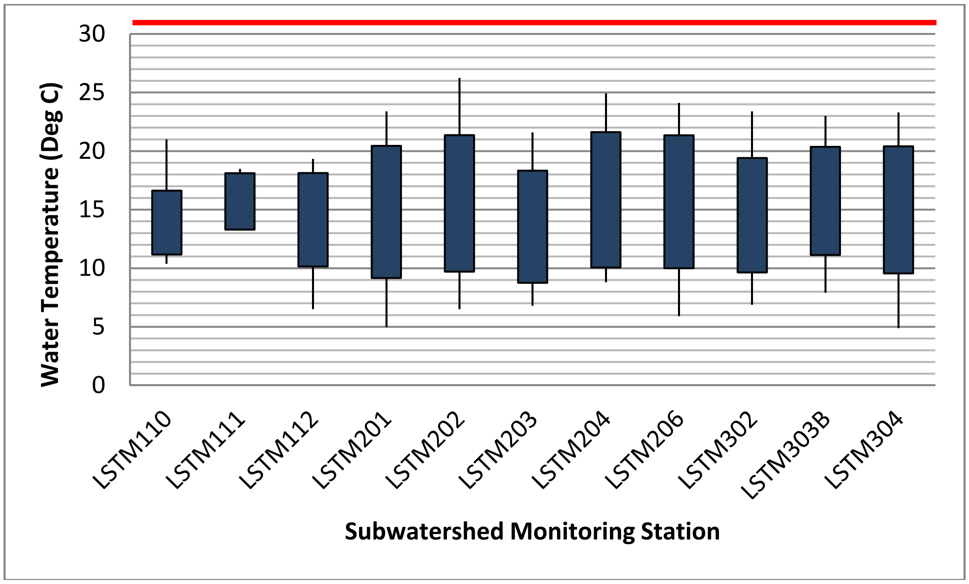


**Figure 3.10. 90% Confidence Interval, Maximum, and Minimum Water Temperature Values for Ten Mile Creek Biological Stream Monitoring Stations. The red line indicates the State Standard for Maximum Temperature in Use I-P Streams (32 deg C).**

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).

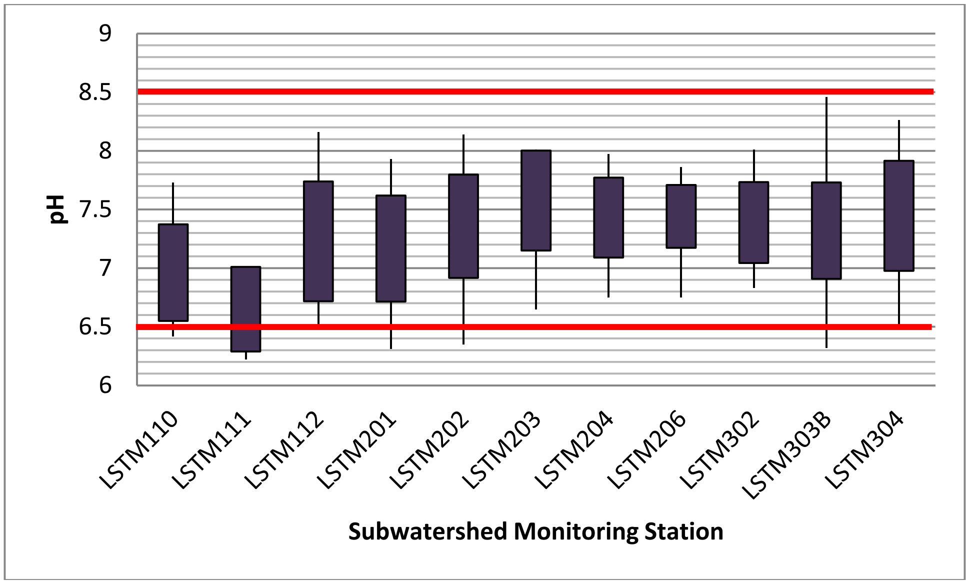


**Figure 3.11. 90% Confidence Interval, Maximum, and Minimum for pH Values for Ten Mile Creek Biological Stream Monitoring Stations. The red lines indicate the State Standard for Maximum (8.5) and Minimum (6.5) pH in Use I-P Streams.**

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).

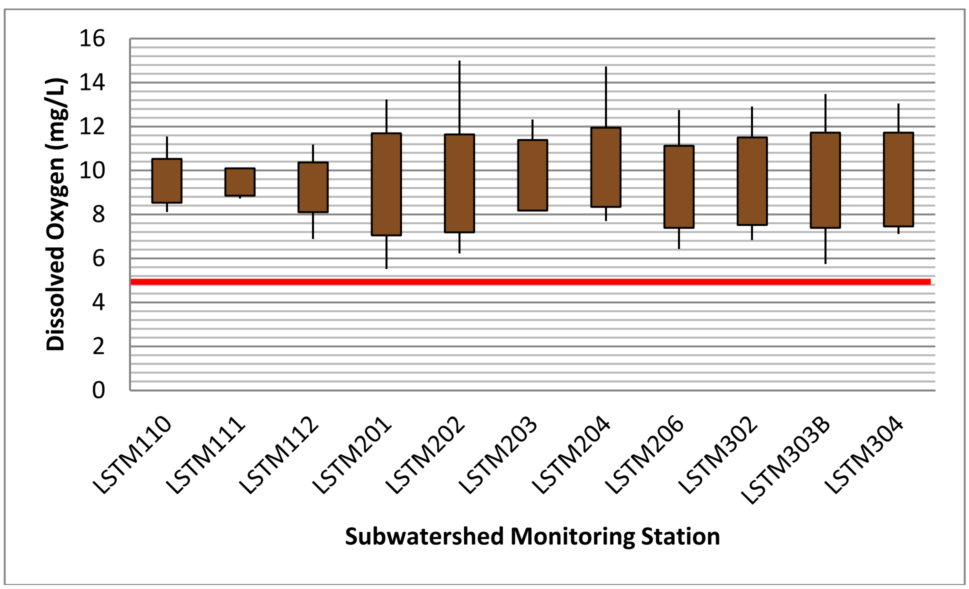


**Figure 3.12. 90% Confidence Interval, Maximum, and Minimum Dissolved Oxygen Values for Ten Mile Creek Biological Stream Monitoring Stations. The red line indicates the State Standard for Minimum Dissolved Oxygen in Use I-P Streams (5 mg/L).**

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).

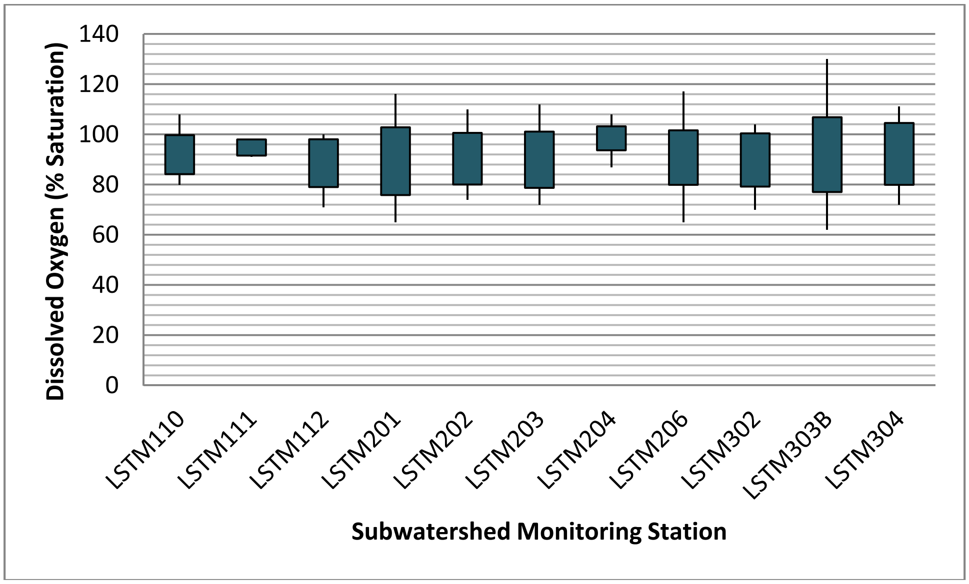


**Figure 3.13. 90% Confidence Interval, Maximum, and Minimum for Percent Saturation of Dissolved Oxygen Values for Ten Mile Creek Biological Stream Monitoring Stations.**

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.

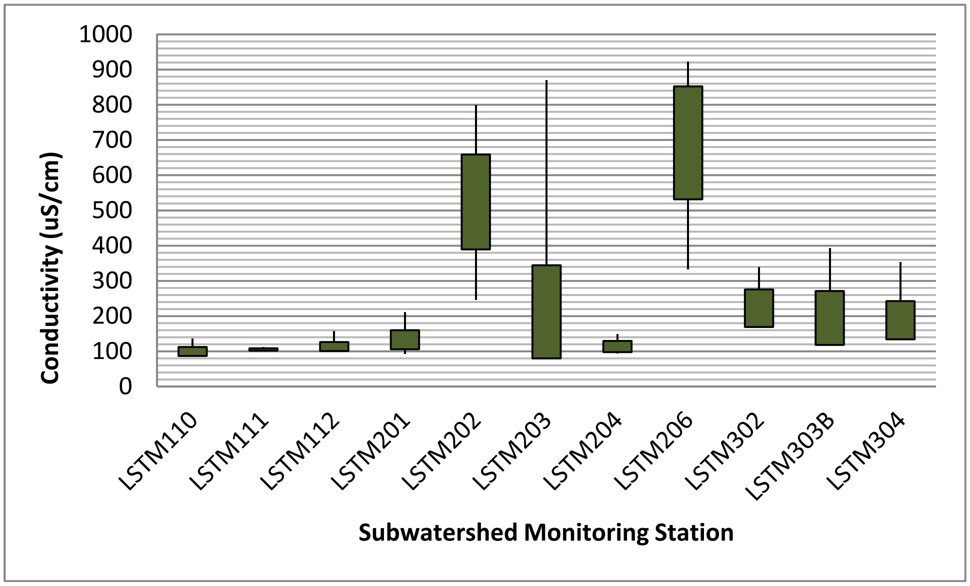


**Figure 3.14. 90% Confidence Interval, Maximum, and Minimum for Conductivity Values for Ten Mile Creek Biological Stream Monitoring Stations**

***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.

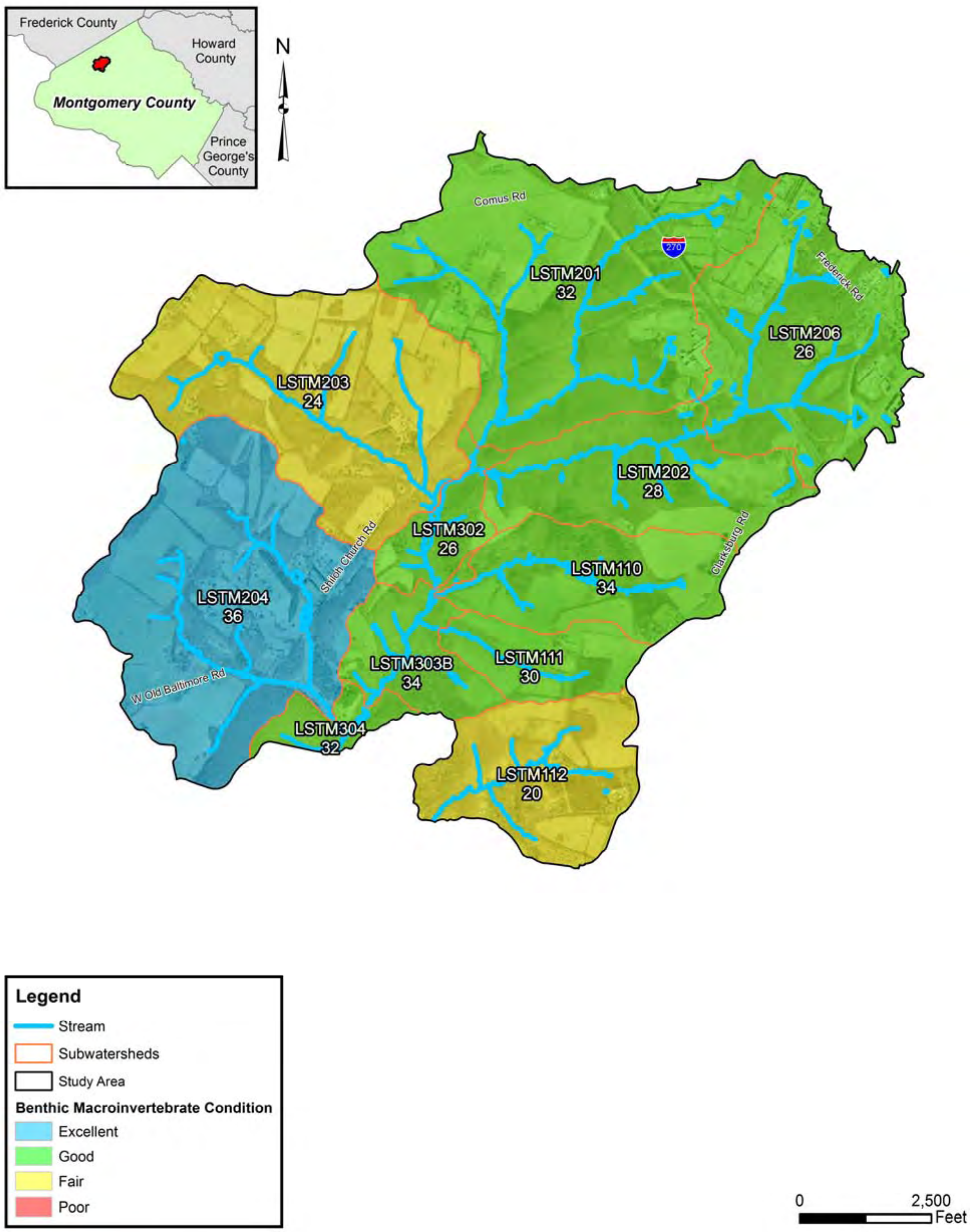


**Figure 3.15. 2012 subwatershed benthic IBI rating.**

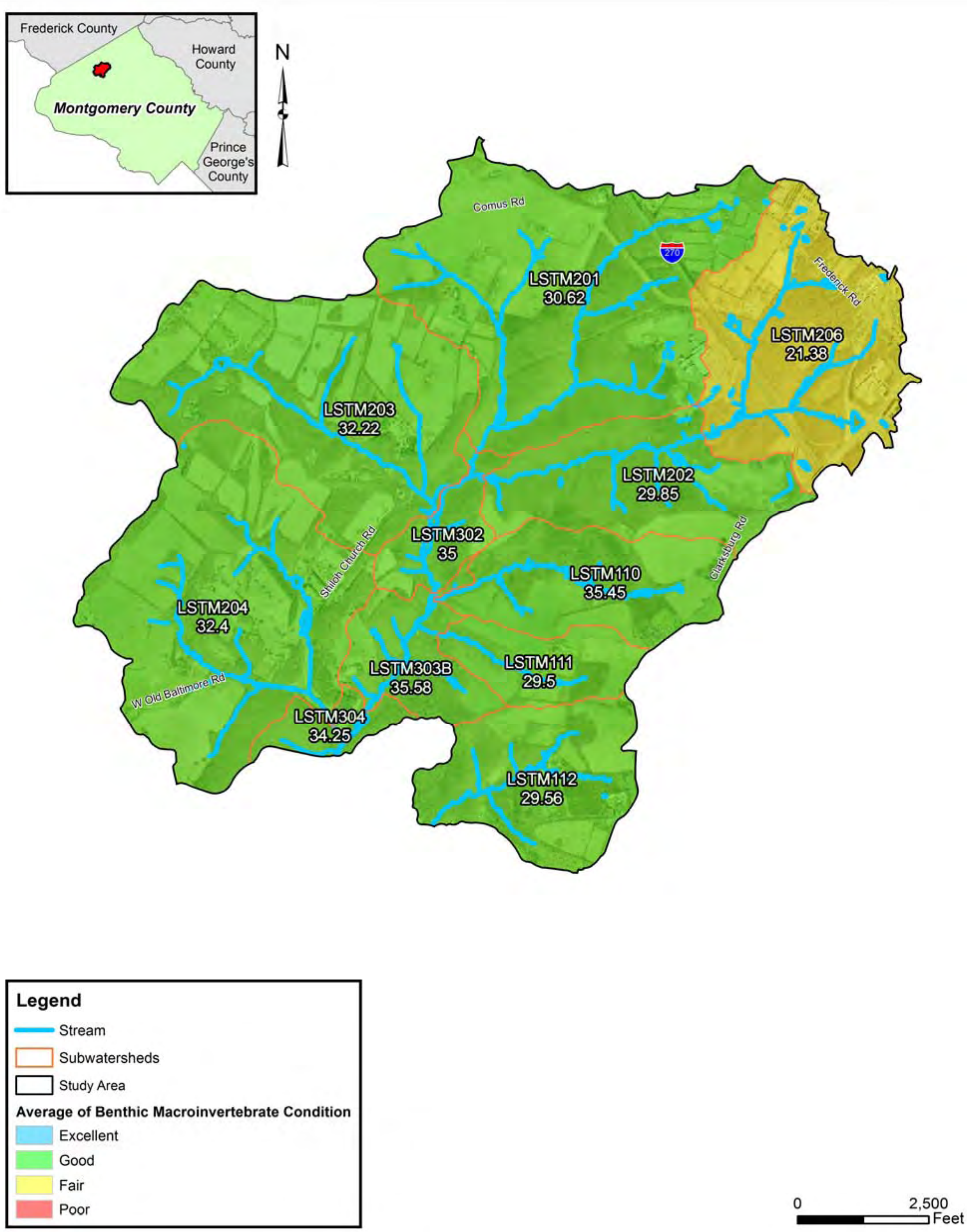


**Figure 3.16. Average subwatershed benthic IBI rating (1994-2012).**

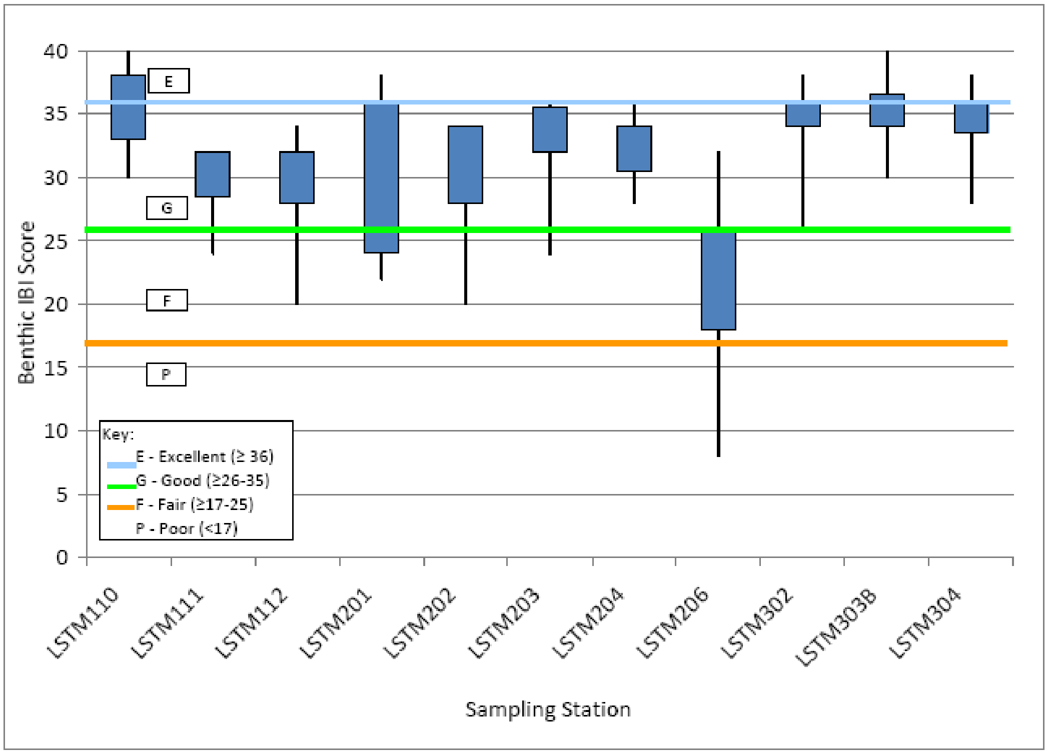


**Figure 3.17. Ranges of composite Benthic IBI scores among the permanent sampling stations (1994-2012).**

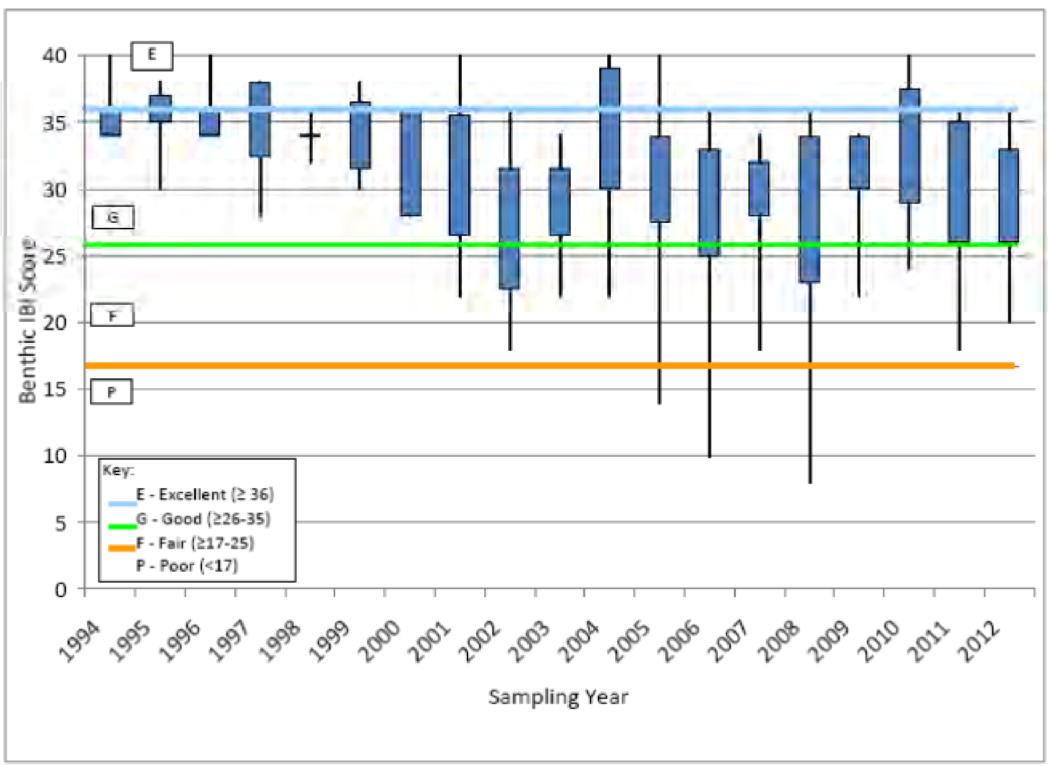


**Figure 3.18. Variability among Benthic IBI scores at all sampling stations over time.**

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).

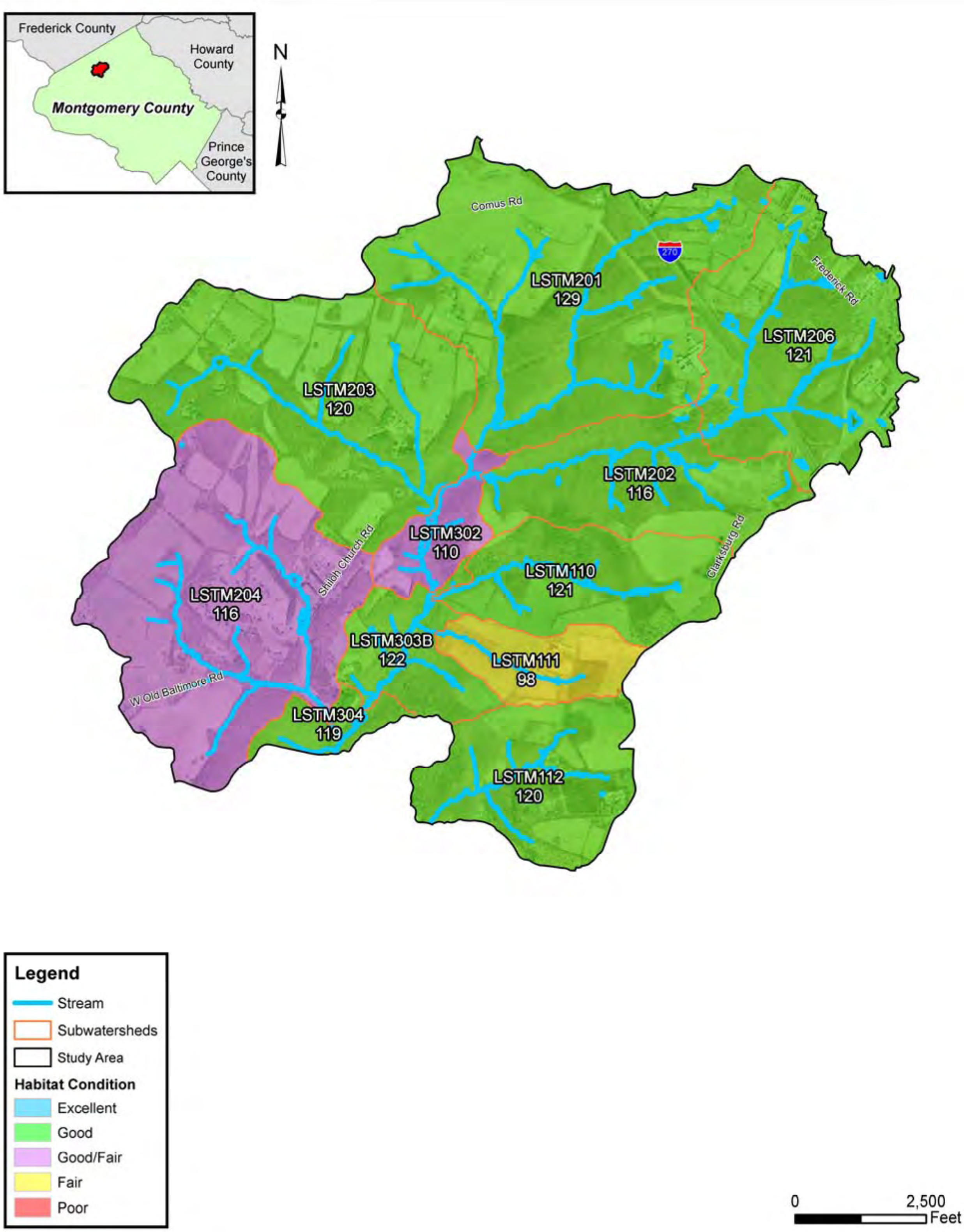


**Figure 3.19. 2012 subwatershed habitat condition rating.**

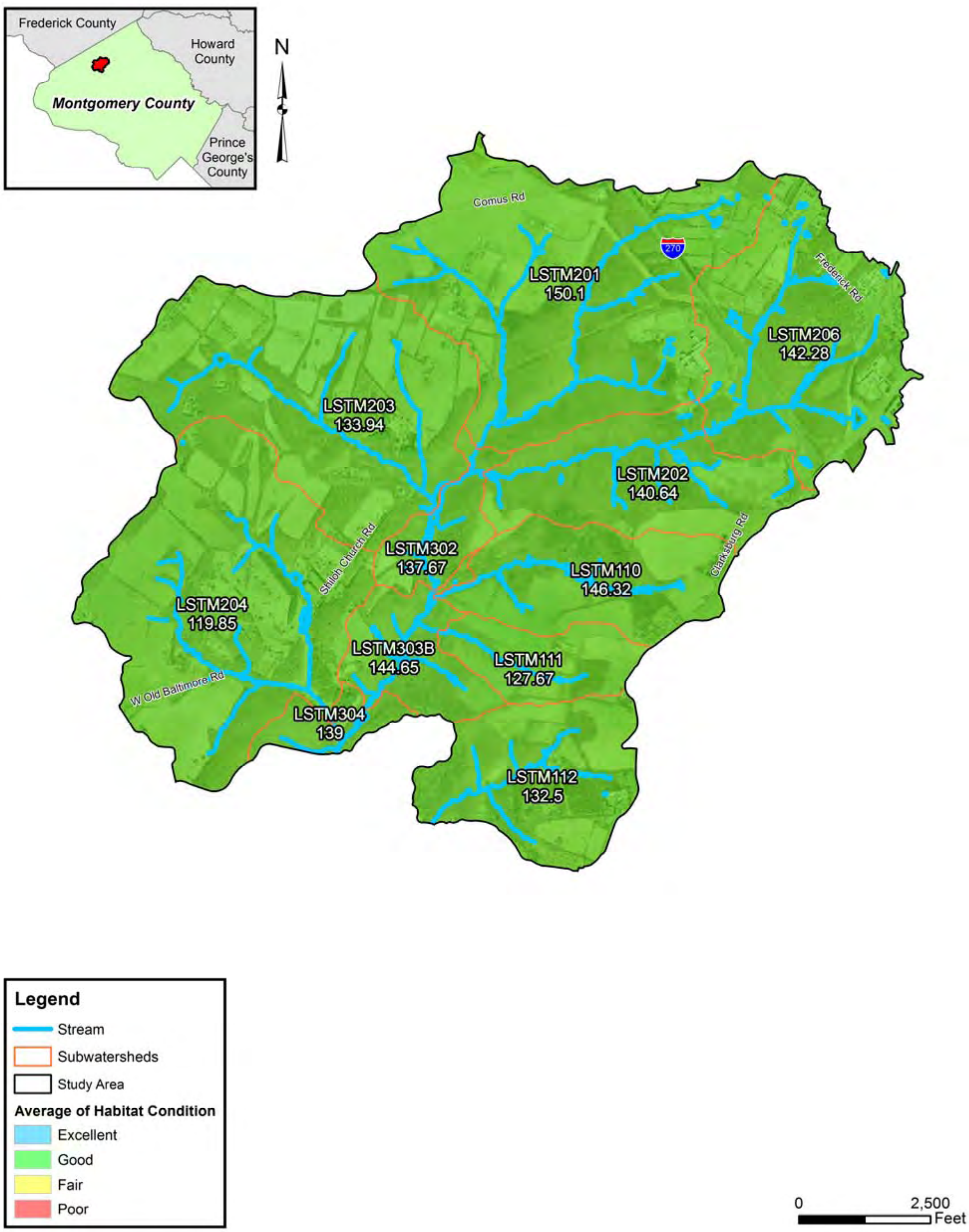


**Figure 3.20. Average subwatershed habitat condition rating (1994-2012).**

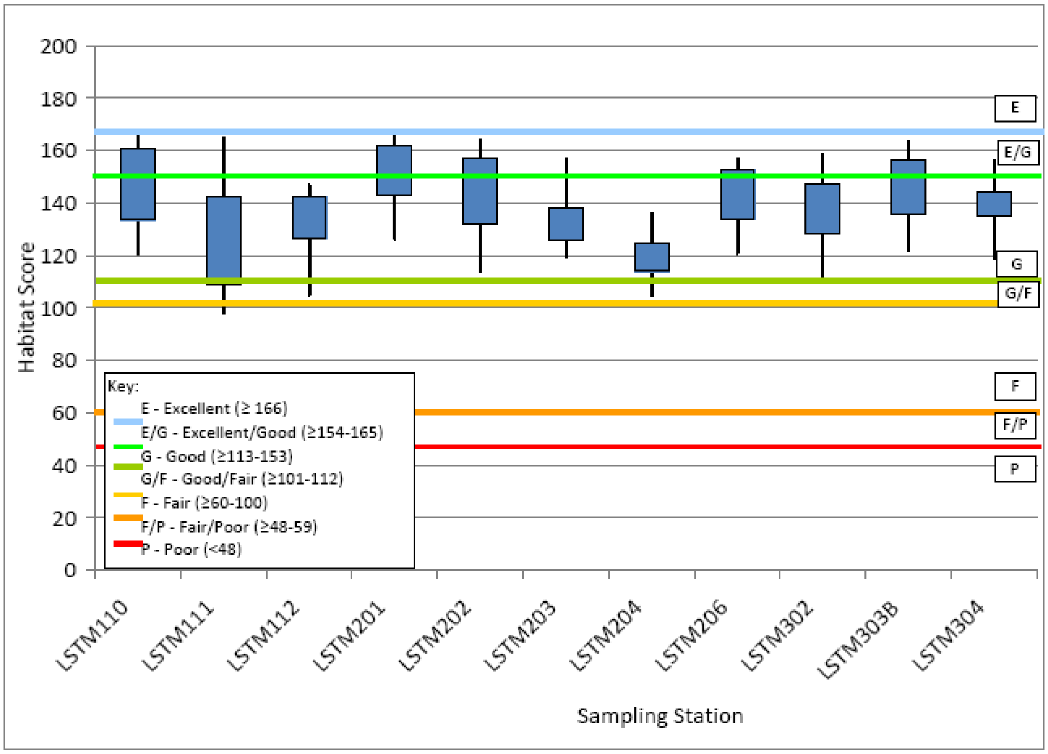


**Figure 3.21. Ranges of composite habitat scores among the permanent sampling stations (1994-2012).**

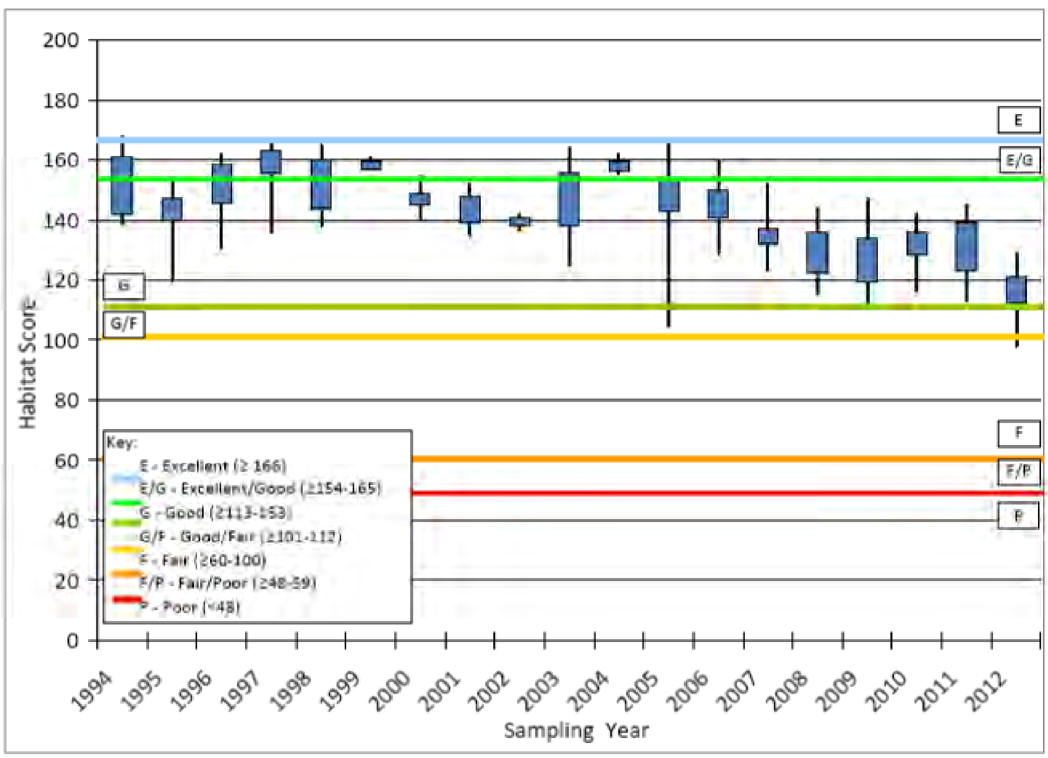


**Figure 3.22. Variability among habitat scores at all sampling stations over time.**

***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.

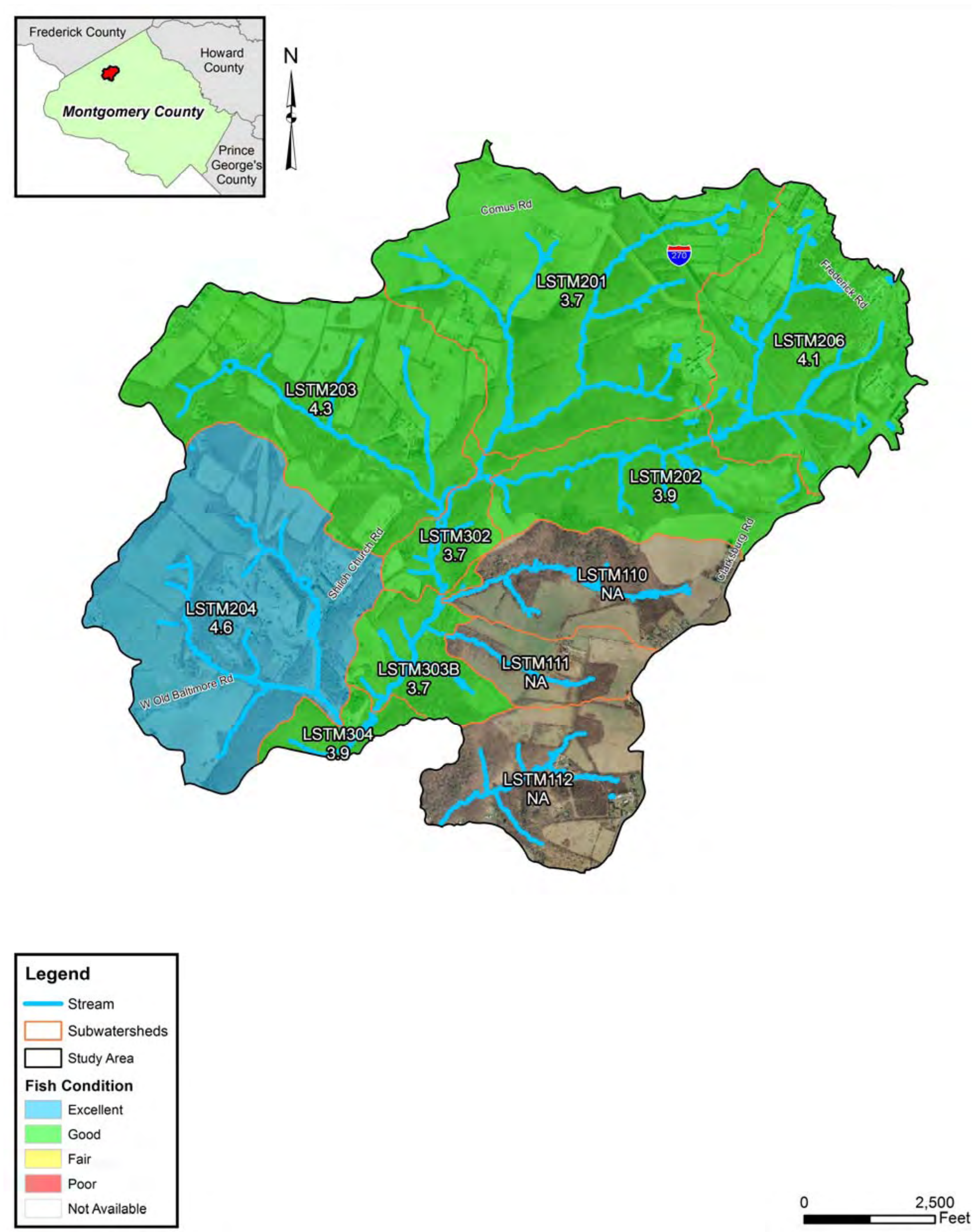


**Figure 3.23. 2012 subwatershed fish IBI rating.**

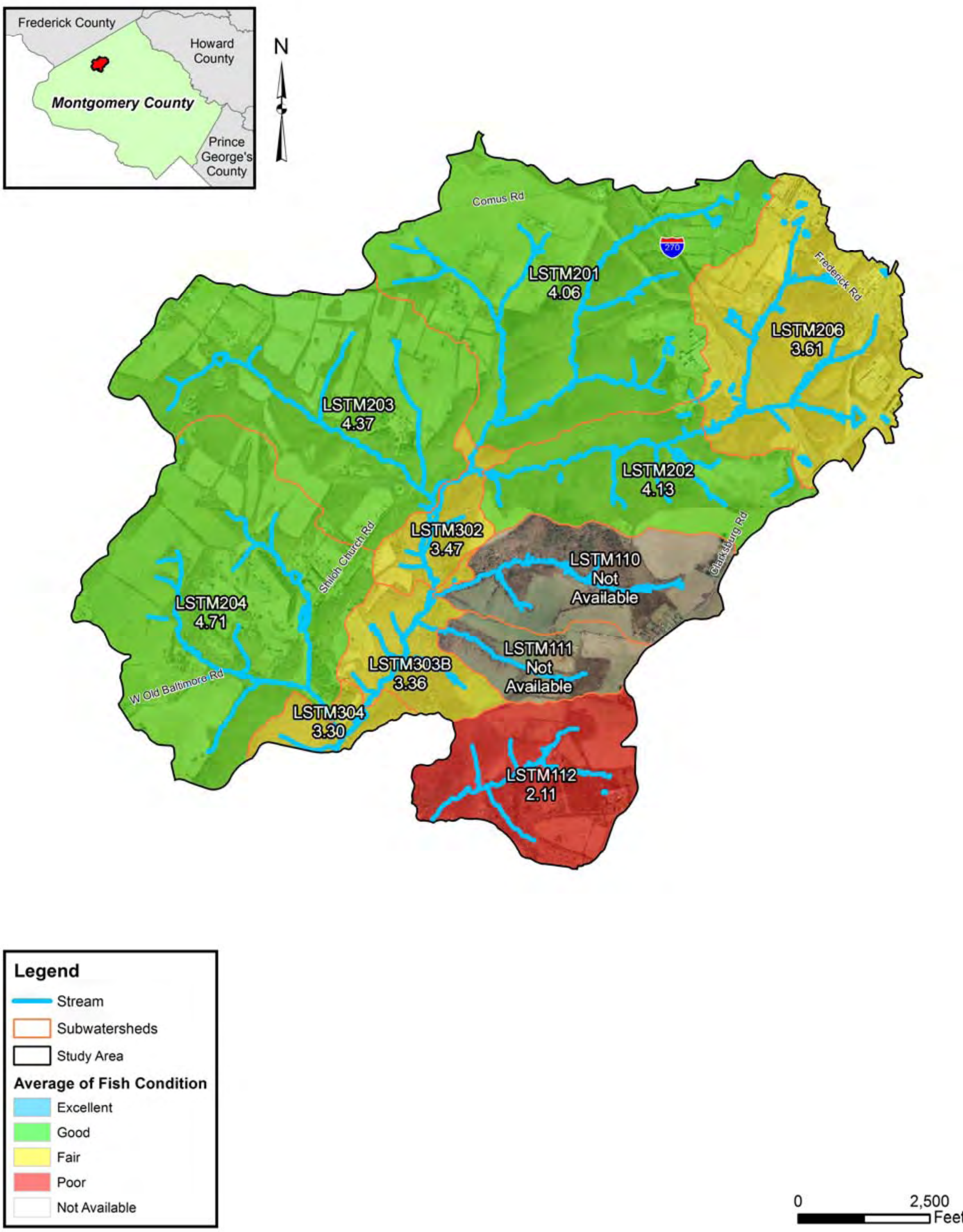


**Figure 3.24. Average subwatershed fish IBI rating (1994-2012).**

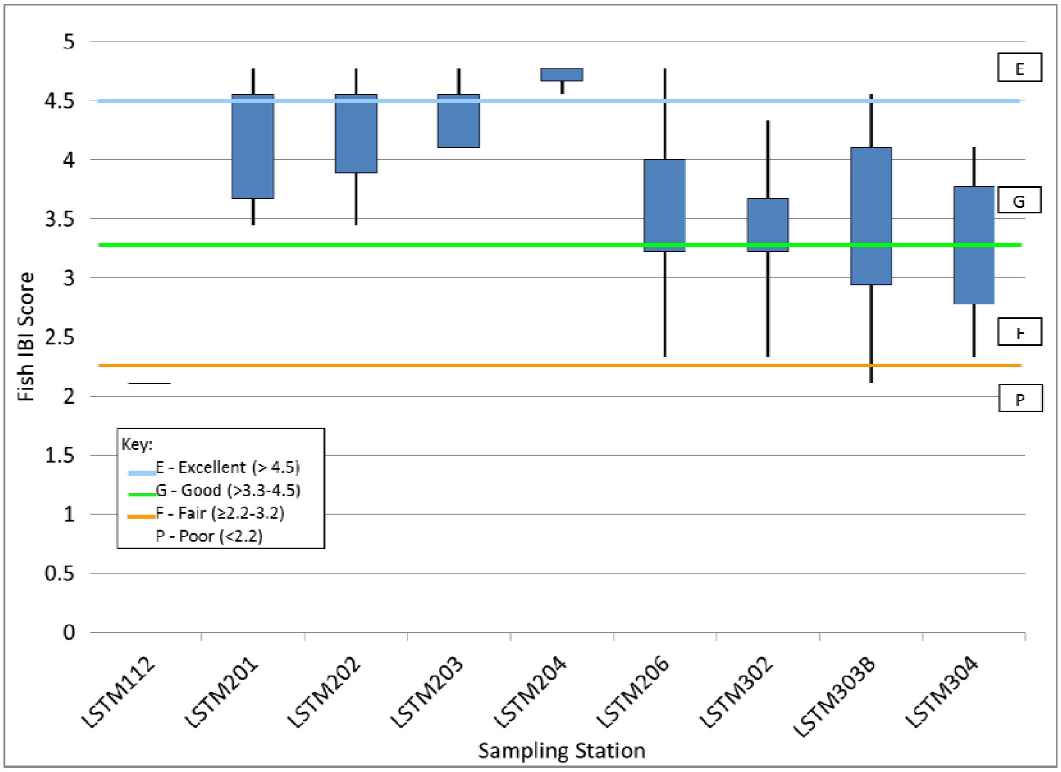


**Figure 3.25. Ranges of composite Fish IBI scores among the permanent sampling stations (1994-2012).**

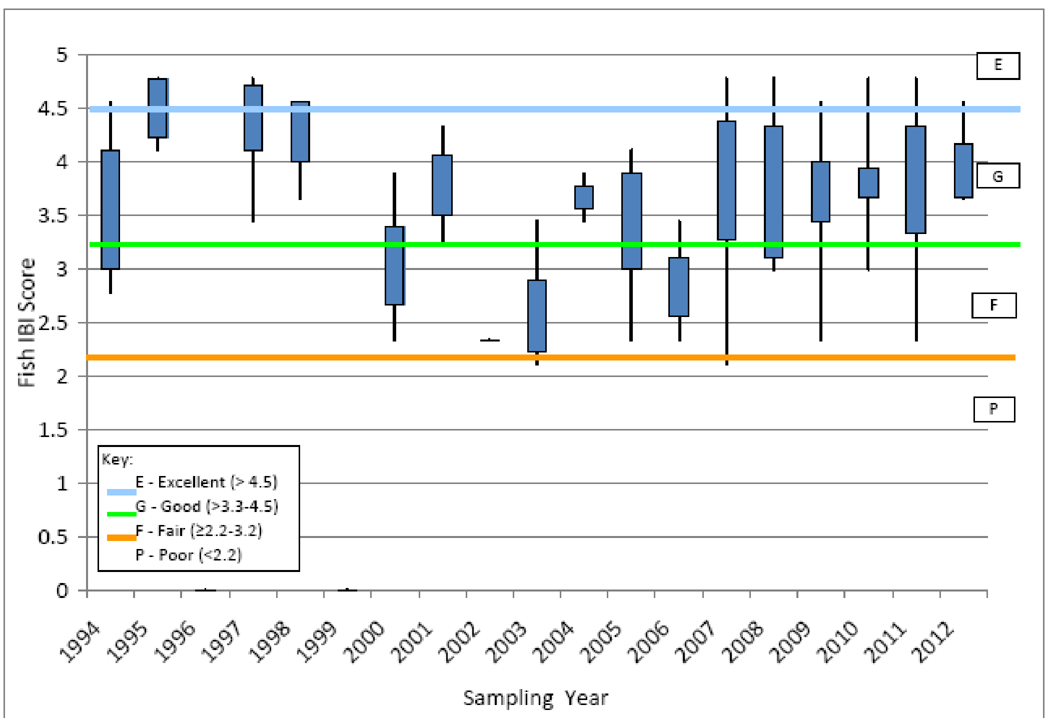


**Figure 3.26. Variability among Fish IBI scores at all sampling stations over time.**

***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.

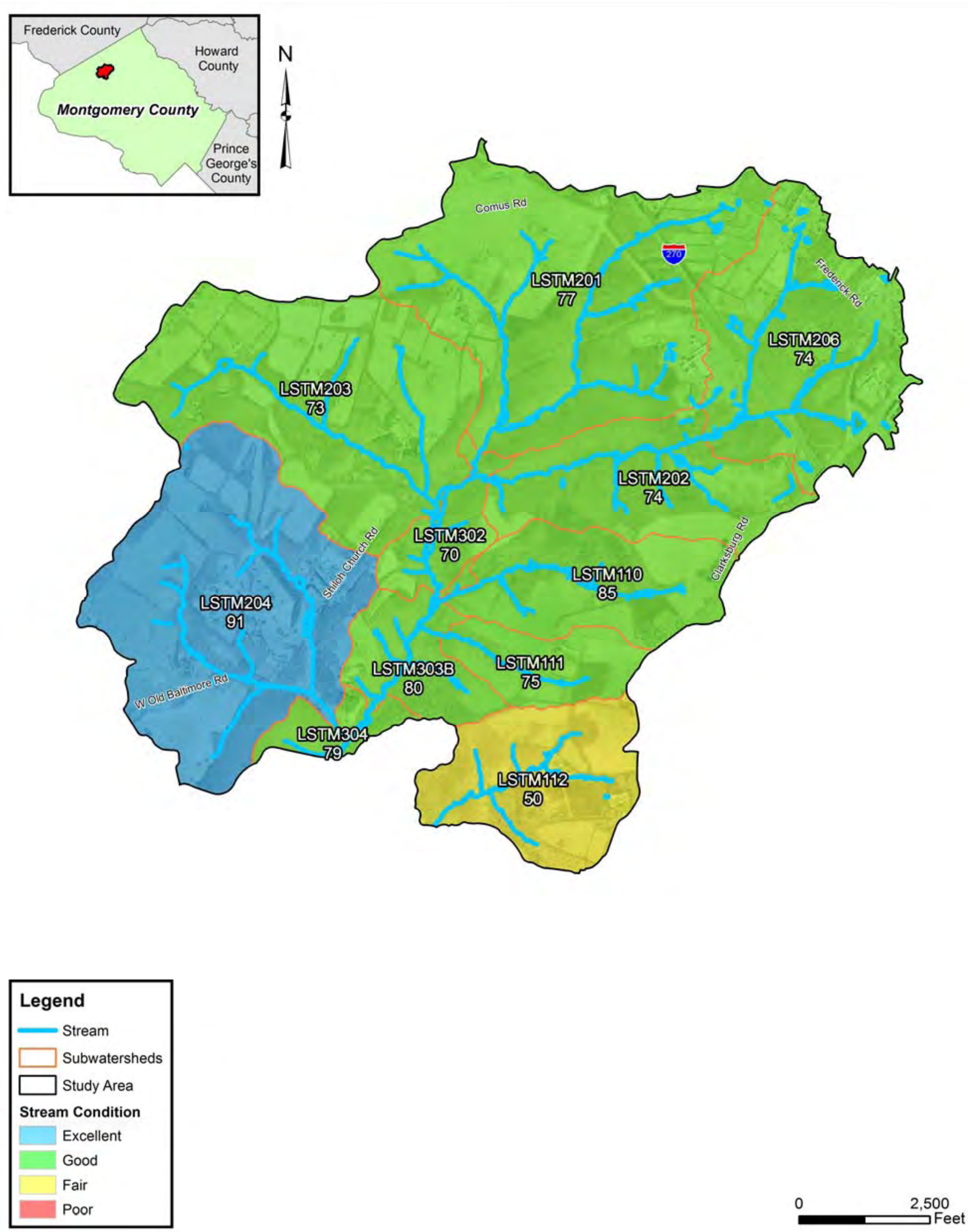


**Figure 3.27. 2012 subwatershed biological condition rating.**

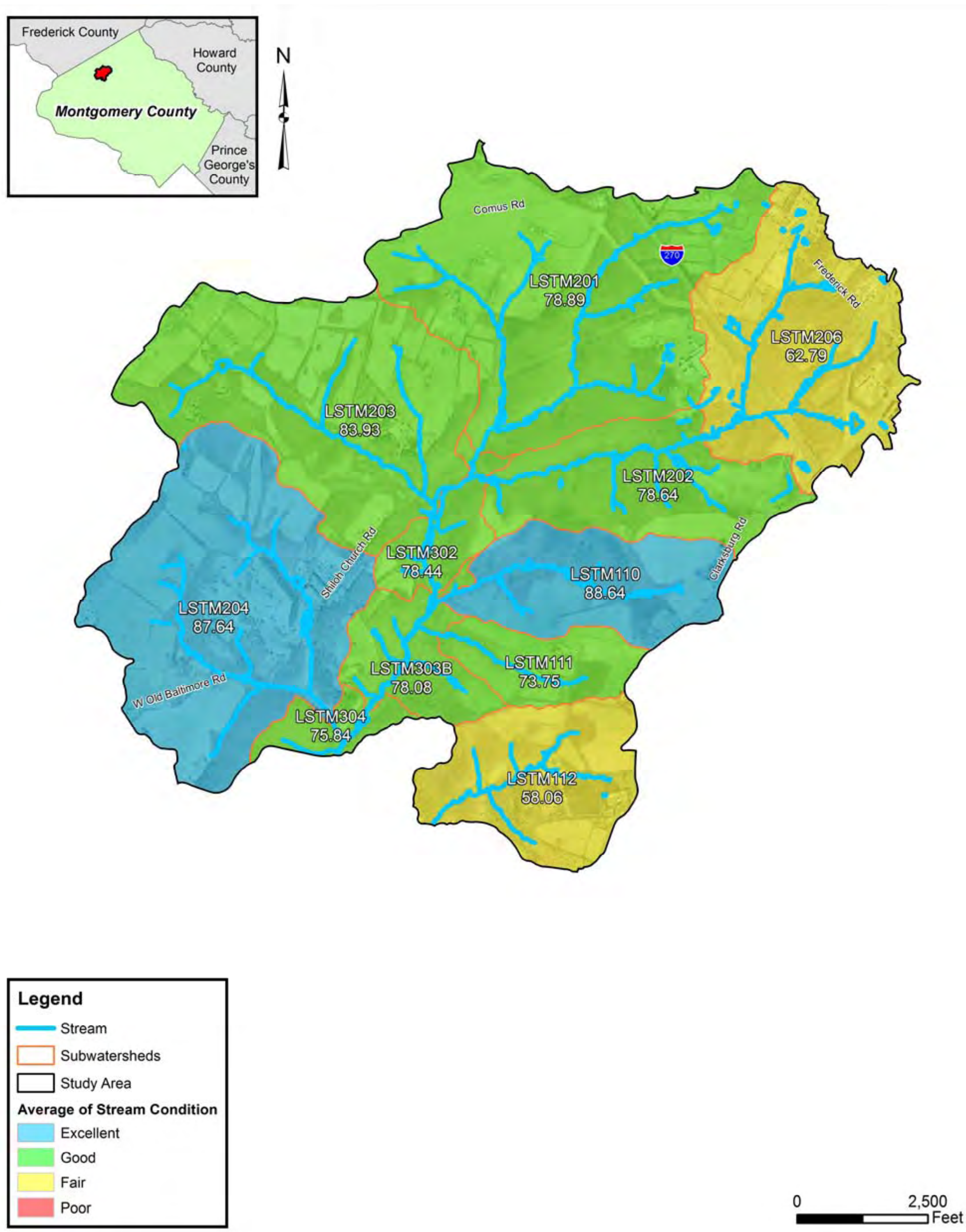


**Figure 3.28. Average subwatershed biological condition rating (1994-2012).**

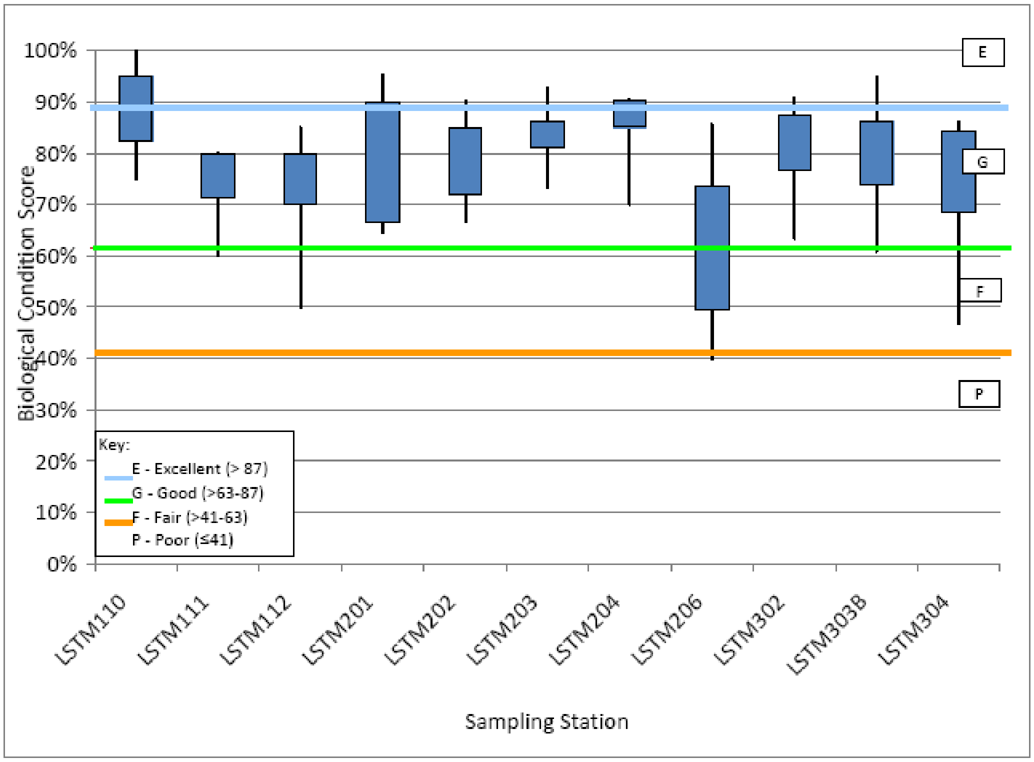


**Figure 3.29. Ranges of composite Biological Condition scores among the permanent sampling stations (1994-2012).**

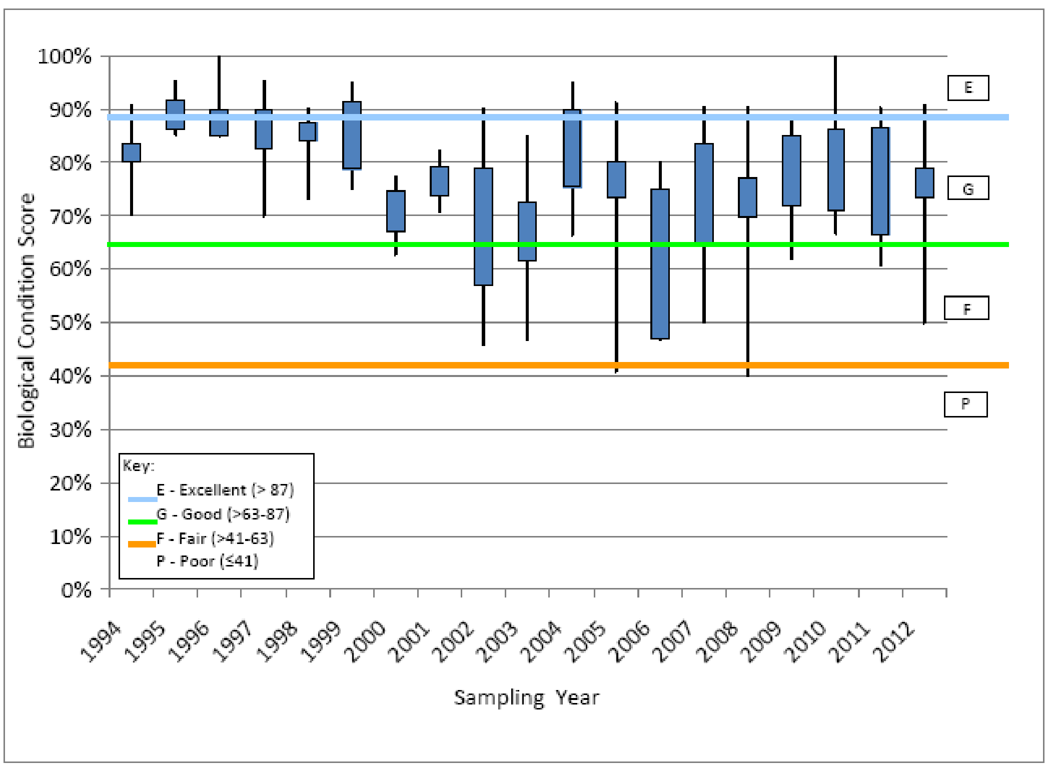


**Figure 3.30. Variability among biological condition scores at all sampling stations over time.**

## 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.

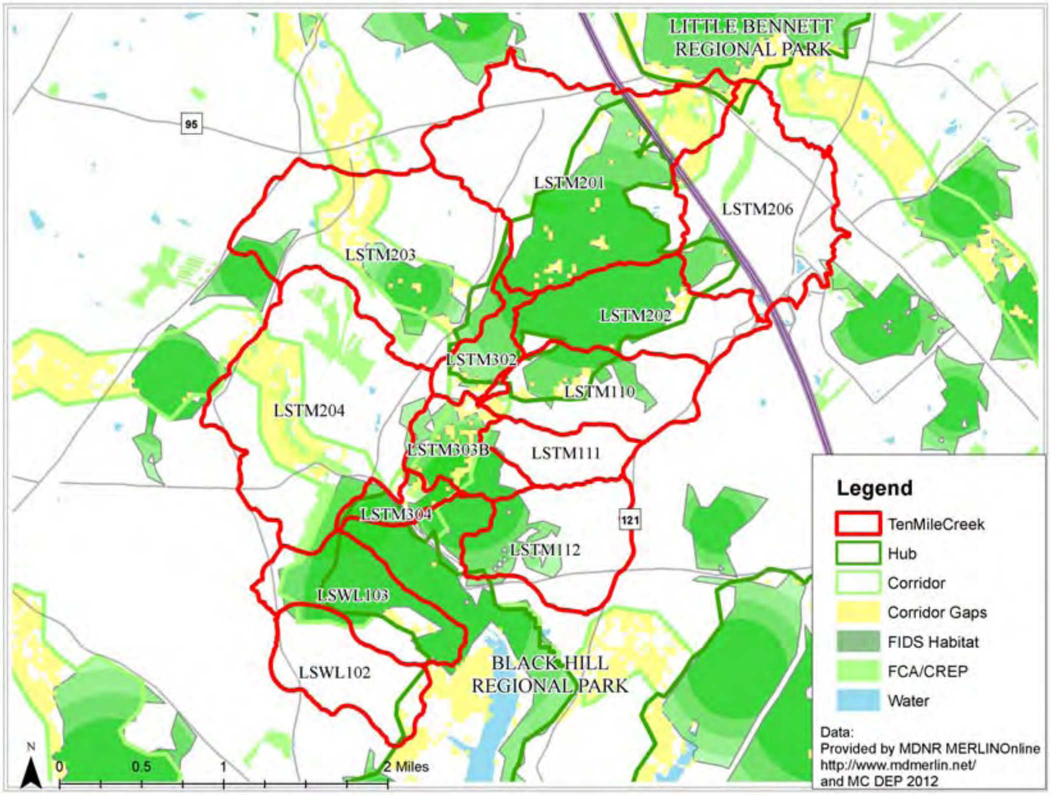


**Figure 3.31. Overview of MDNR's hubs and corridors and forest connectivity data within the project area.**

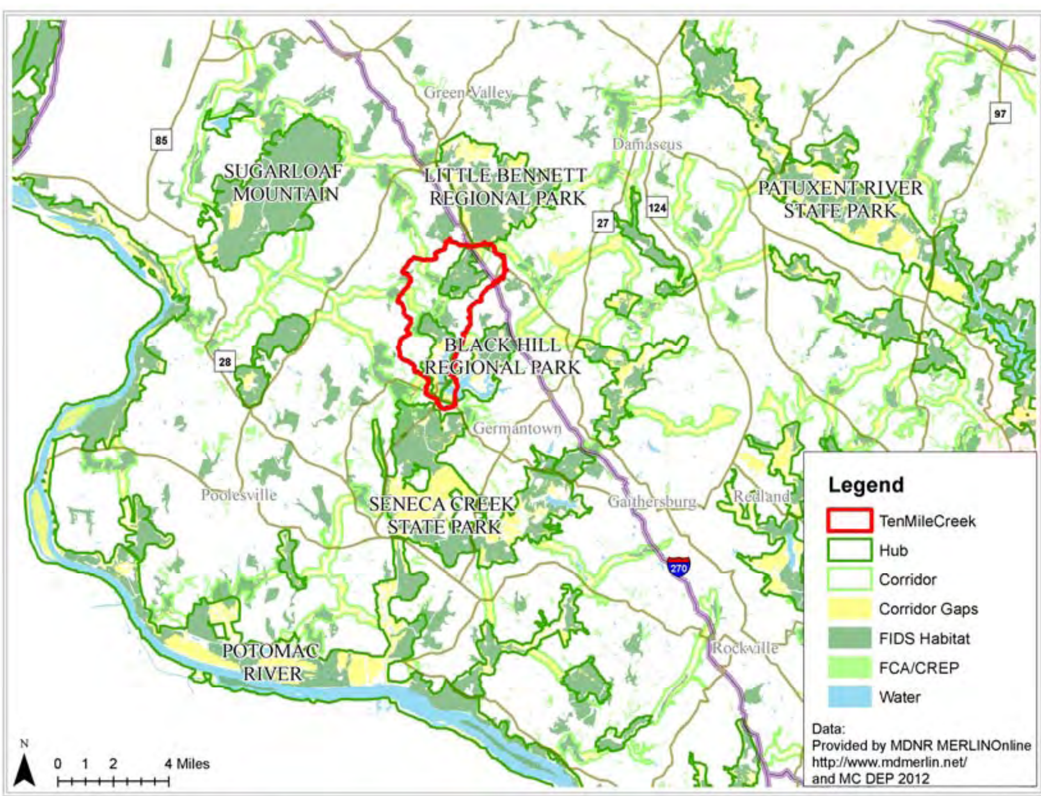


**Figure 3.32. Regional overview of MDNR's hubs and corridors and forest connectivity data.**

### *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 18$^{th}$ to early 19$^{th}$ 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).

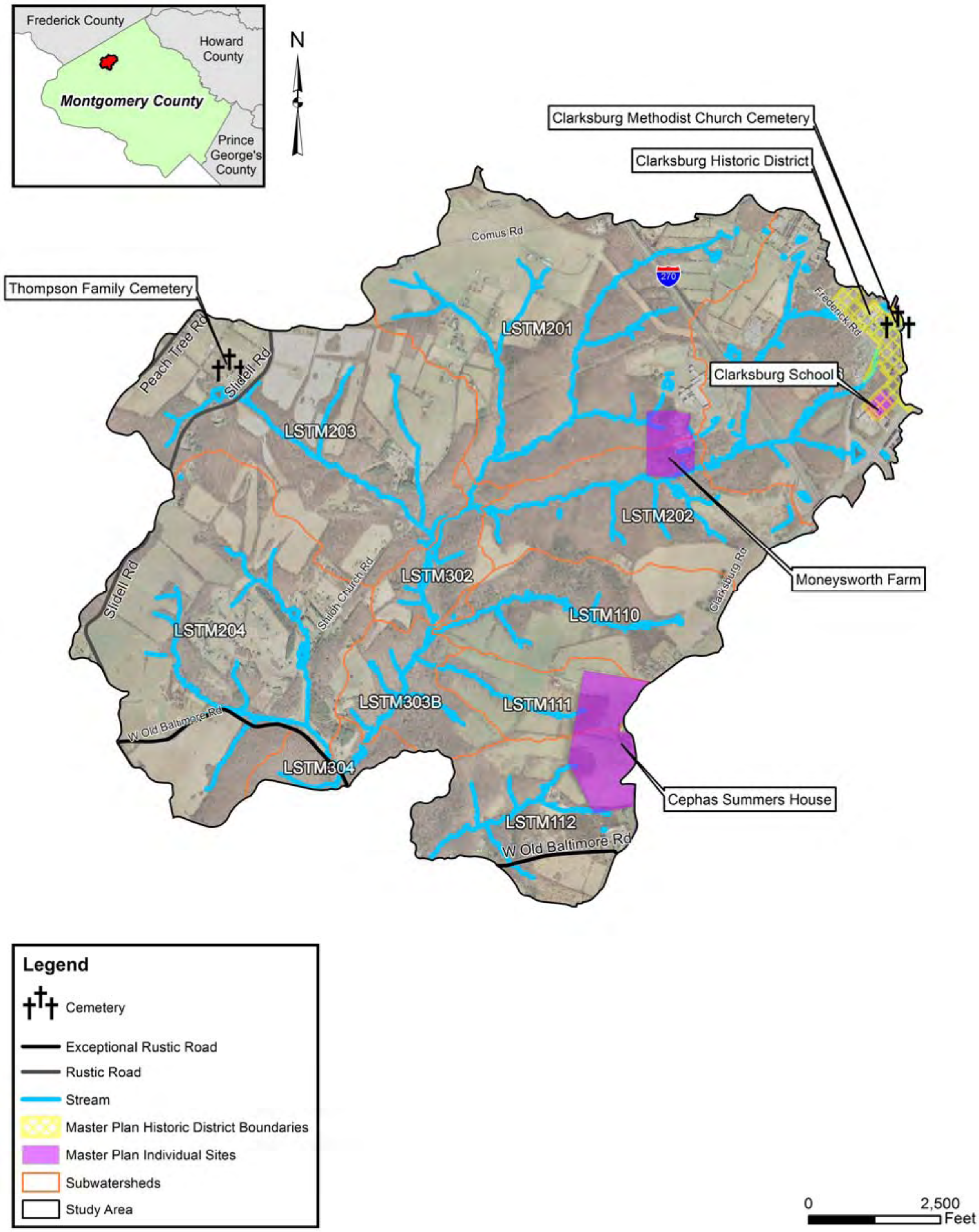


**Figure 4.1. Historic and Cultural Sites**

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 19$^{th}$ 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.

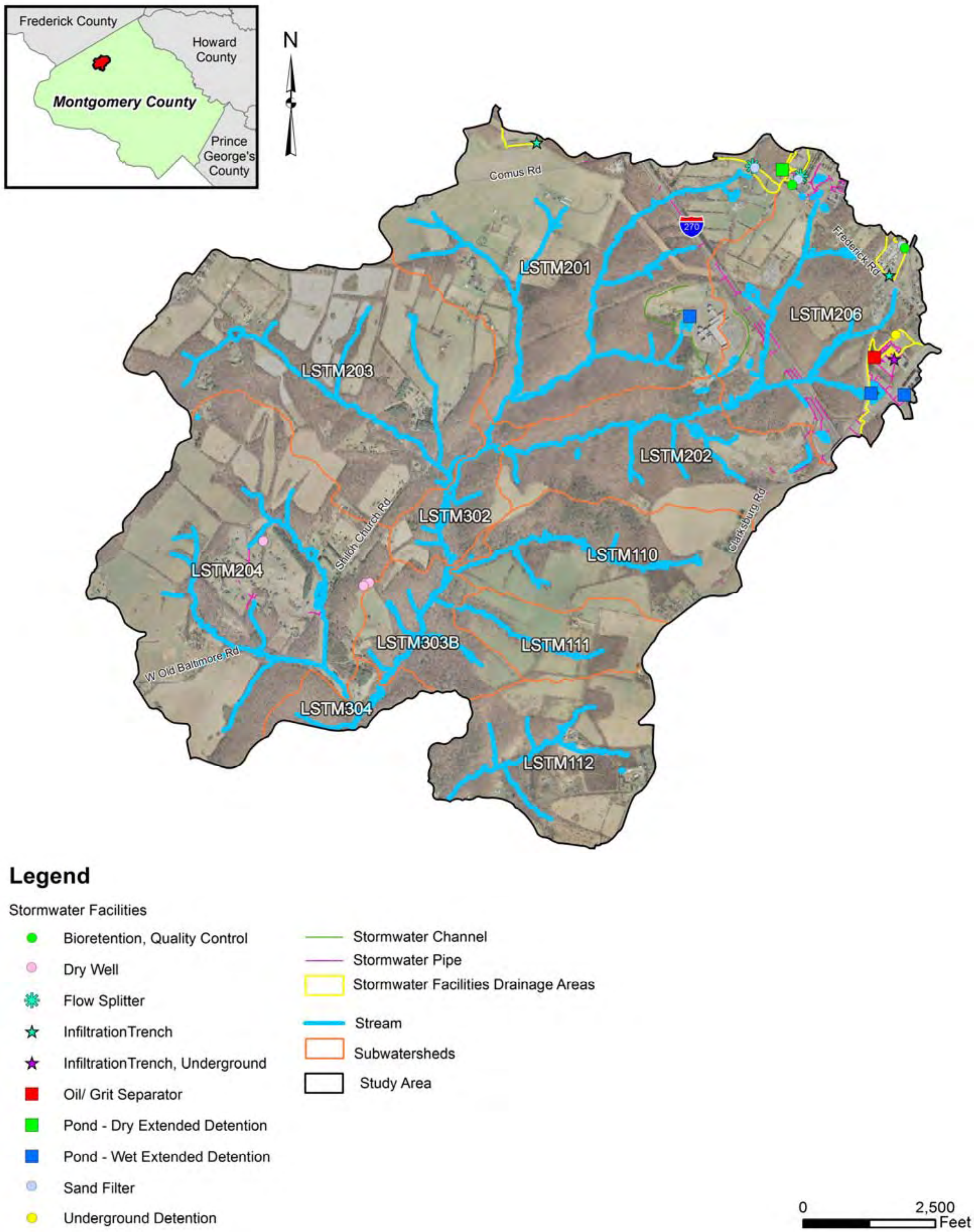


**Figure 4.2. Existing Stormwater Infrastructure in the Ten Mile Creek Study Area**

**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<br>FOR THE CLARKSBURG MASTER PLAN LIMITED AMENDMENT<br>BIBLIOGRAPHY<br>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<br>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<br>FOR THE CLARKSBURG MASTER PLAN LIMITED AMENDMENT<br>BIBLIOGRAPHY<br>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<br>FOR THE CLARKSBURG MASTER PLAN LIMITED AMENDMENT<br>BIBLIOGRAPHY<br>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<br>FOR THE CLARKSBURG MASTER PLAN LIMITED AMENDMENT<br>BIBLIOGRAPHY<br>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<br>FOR THE CLARKSBURG MASTER PLAN LIMITED AMENDMENT<br>BIBLIOGRAPHY<br>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<br>FOR THE CLARKSBURG MASTER PLAN LIMITED AMENDMENT<br>BIBLIOGRAPHY<br>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<br>FOR THE CLARKSBURG MASTER PLAN LIMITED AMENDMENT<br>BIBLIOGRAPHY<br>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<br>FOR THE CLARKSBURG MASTER PLAN LIMITED AMENDMENT<br>BIBLIOGRAPHY<br>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<br>FOR THE CLARKSBURG MASTER PLAN LIMITED AMENDMENT<br>BIBLIOGRAPHY<br>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<br>FOR THE CLARKSBURG MASTER PLAN LIMITED AMENDMENT<br>BIBLIOGRAPHY<br>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<br>FOR THE CLARKSBURG MASTER PLAN LIMITED AMENDMENT<br>GIS DATA SOURCES<br>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 |

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|---|---|
| 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

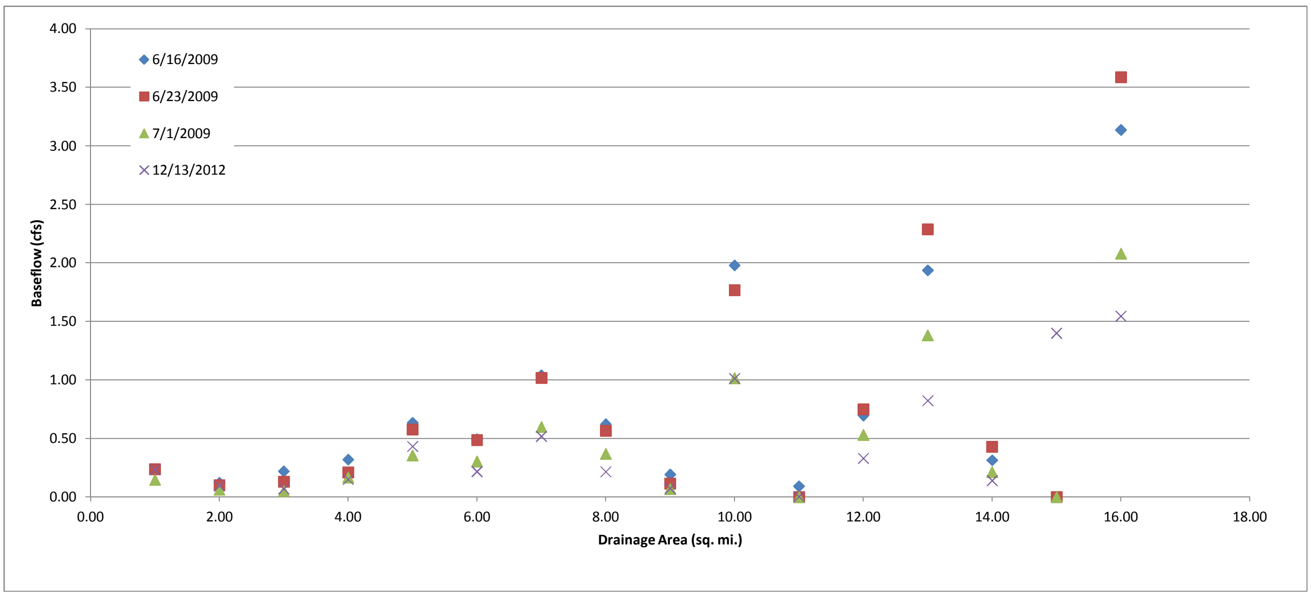
00060, Discharge, cubic feet per second,

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 | | | 2012 | | | | | | |
| | Date | | | Date | | | | | | |
| Sample Point | 6/16/2009 | 6/23/2009 | 7/1/2009 | 12/13/2012 | CUMUL Drainage Area (SF) | CUMUL Drainage Area (sq mi) | COMMENTS | Sample Point | Latitude | Longitude |
| 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* |

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**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* |

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**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* |

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**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.

**Appendix D**

## 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

- 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* |

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 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* |

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 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* |

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 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* |

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

**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* |

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

**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* |

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 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* |

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 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* |

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

**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* |

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

**# 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* |

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

**# 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* |

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.

**% 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* |

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

**% 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* |

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.

# 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* |

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.

**%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

# 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

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.

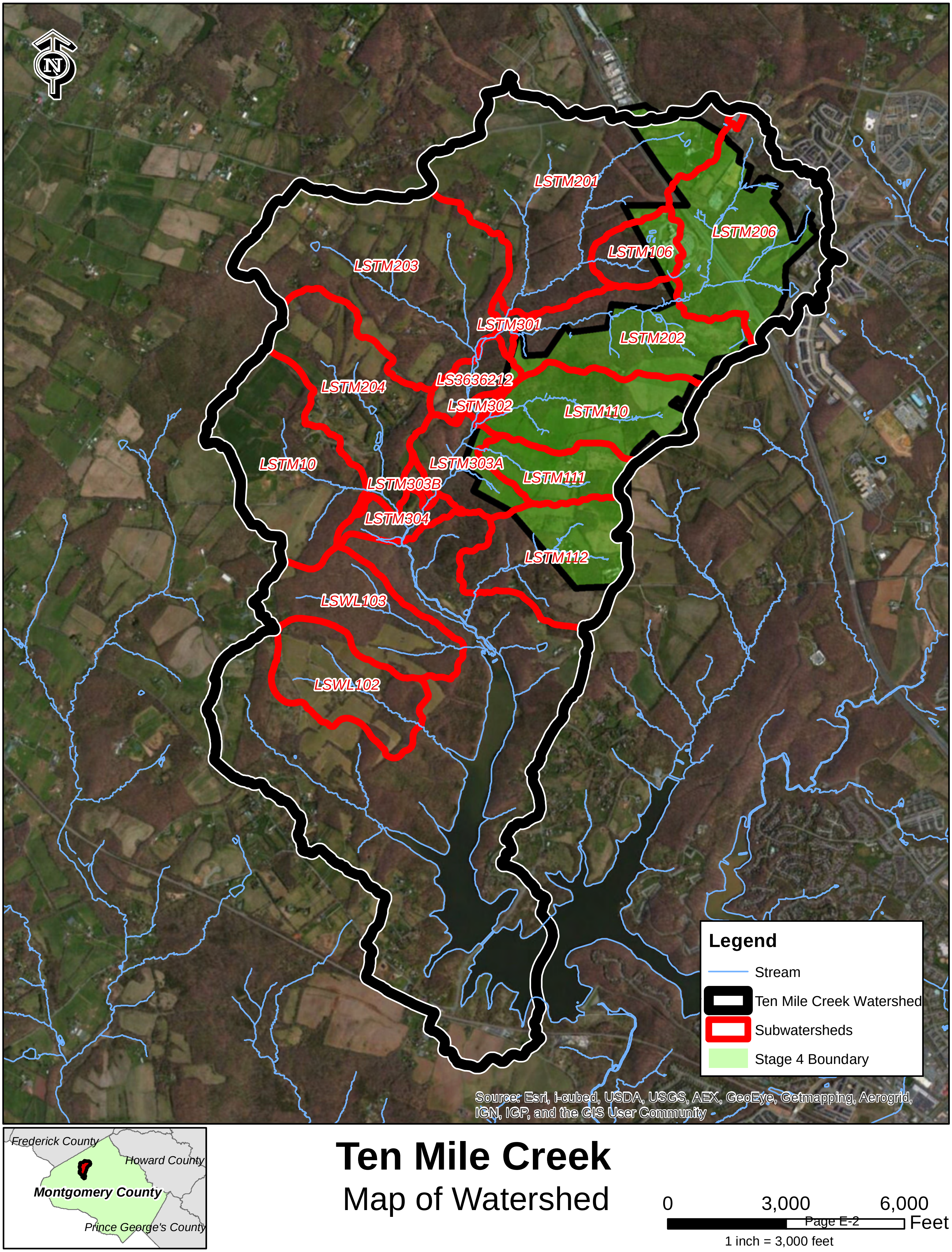
The site encompasses Ten Mile Creek watershed located in northern Montgomery County (ADC Map #12, B-H, 1-9 and Map #4, B-K, 9-13). Brown and Caldwell/Biohabitats, a Joint Venture, are contracted by Maryland - National Capital Park and Planning Commission (M-NCPPC) Montgomery County Planning Department 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

**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.

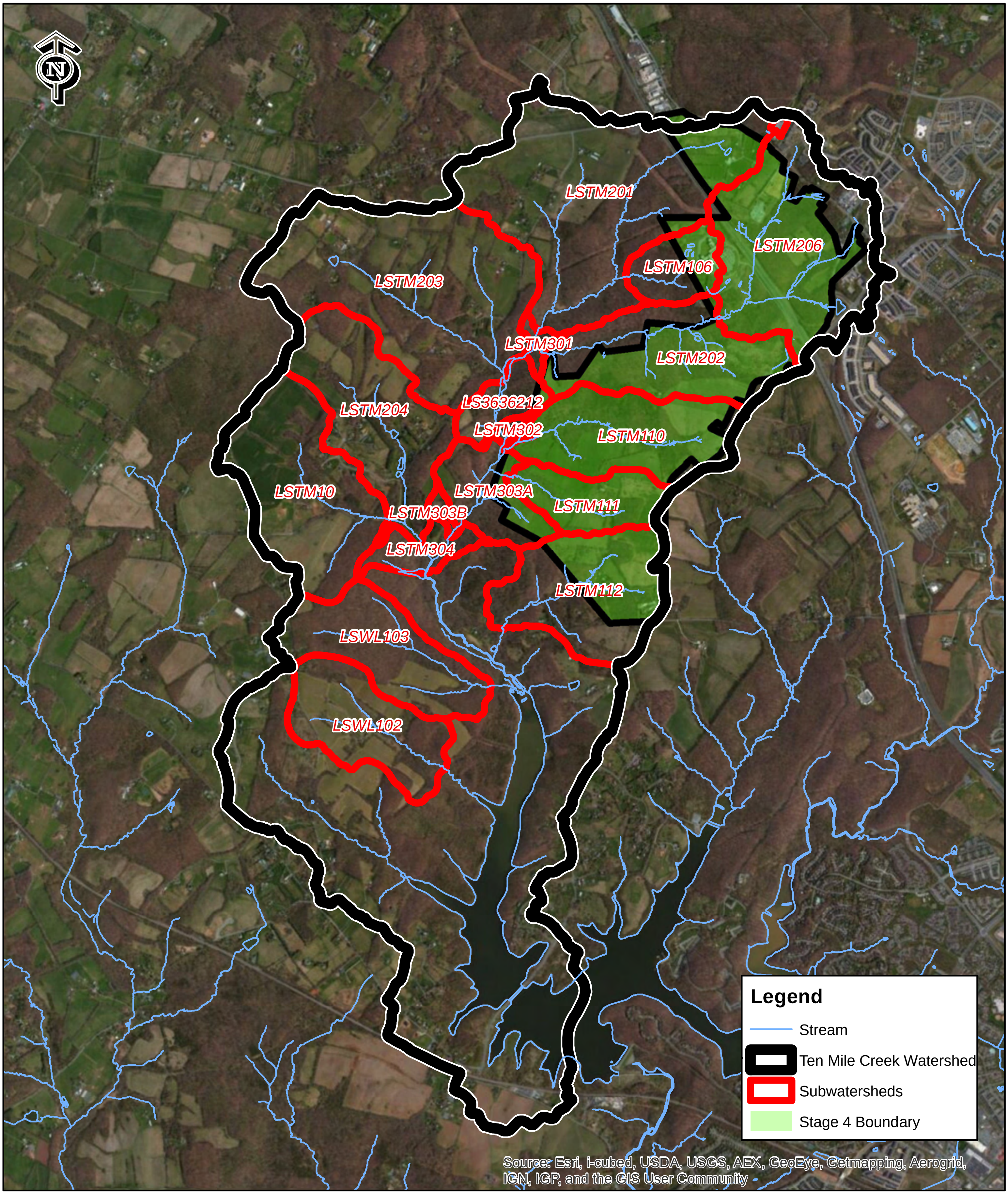
The site encompasses Ten Mile Creek watershed located in northern Montgomery County (ADC Map #12, B-H, 1-9 and Map #4, B-K, 9-13). The watershed is located on the Georgetown quadrangle 7.5-minute USGS Topo Map. Brown and Caldwell/Biohabitats, a Joint Venture, are contracted by Maryland - National Capital 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.

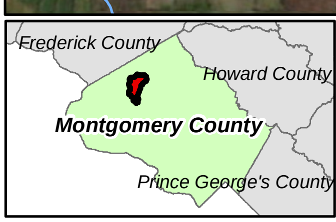
Please find the enclosed vicinity map showing the watershed location. Feel free to call me at 410-554-0156 should you have any questions. Thank you for your time and attention.

*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,

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

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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*

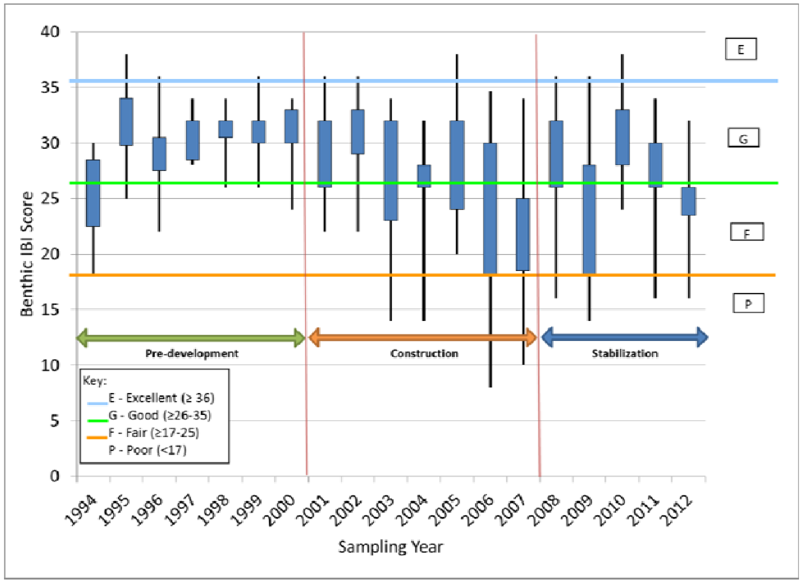


**Figure A1. Variability among BIBI scores at all sampling stations over time.**

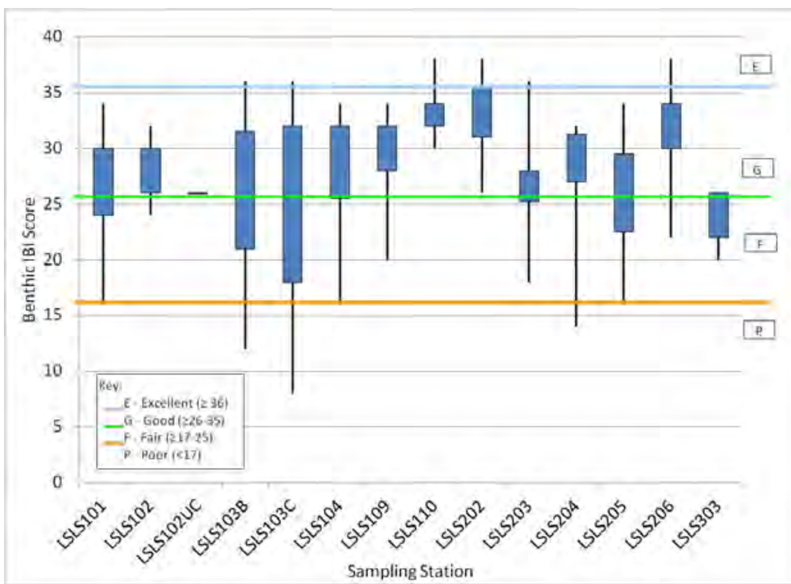


**Figure A2. Variability among BIBI scores at all sampling stations over time (1994-2012).**

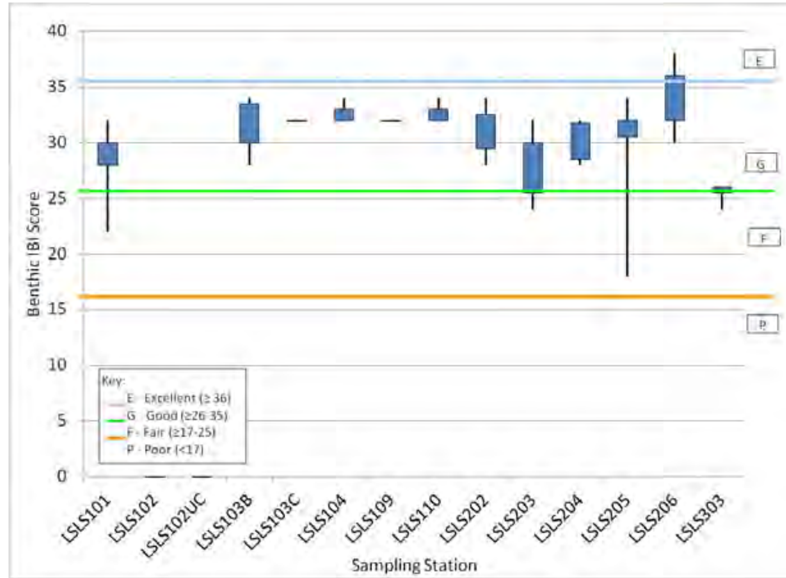


**Figure A3. Variability among pre-development period BIBI scores**

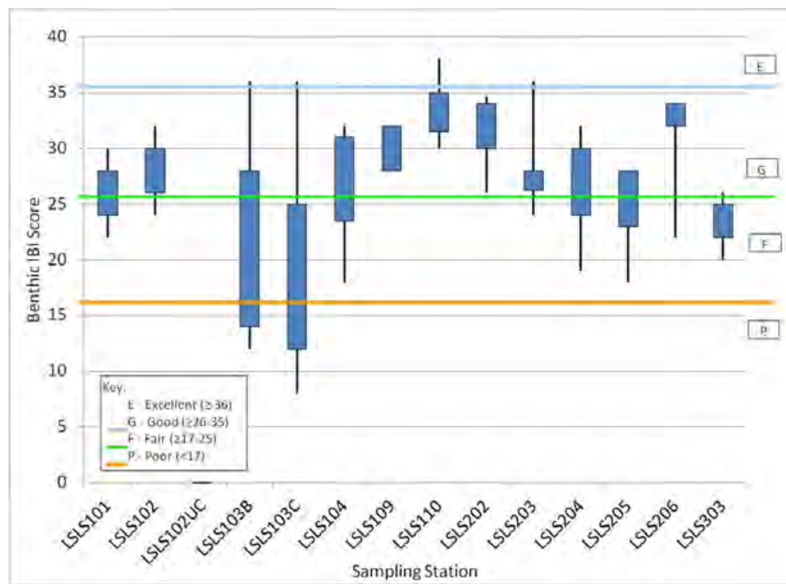


**Figure A4. Variability among construction period BIBI scores**

# Attachment A

*Graphical Data Summaries*

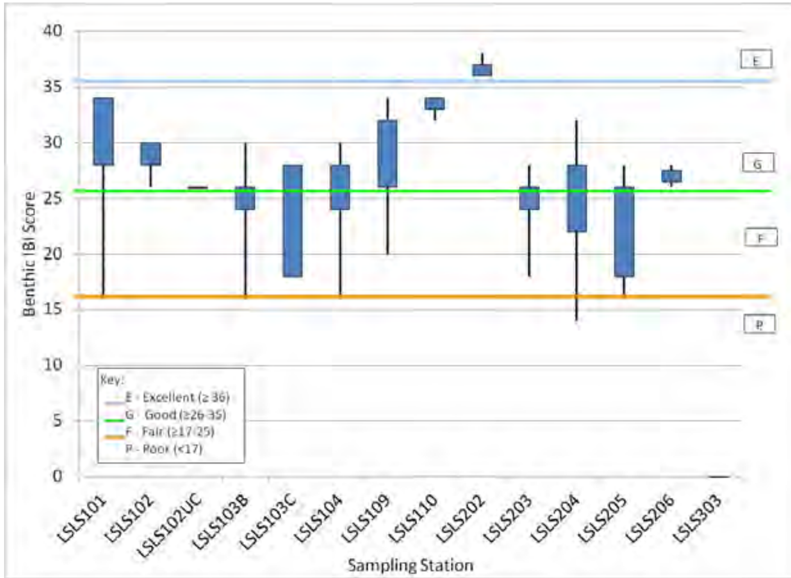


**Figure A5. Variability among stabilization period phase BIBI scores**

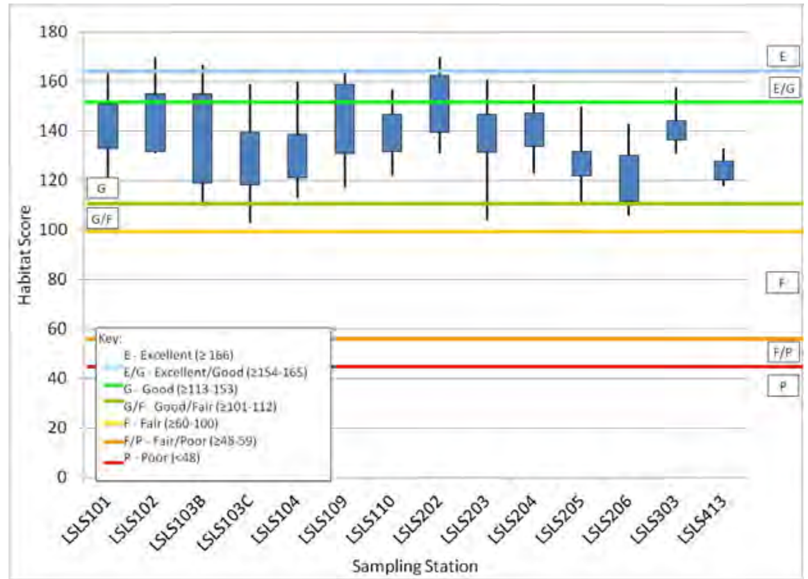


**Figure A7. Ranges of composite habitat scores among the permanent sampling stations**

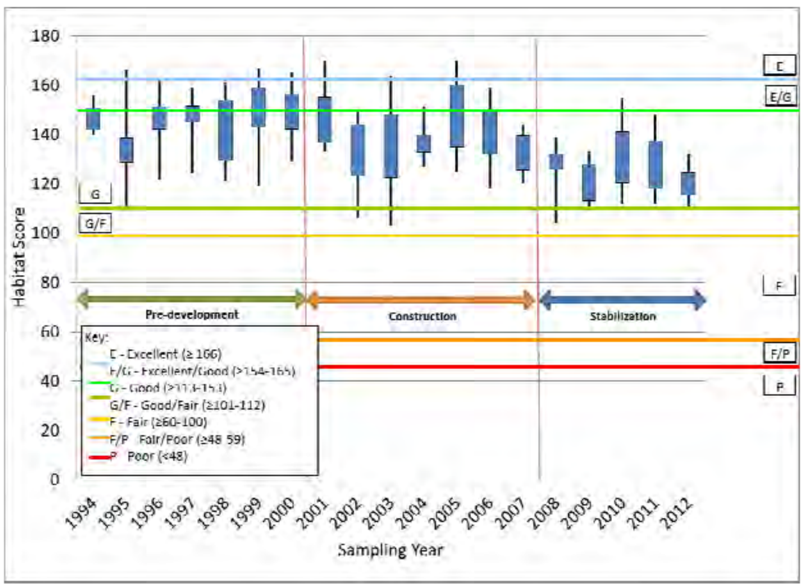


**Figure A6. Variability among habitat scores at all sampling stations over time (1994-2012).**

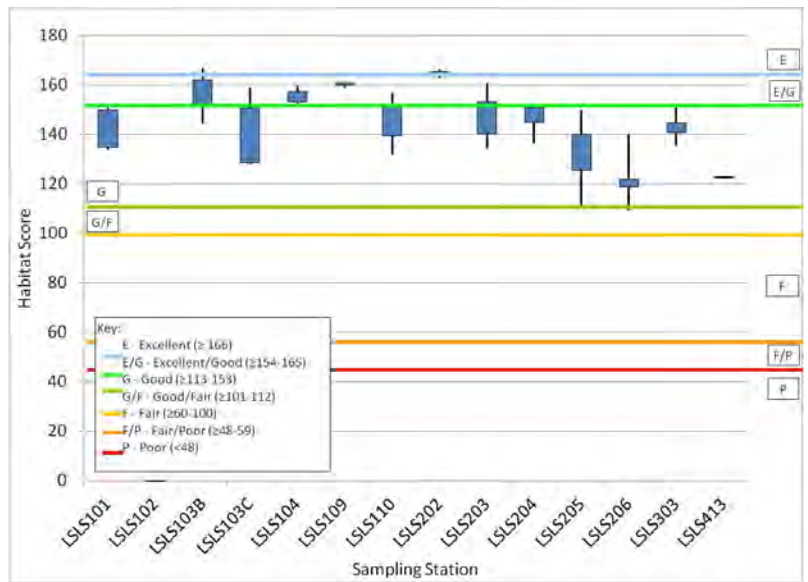


**Figure A8. Variability among pre-development period habitat scores**

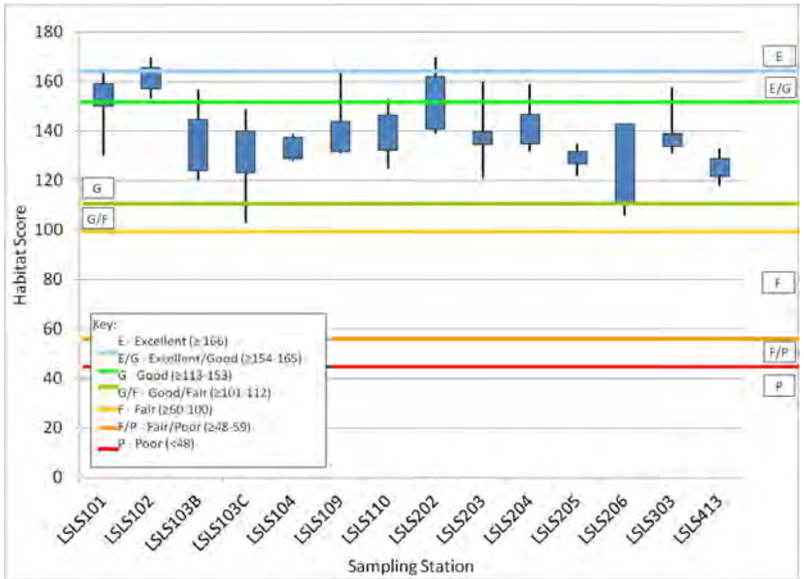


**Figure A9. Variability among construction habitat scores**

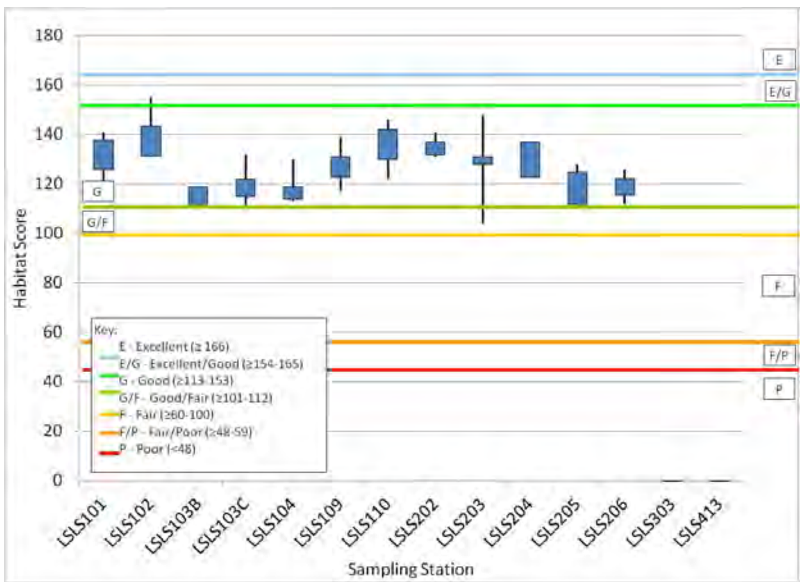


**Figure A10. Variability among stabilization period habitat scores**

## 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** | **0.56** | **0.64** | **0.62** | **0.99** | 0.16 | **0.73** | **0.73** | **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** | **0.58** | 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 | **0.46** |
| | 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 | **0.99** | #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 | **0.95** | 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** | **0.49** | 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.

## 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** | **0.51** | **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.

## 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 | **0.57** | 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.

## 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 |

| Time Period | Statistic | LSLS101 | LSLS102 | LSLS103B | LSLS103C | LSLS104 | LSLS109 | LSLS110 | LSLS202 | LSLS203 | LSLS204 | LSLS205 | LSLS206 | LSLS303 | LSLS413 | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 |

| Time Period | Statistic | LSLS101 | LSLS102 | LSLS103B | LSLS103C | LSLS104 | LSLS109 | LSLS110 | LSLS202 | LSLS203 | LSLS204 | LSLS205 | LSLS206 | LSLS303 | LSLS413 | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 |

| Time Period | Statistic | LSLS101 | LSLS102 | LSLS103B | LSLS103C | LSLS104 | LSLS109 | LSLS110 | LSLS202 | LSLS203 | LSLS204 | LSLS205 | LSLS206 | LSLS303 | LSLS413 | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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.

## 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.

## 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.

## 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.

## 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.

## 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

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# MEMORANDUM

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.

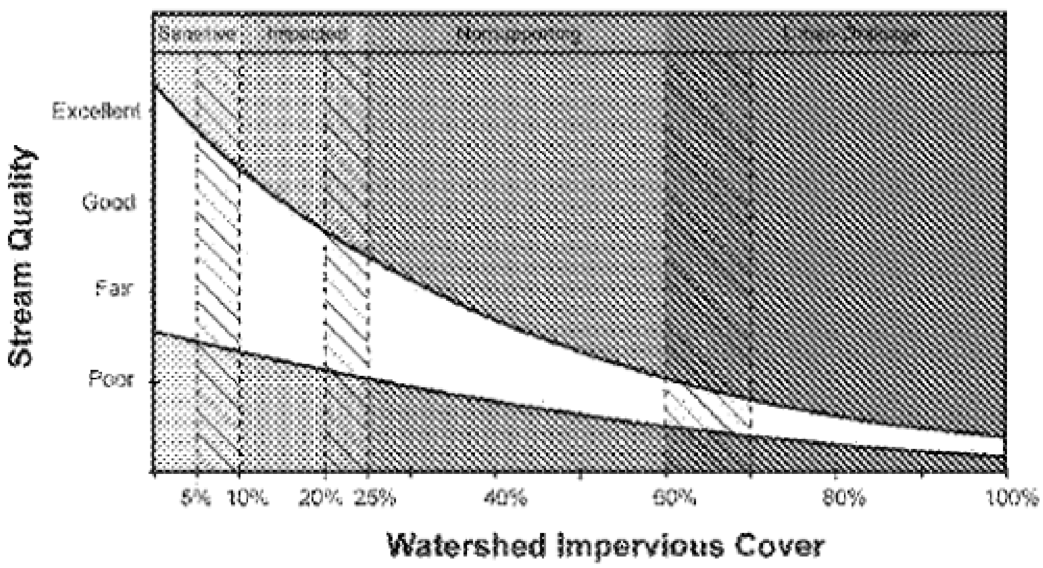


Figure 1. Reformulated Impervious Cover Model (Schueler et al., 2009)

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.

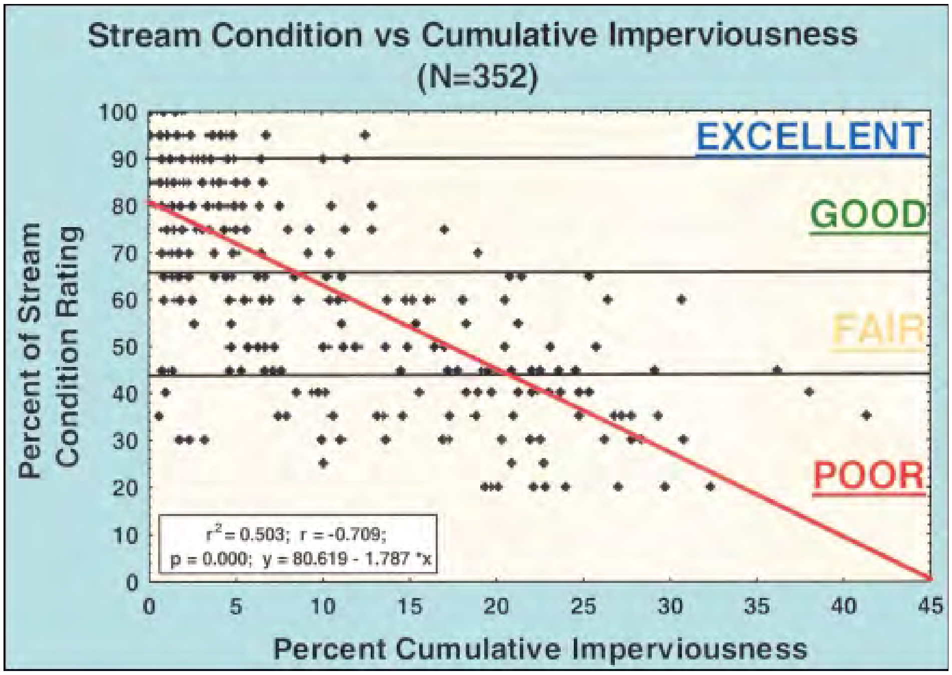


Figure 2. Relationship Between Stream Condition and Impervious Cover in Montgomery County Streams (MCDEP, 2003)

### *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 |

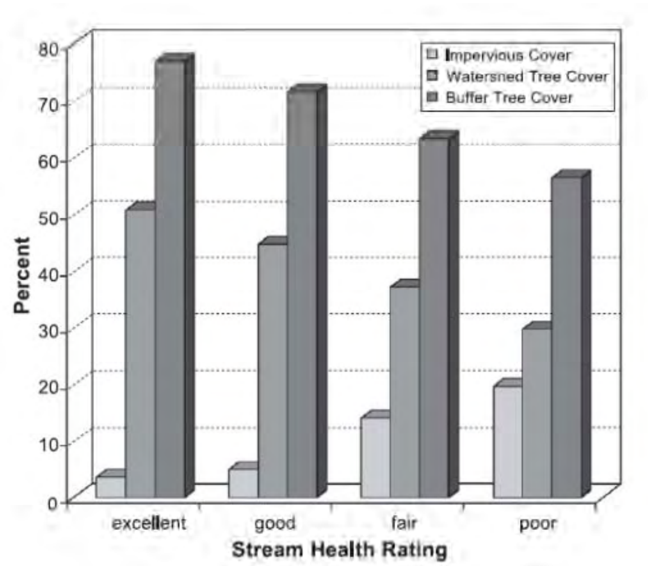


Figure 3. Relationship of Land Cover to Stream Health (Goetz et al., 2003)

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.

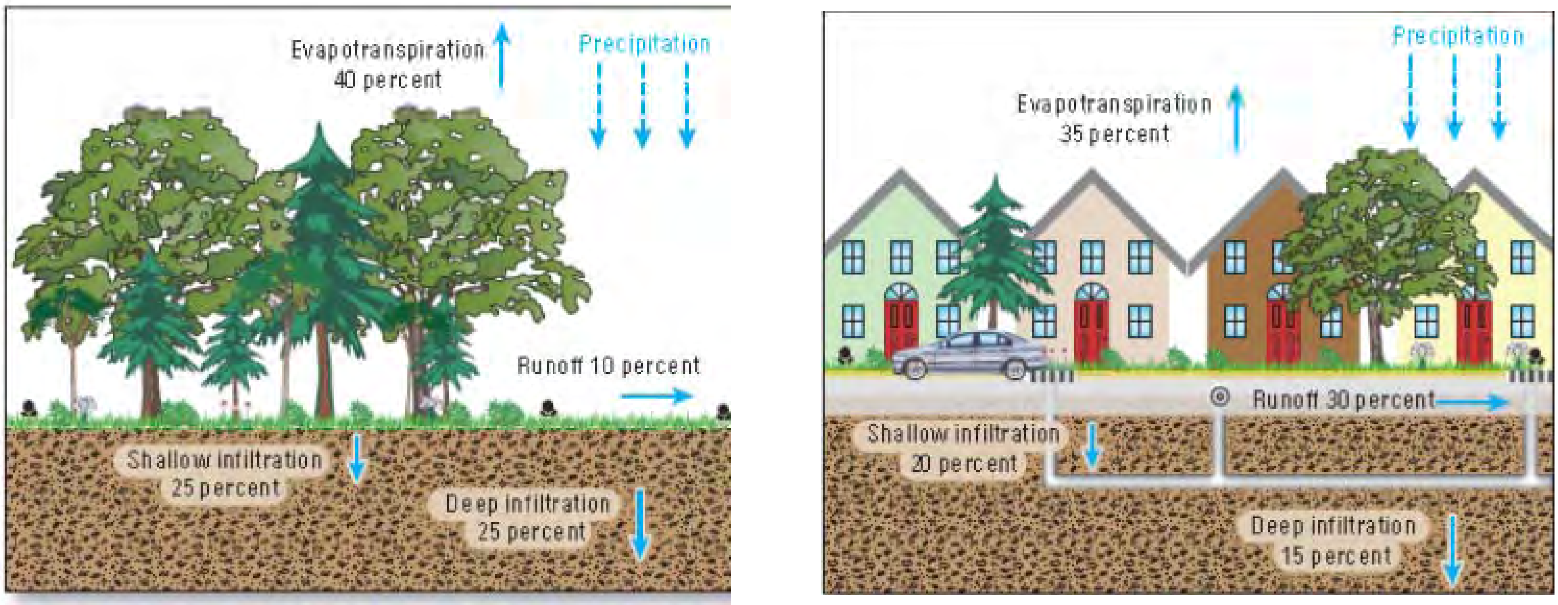


**Figure 4. Change in Water Balance with Development (Coles et al., 2012)**

### *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)**

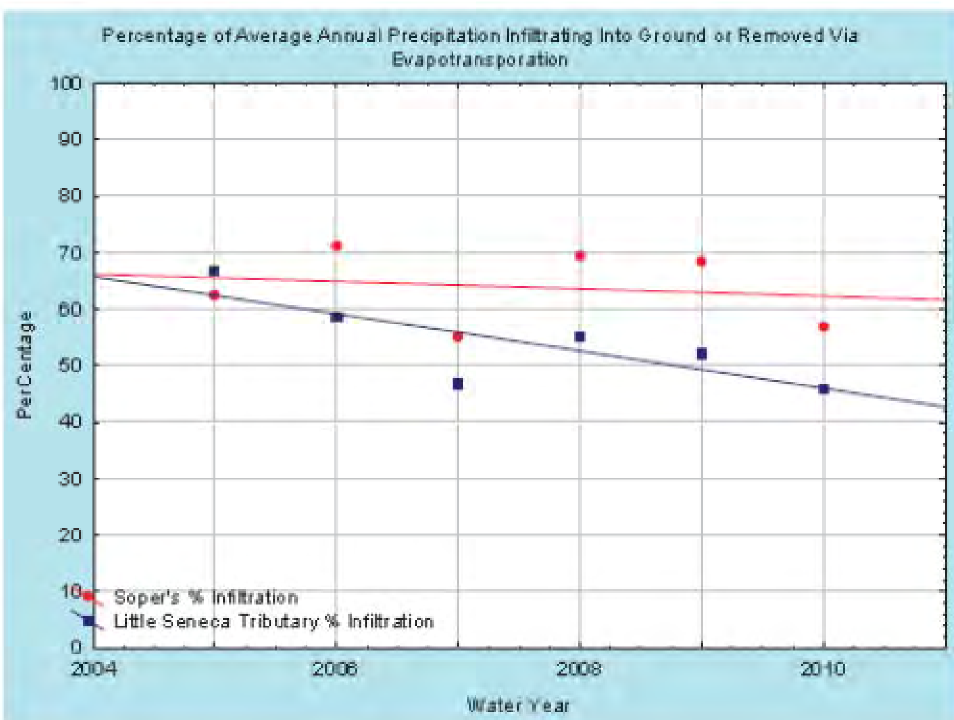


**Figure 6. "Runoff Reduction" volume in a developing Little Seneca tributary (Clarksburg)**

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).

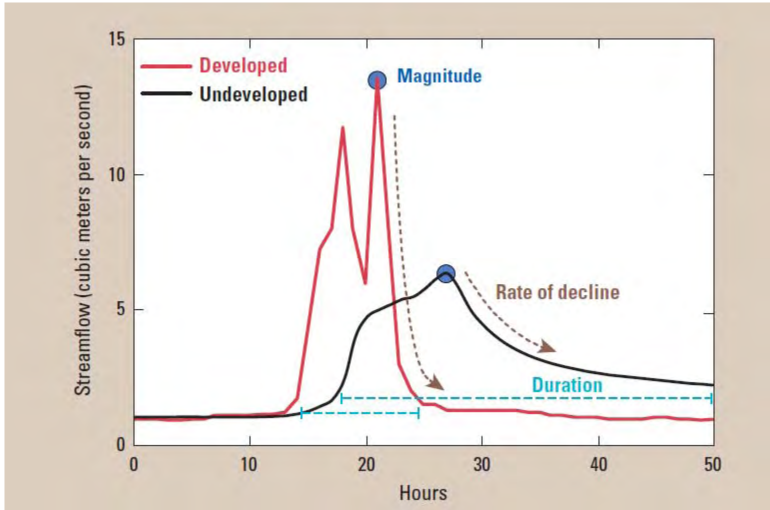


**Figure 7. Stream Flashiness (Coles et al., 2012)**

**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

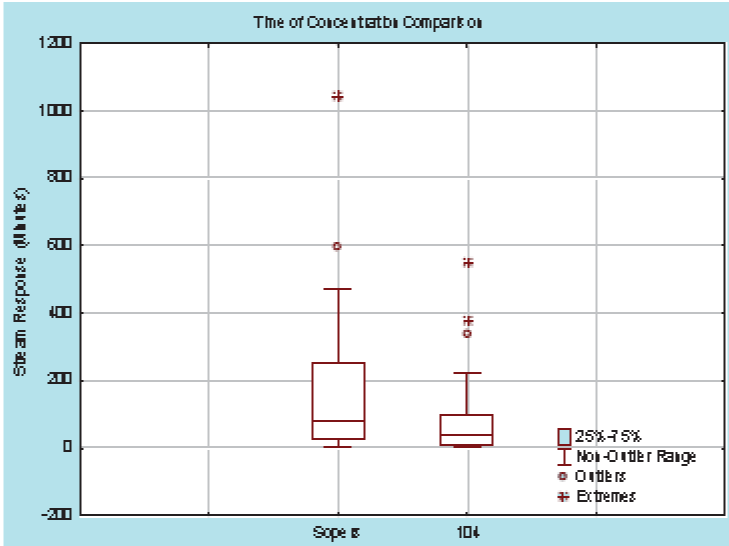


**Figure 8. Time of Concentration is lower in the developed "Tributary 104" versus undeveloped Sopers Branch**

### *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 | Channel Stability | At greater than 10% impervious, most stream channels are unstable. |
| Coles et al., 2004 | 89 Habitat metrics | 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 $2^{nd}$ order streams, and 55% of water volume and 40% of nitrogen to $4^{th}$and 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.

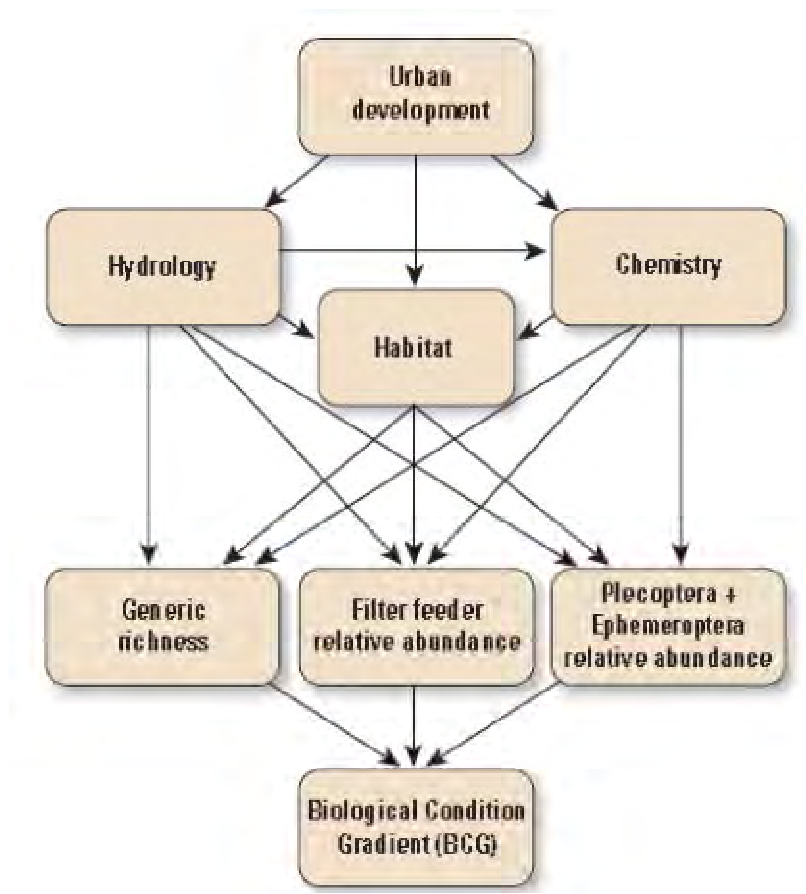


**Figure 9. Network Describing Northeast Stream Conditions (Kashuba, 2012; figure from Coles et al., 2012).**

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<br>• A-2. Permeable Pavements<br>• A-3. Reinforced Turf |
| **Non-Structural Practices** |
| • N-1. Disconnection of Rooftop Runoff<br>• N-2. Disconnection of Non-Rooftop Runoff<br>• N-3. Sheetflow to Conservation Areas |
| **Micro-Scale Practices** |
| • M-1. Rainwater Harvesting<br>• M-2. Submerged Gravel Wetlands<br>• M-3. Landscape Infiltration<br>• M-4. Infiltration Berms<br>• M-5. Dry Wells<br>• M-6. Micro-Bioretention<br>• M-7. Rain Gardens<br>• M-8. Swales<br>• 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.

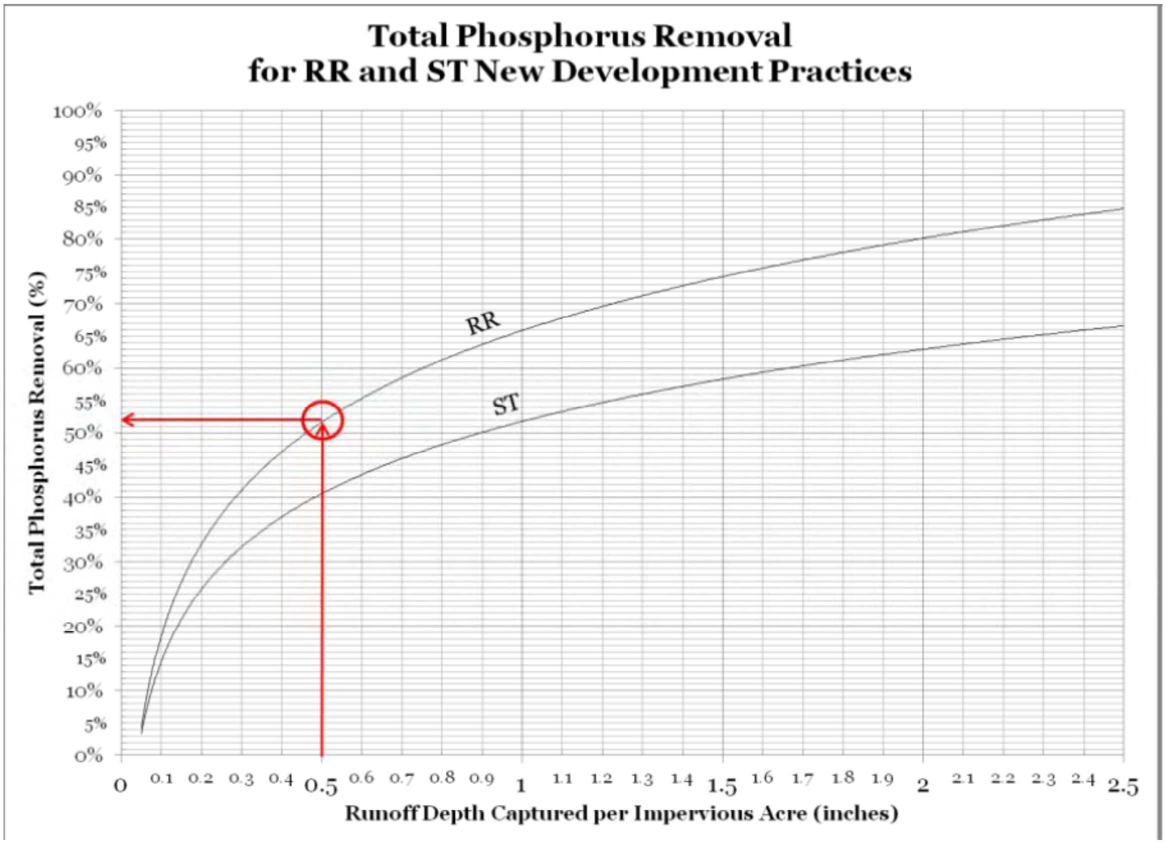


**Figure 10. Phosphorus Removal Curve for "Runoff Reduction" (i.e., ESD) versus traditional stormwater management (Schueler and Lane, 2012)**

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.<br><br>Compares runoff volumes for design storms | • Cluster designs that preserve open space create the least runoff.<br>• Strategic placement of infiltration practices can reduce runoff for any development type.<br>• Soil compaction during construction can hamper efforts to achieve runoff reductions.<br>• 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.<br>• Modeling the urban watershed with the use of a wetland system was ineffective at reproducing the natural hydrograph.<br>• 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.<br>• 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.<br>• 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.<br>• 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.<br>• 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.

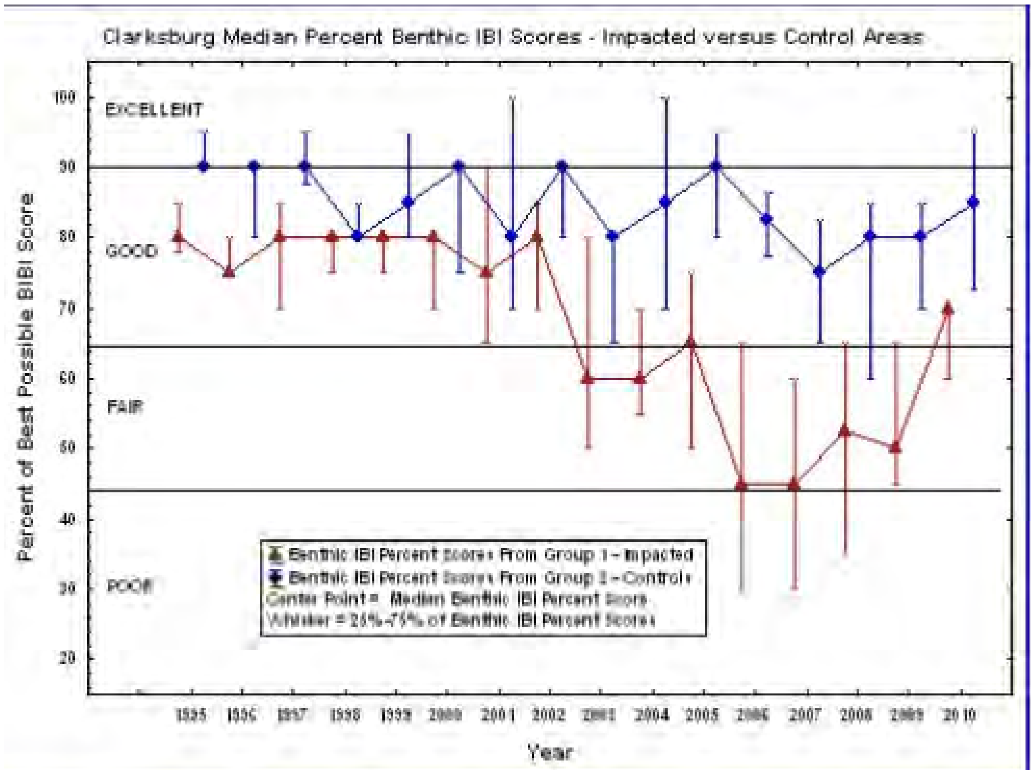


**Figure 11. Benthic IBI Scores decline during the peak construction period in Clarksburg, and begin to recover (MCDEP, 2010).**

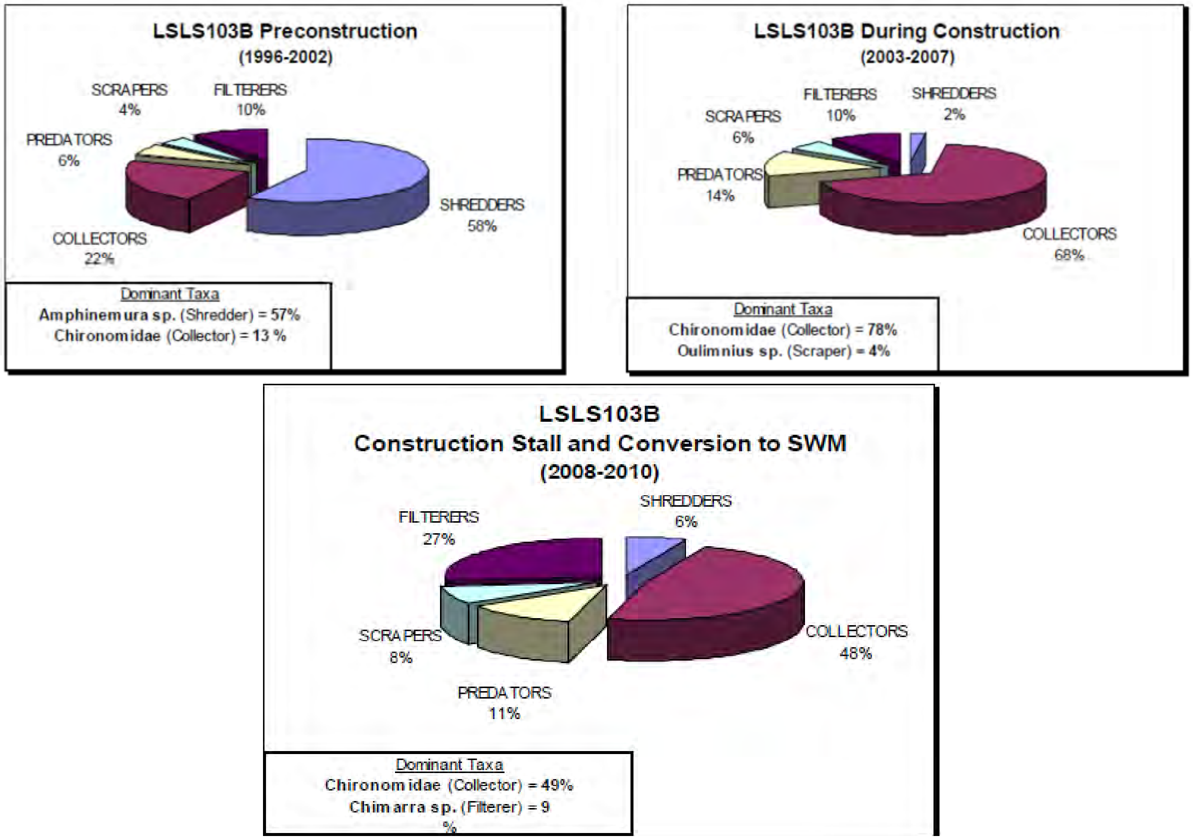


**Figure 12. Functional Feeding Groups switched during construction, with a dramatic loss in shredder species, and significant increases in collectors and predators (MCDEP, 2010).**

# 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

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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.

# 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% |

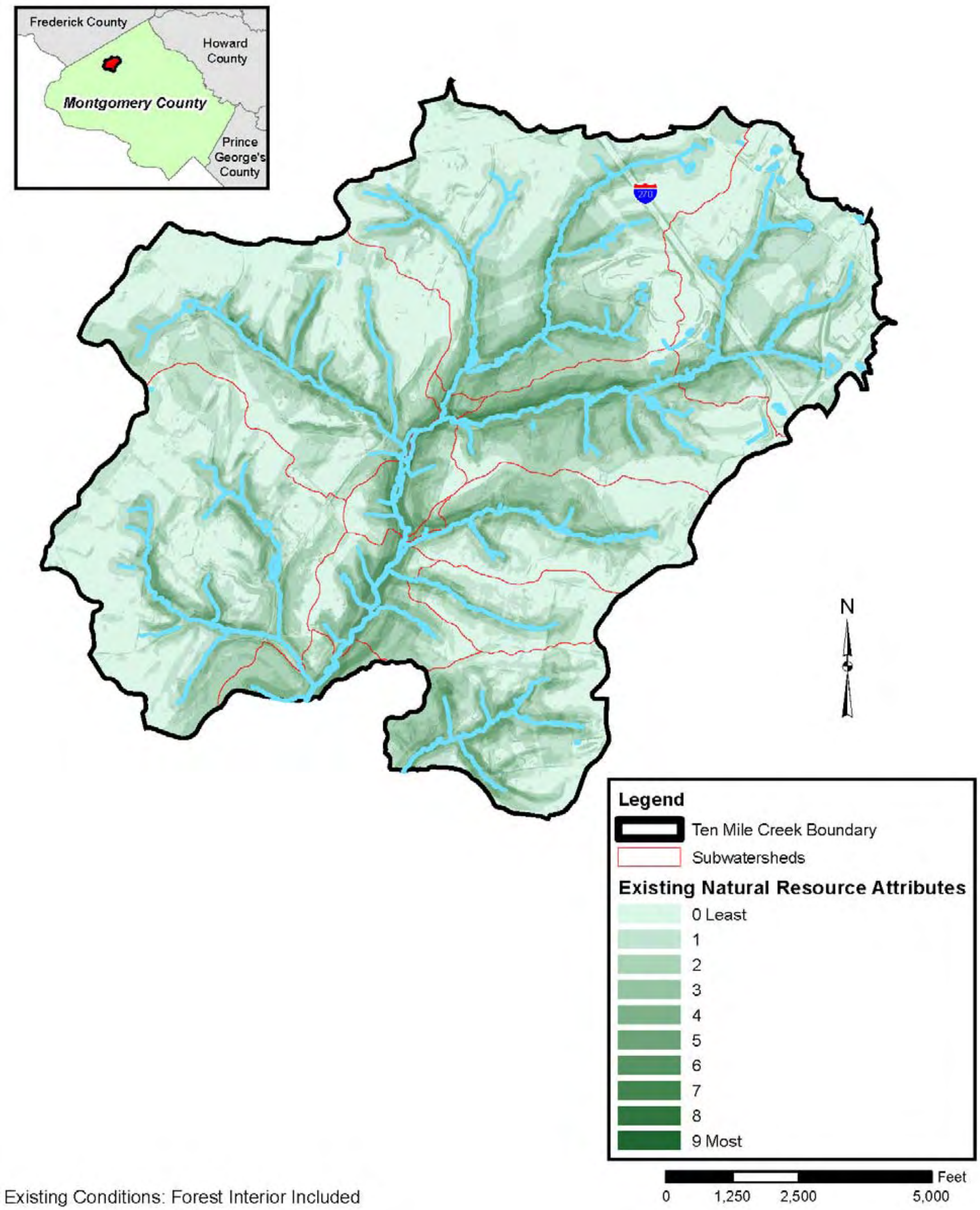



**Figure 1a. Natural Resources Attribute Scores for Existing Conditions, Forest Interior Included**

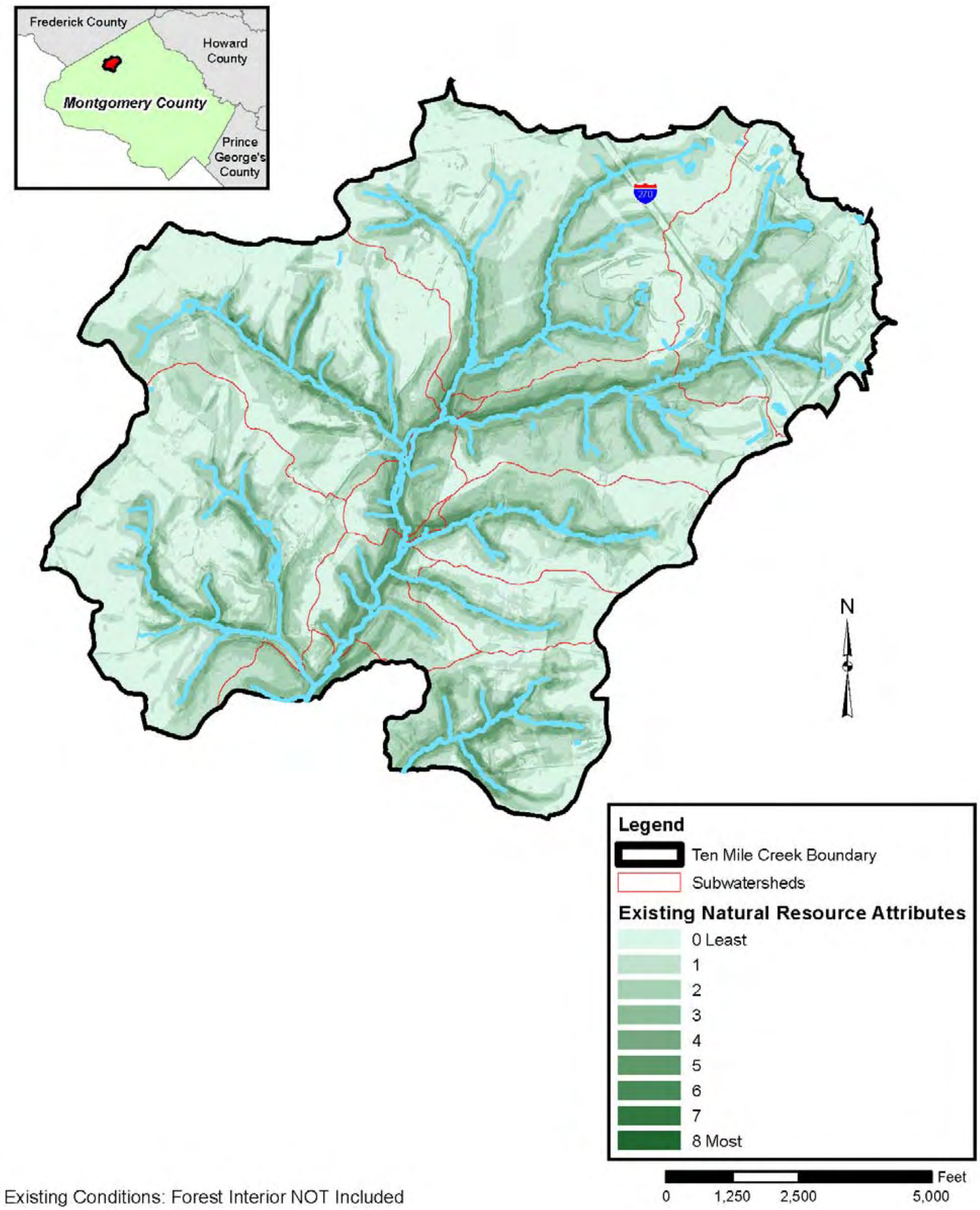



**Figure 1b. Natural Resources Attribute Scores for Existing Conditions, Forest Interior Not Included**

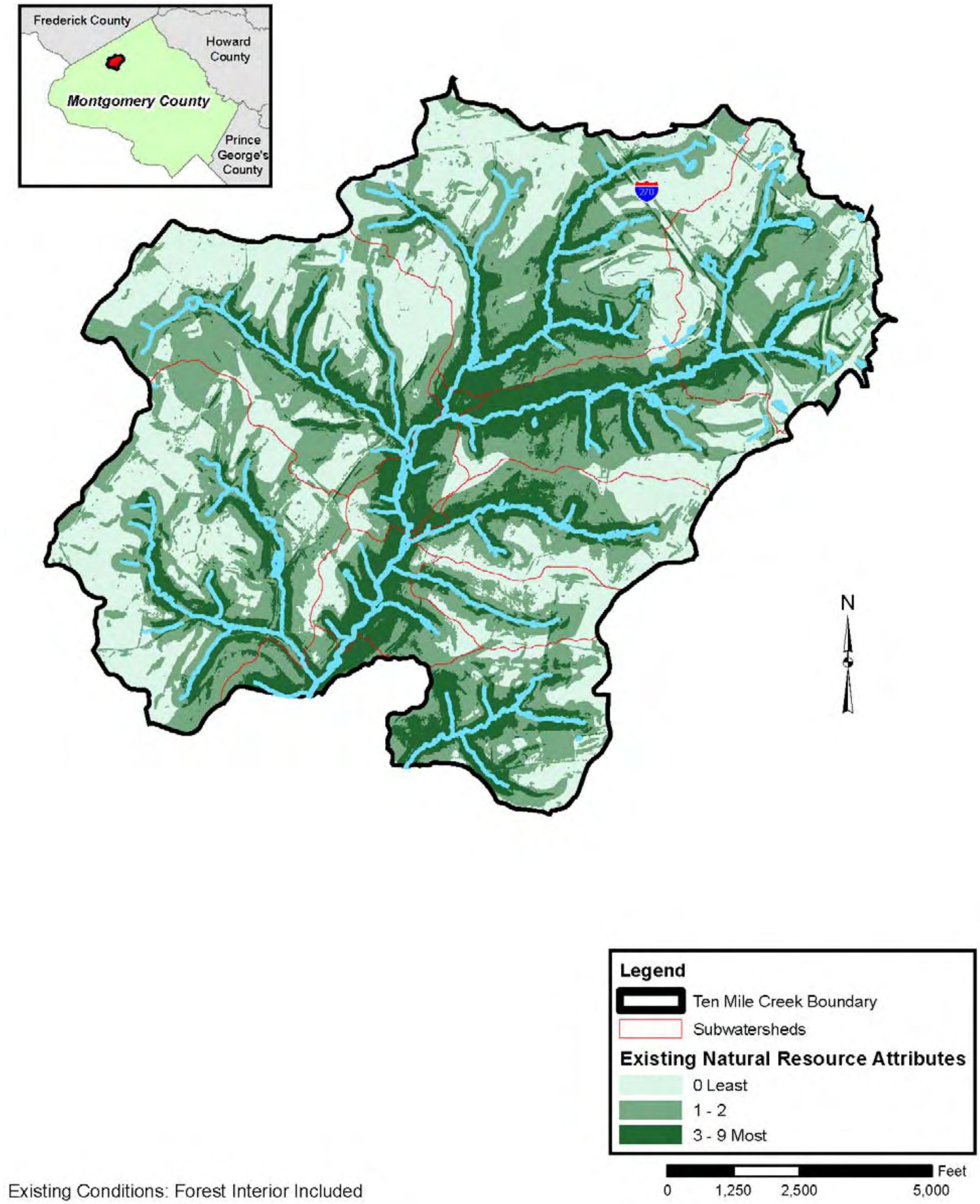



**Figure 2a. Natural Resources Attribute Scores for Existing Conditions (Grouped into Three Categories), Forest Interior Included**

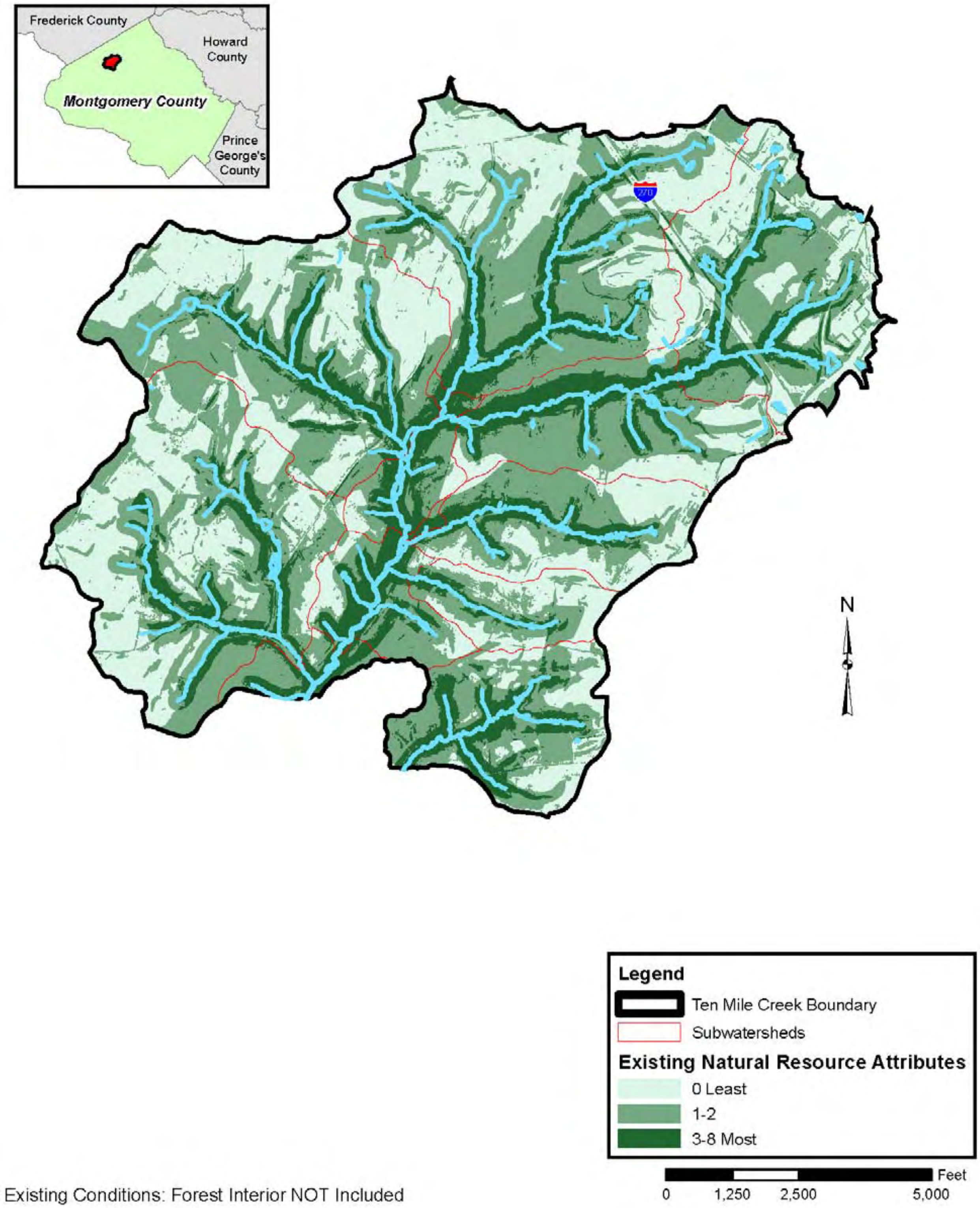



**Figure 2b. Natural Resources Attribute Scores for Existing Conditions (Grouped into Three Categories), Forest Interior Not Included**

## 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% |

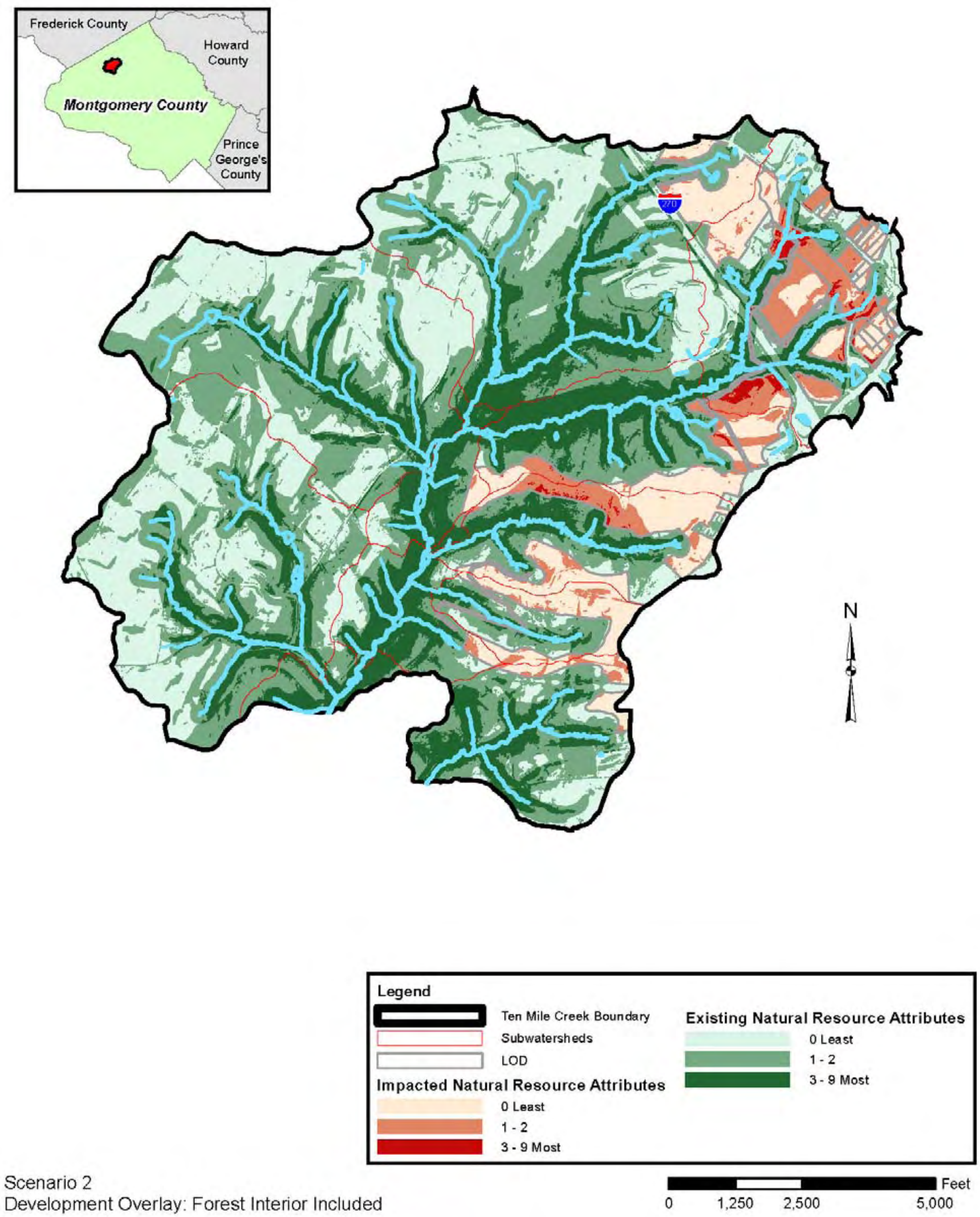



**Figure 3a. Natural Resource Attribute Areas that will be Impacted by Scenario 2 (grouped into Three Categories), Forest Interior Included**

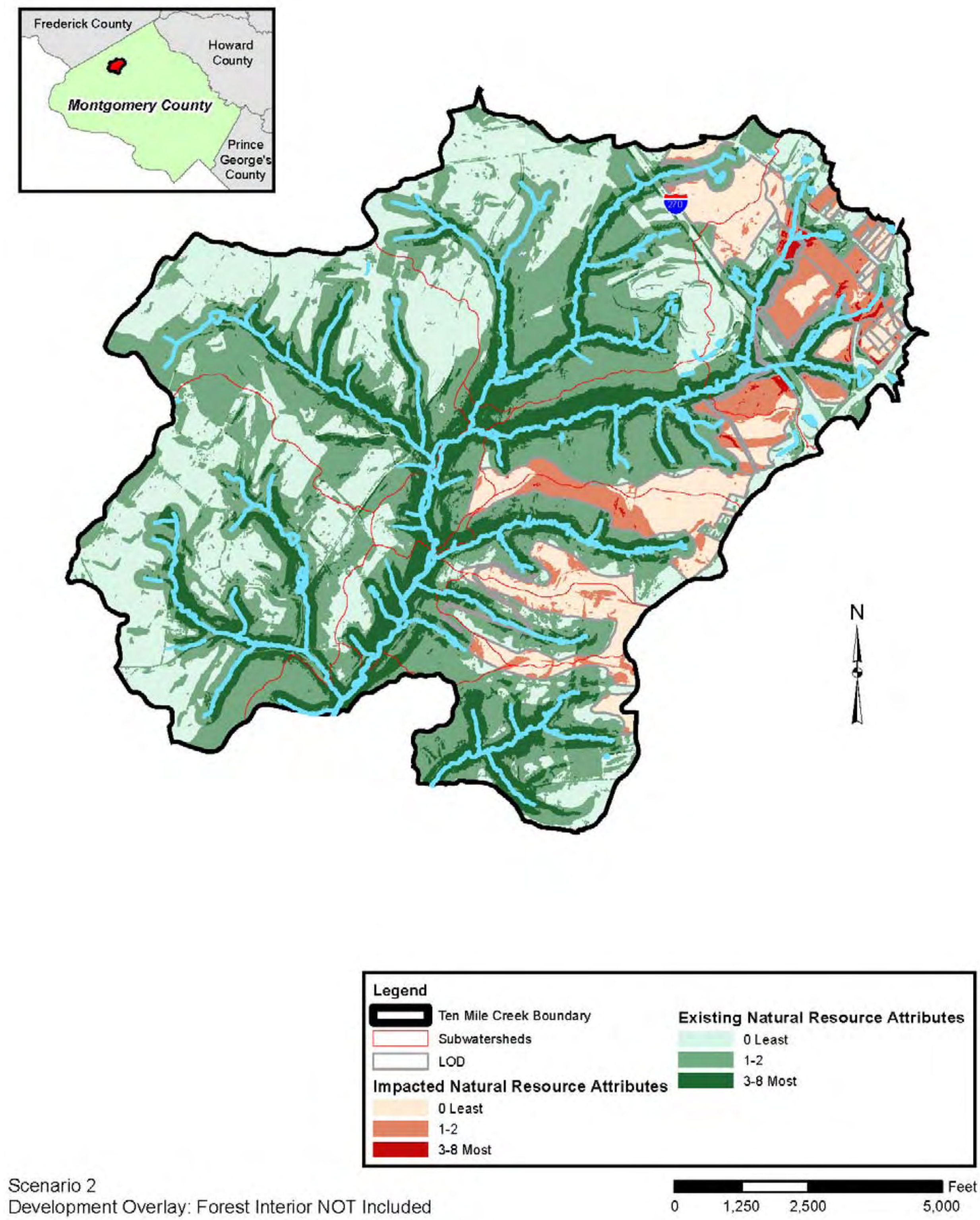



**Figure 3b. Natural Resource Attribute Areas that will be Impacted by Scenario 2 (grouped into Three Categories), Forest Interior Not Included**

### *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% |

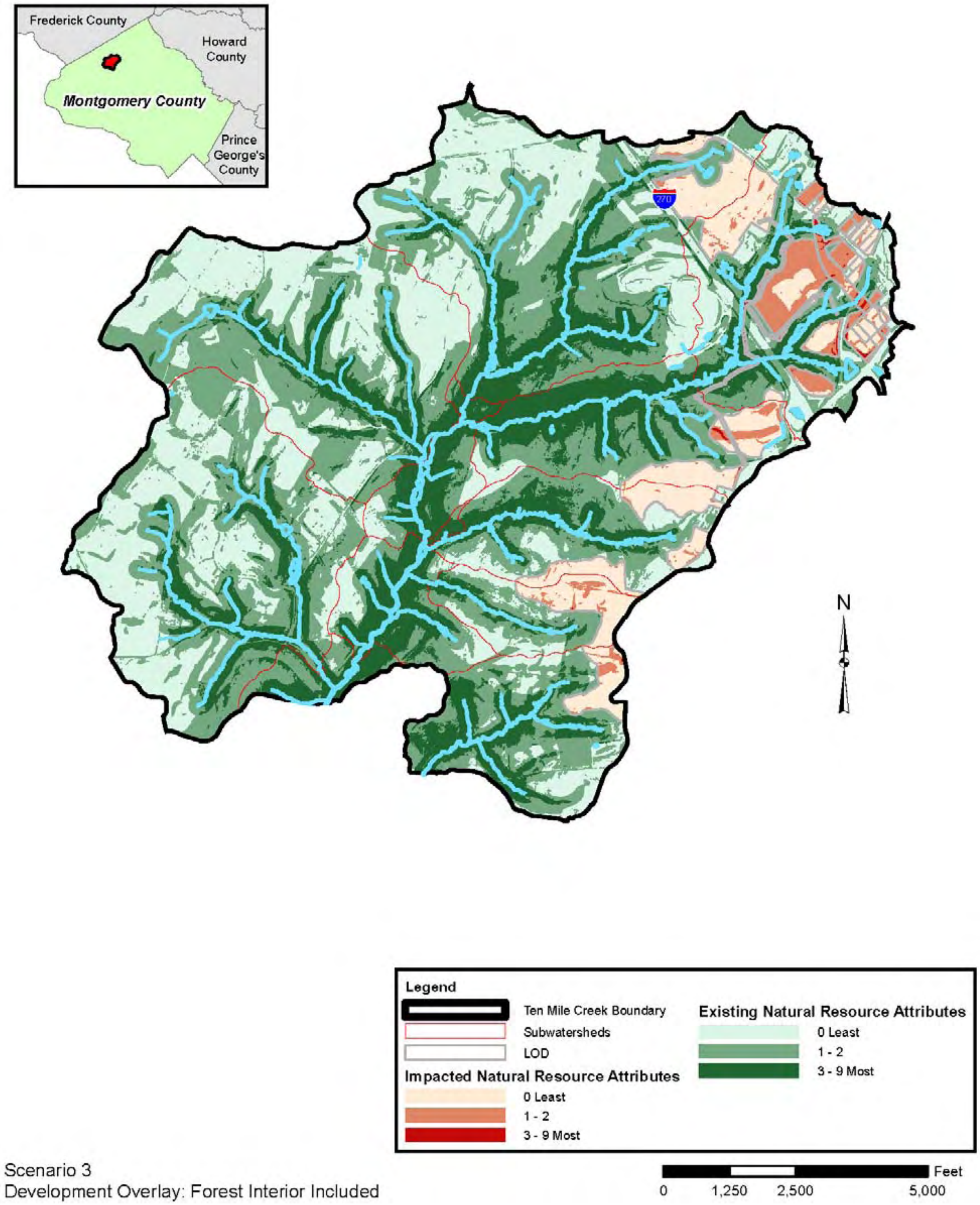



**Figure 4a. Natural Resource Attribute Areas that will be Impacted by Scenarios 3 and 4 (grouped into Three Categories), Forest Interior Included**

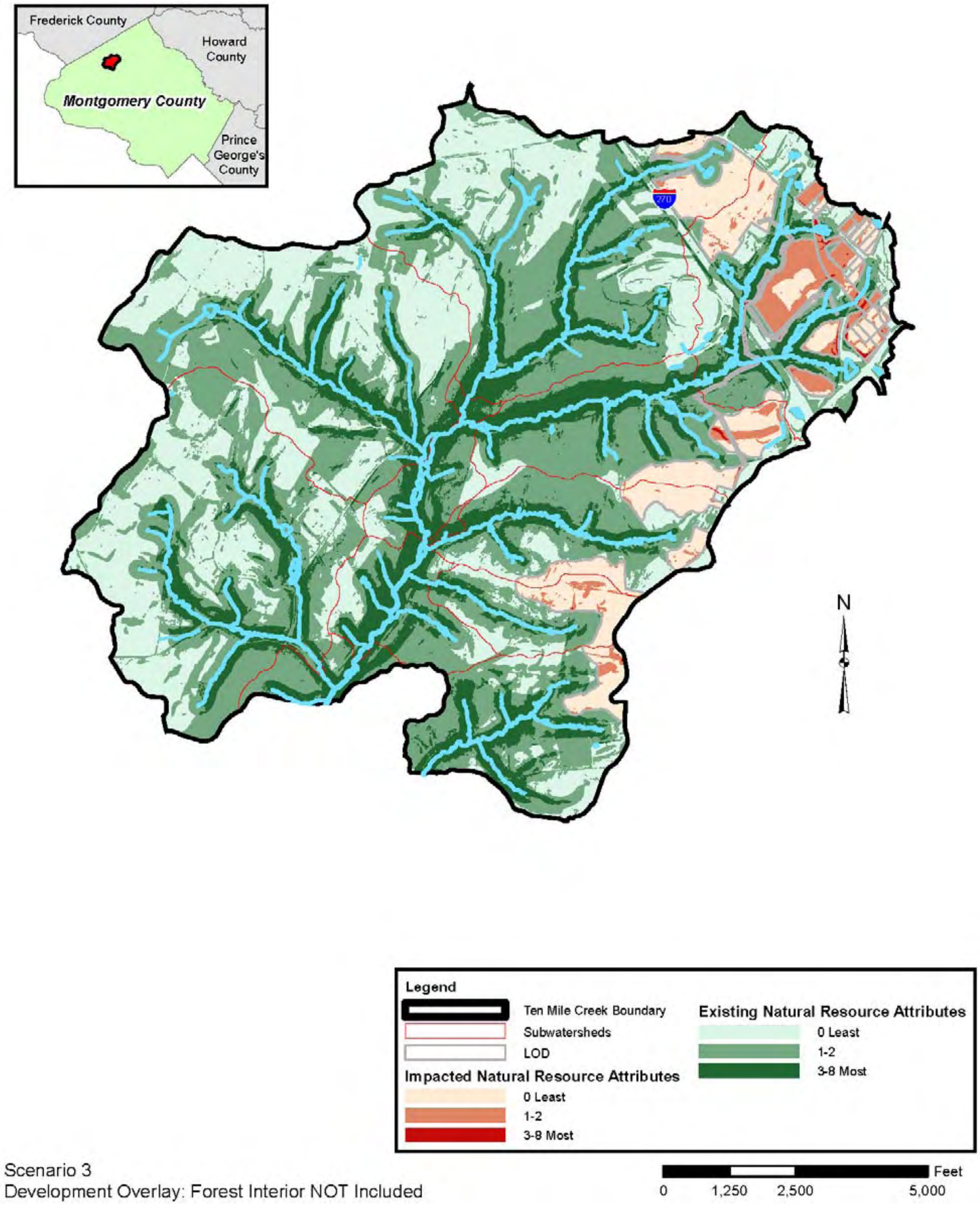



**Figure 4b. Natural Resource Attribute Areas that will be Impacted by Scenarios 3 and 4 (grouped into Three Categories), Forest Interior Not Included**

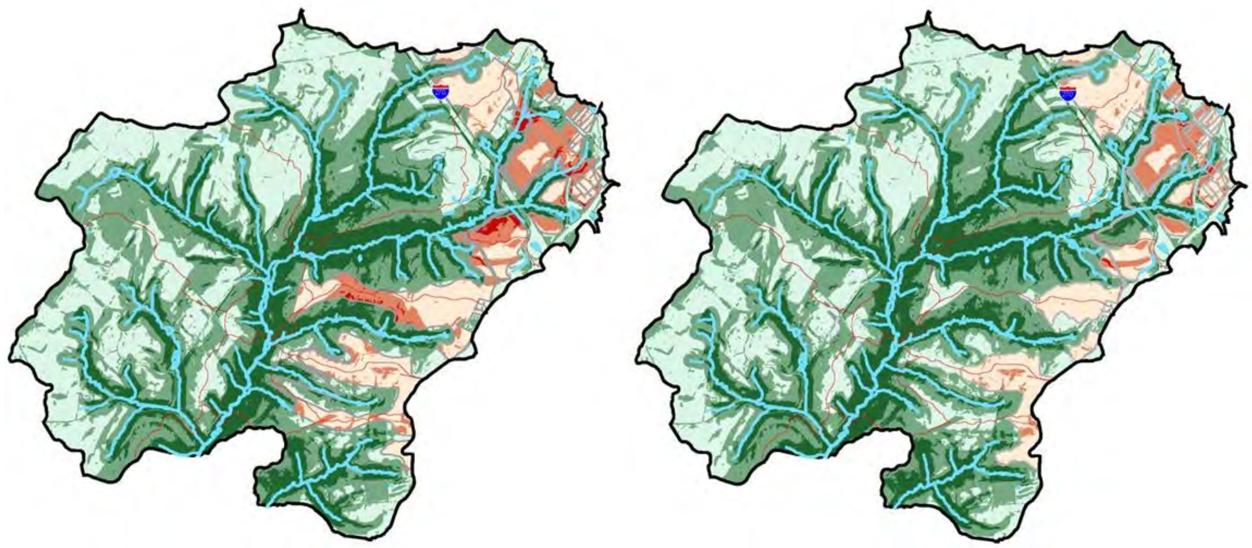
# DISCUSSION

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*

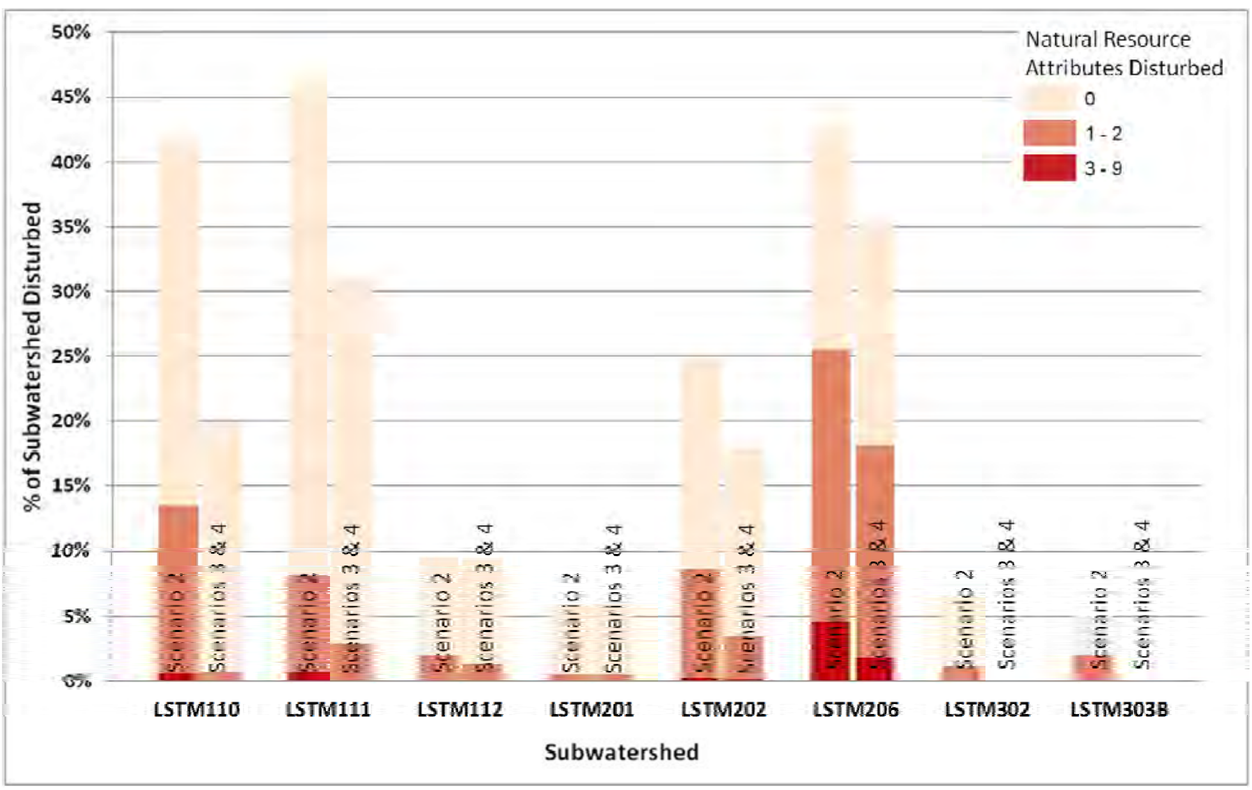
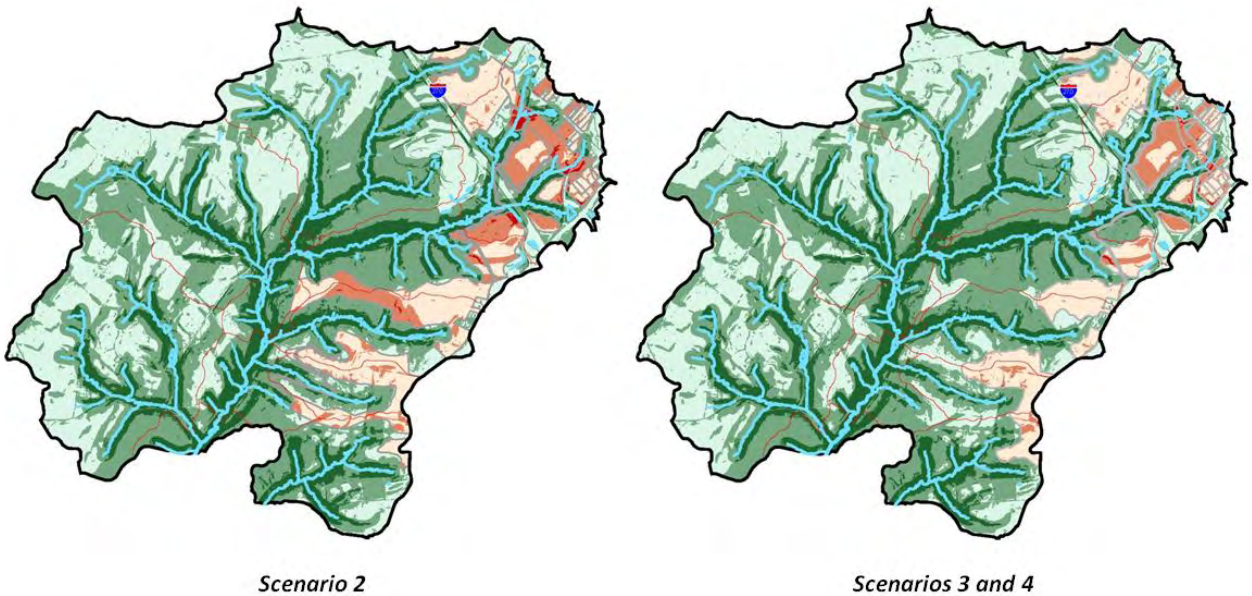



**Figure 5. Potential for Disturbance of Natural Resource Attributes in Scenarios 2, 3 and 4**
***(Forest Interior Included)***



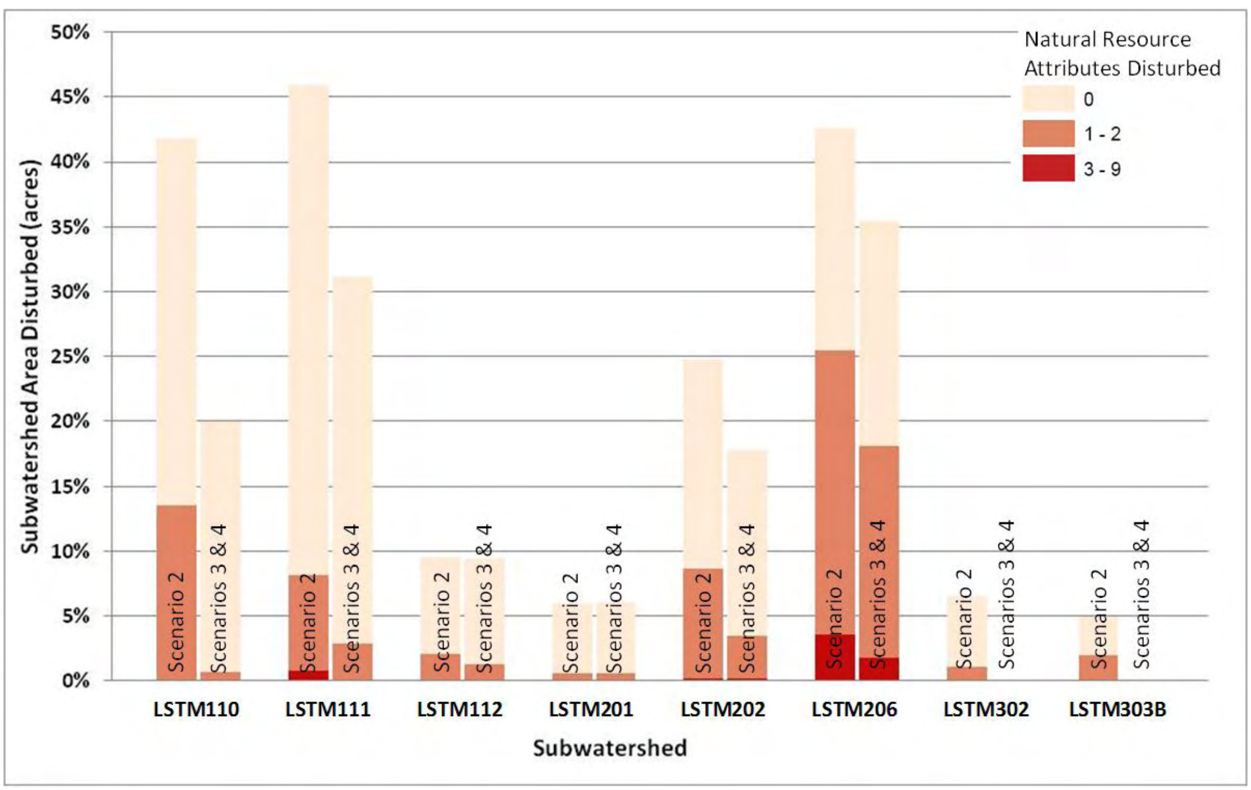




**Figure 6. Potential for Disturbance of Natural Resource Attributes in Scenarios 2, 3 and 4**
***(Forest Interior NOT Included)***

# 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

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# MEMORANDUM

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

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## 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<br>Medium-Density Residential<br>High-Density Residential |
| **Commercial** | Commercial<br>Industrial |
| **Transportation** | Transportation |
| **Municipal** | Open Urban Land<br>Institutional |
| **Rural** | Cropland<br>Pasture<br>Large-Lot Subdivision – Agriculture<br>Large-Lot Subdivision - Forest |
| **Forest** | Deciduous Forest<br>Evergreen Forest<br>Wetlands – Forested<br>Wetlands - Nonforested<br>Mixed Forest<br>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)<br>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.

$$CC = 10^{0.277 \cdot \mathrm{Log}(P_{Capture})}$$

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

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# MEMORANDUM

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.

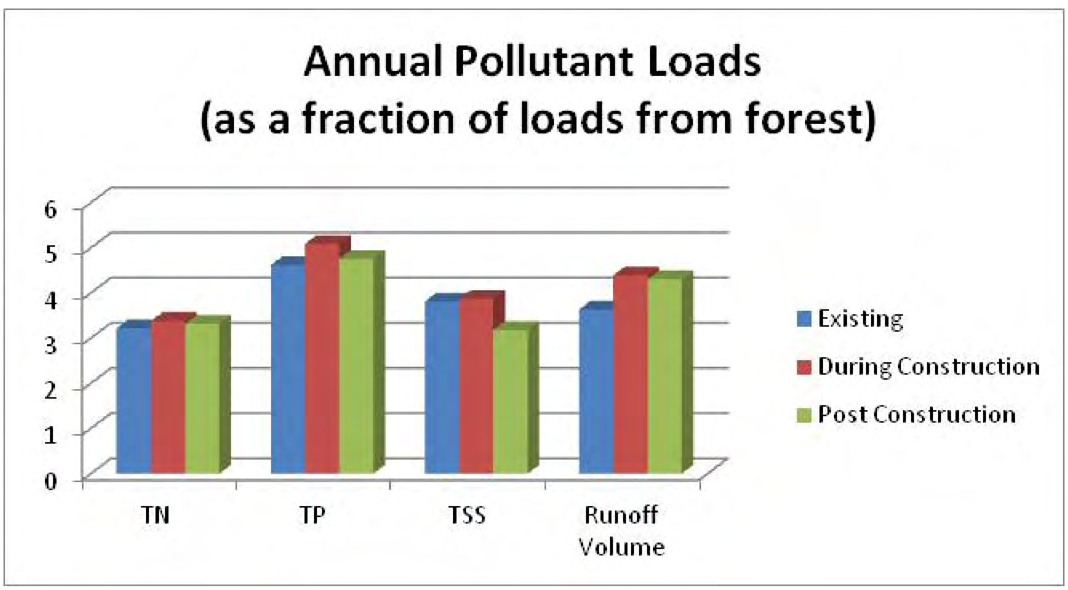


**Figure 1. Comparative Pollutant Loads Throughout the Development Process**

## 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**

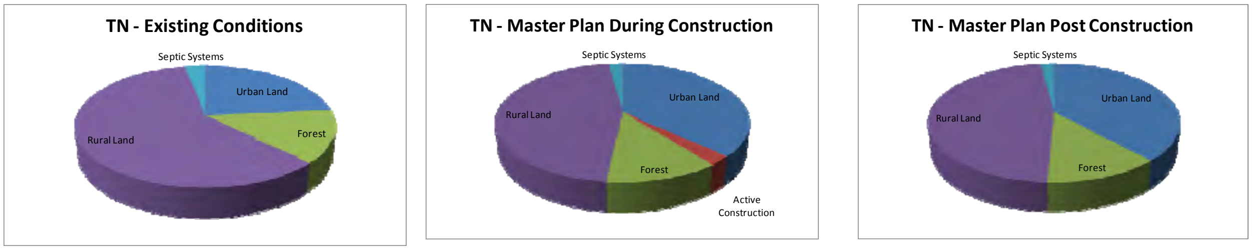


**Figure 3. TN Sources: Current, During Construction and Post Construction**

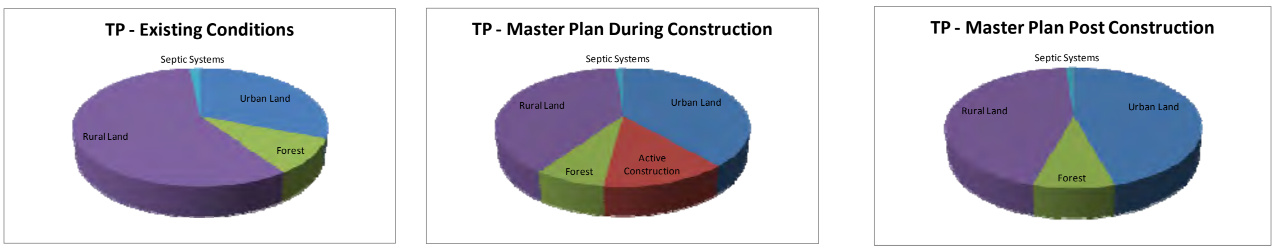


**Figure 4. TP Sources: Current, During Construction and Post Construction**

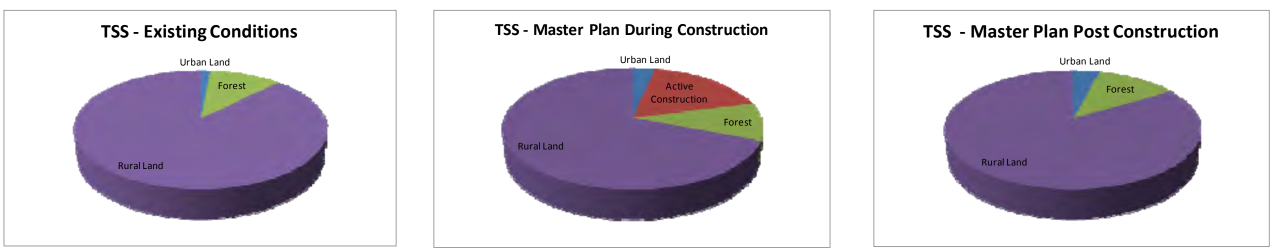


**Figure 5. Sediment Sources: Current, During Construction and Post Construction**

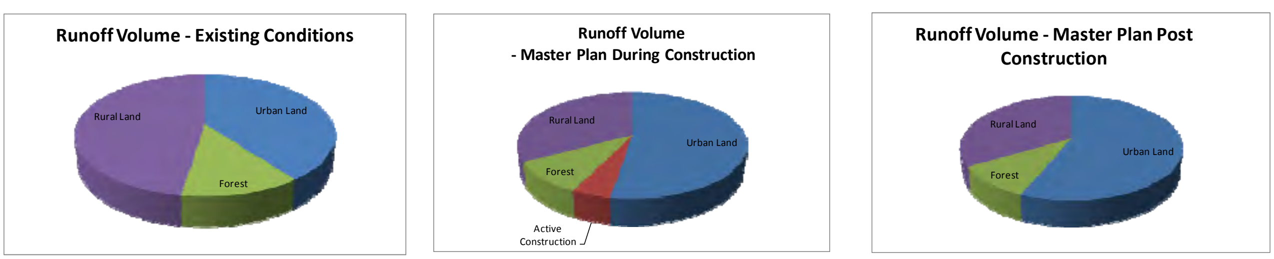


**Figure 6. Sources of Runoff Volume: Current, During Construction and Post Construction**

# 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.

---

[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.

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[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 –

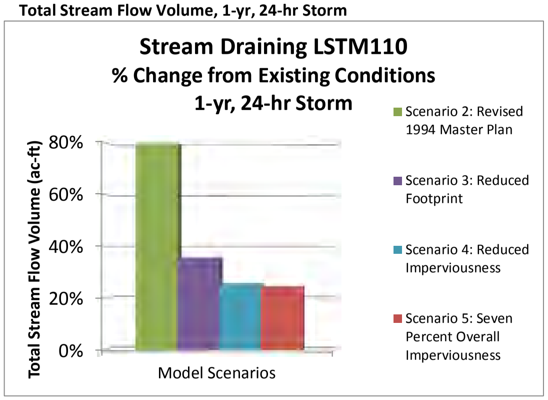
# Model Results

| 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% |

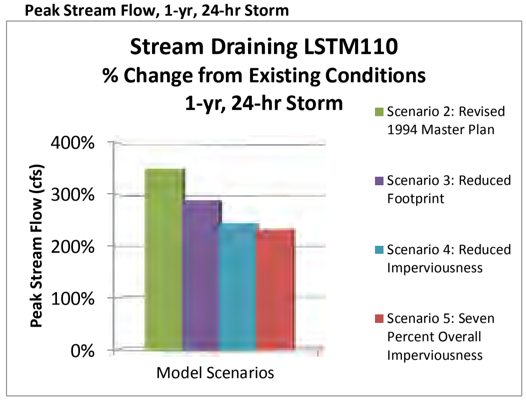
drains to link 71

Change compared to Existing Conditions

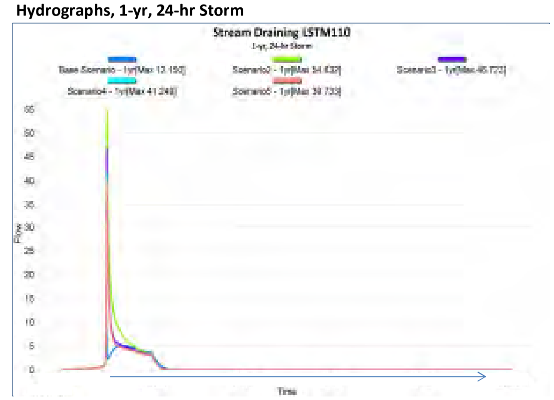
**Total Stream Flow Volume, 1-yr, 24-hr Storm**



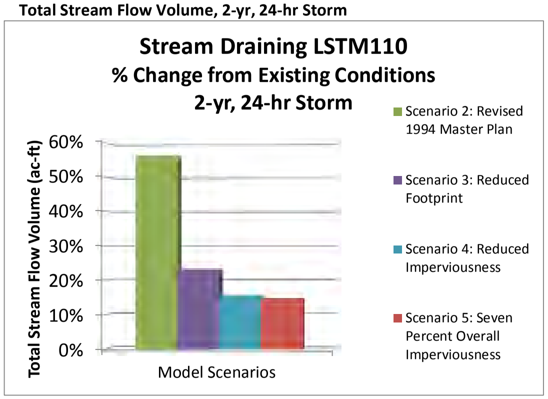

**Peak Stream Flow, 1-yr, 24-hr Storm**



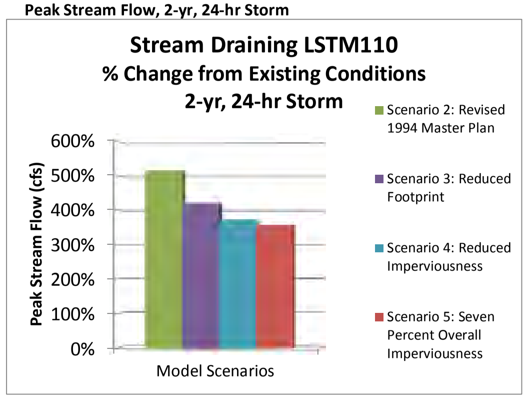

**Hydrographs, 1-yr, 24-hr Storm**



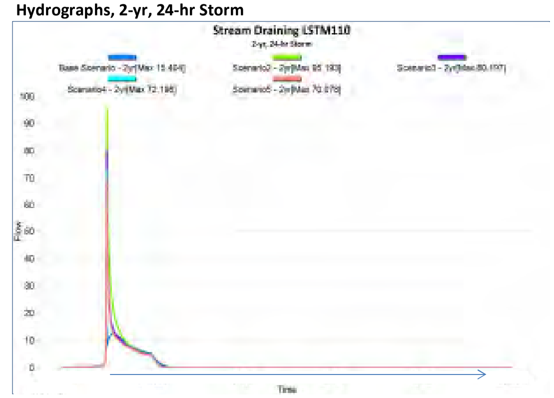

**Total Stream Flow Volume, 2-yr, 24-hr Storm**




**Peak Stream Flow, 2-yr, 24-hr Storm**




**Hydrographs, 2-yr, 24-hr Storm**

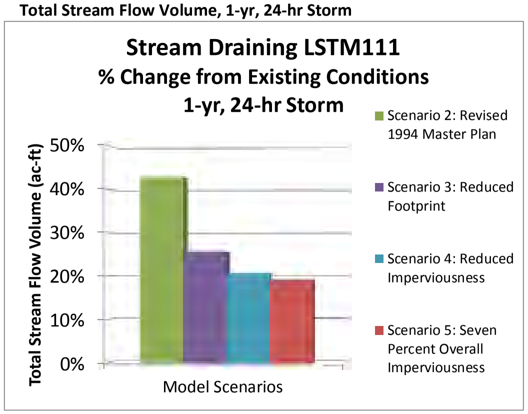


| Model Results | LSTM111 | | Existing Conditions | Scenario 2: Revised 1994 Master Plan | | | Scenario 3: Reduced Footprint | | | Scenario 4: Reduced Imperviousness | | | Scenario 5: Seven Percent Overall Imperviousness | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Storm 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 |
| | 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% |

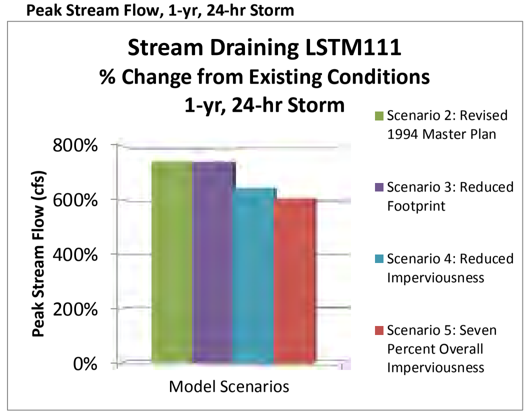
drains to link 61

Change compared to Existing Conditions

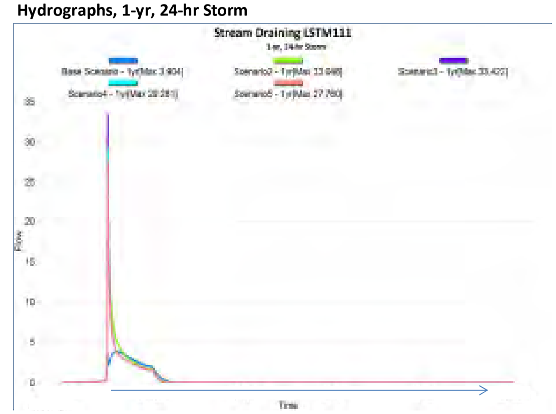
**Total Stream Flow Volume, 1-yr, 24-hr Storm**



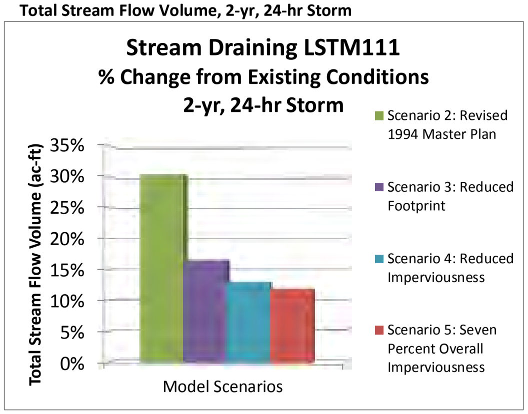

**Peak Stream Flow, 1-yr, 24-hr Storm**



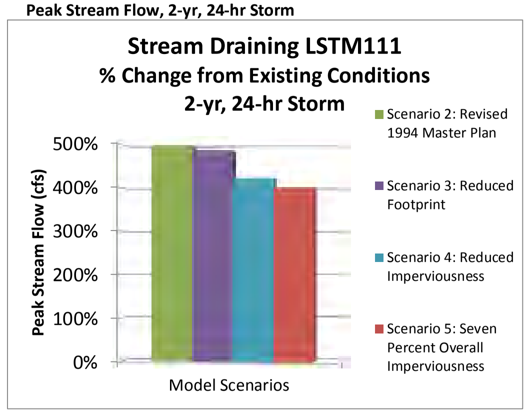

**Hydrographs, 1-yr, 24-hr Storm**



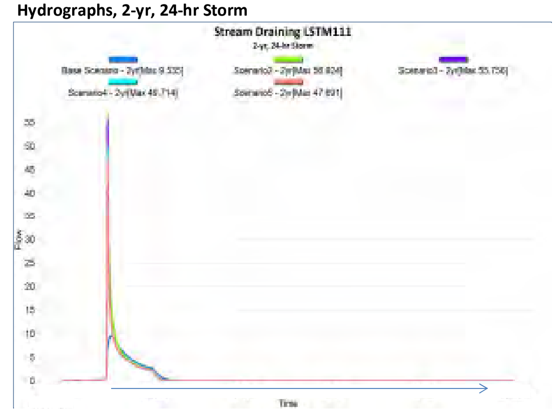

**Total Stream Flow Volume, 2-yr, 24-hr Storm**




**Peak Stream Flow, 2-yr, 24-hr Storm**




**Hydrographs, 2-yr, 24-hr Storm**

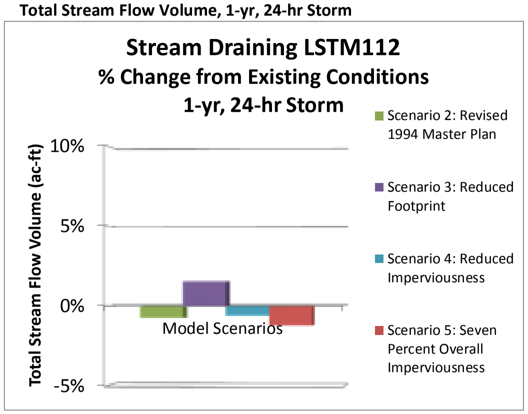


| LSTM112 | | | Existing Conditions | Scenario 2: Revised 1994 Master Plan | | | Scenario 3: Reduced Footprint | | | Scenario 4: Reduced Imperviousness | | | Scenario 5: Seven Percent Overall Imperviousness | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Model Results | Storm 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% |

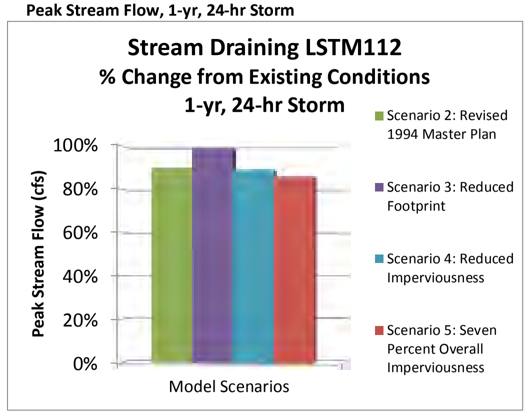
drains to link 21

Change compared to Existing Conditions

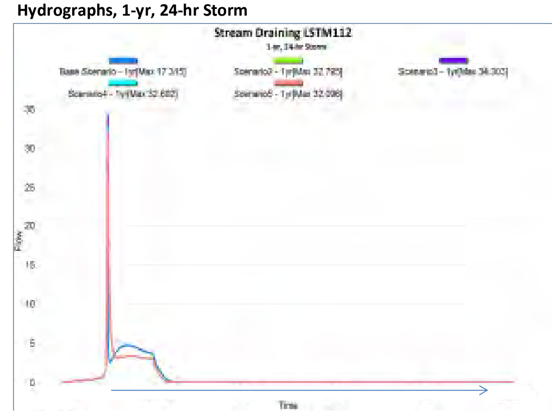
**Total Stream Flow Volume, 1-yr, 24-hr Storm**



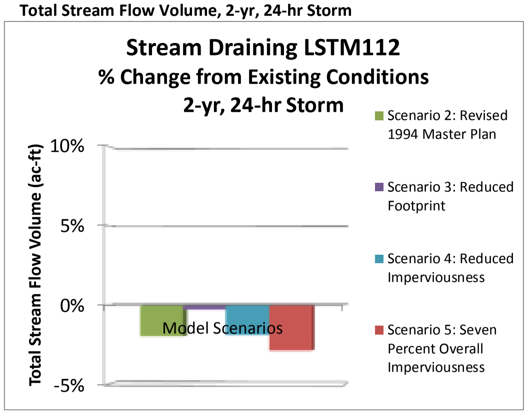

**Peak Stream Flow, 1-yr, 24-hr Storm**



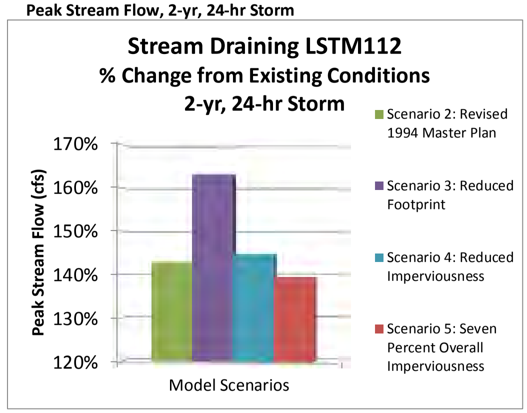

**Hydrographs, 1-yr, 24-hr Storm**



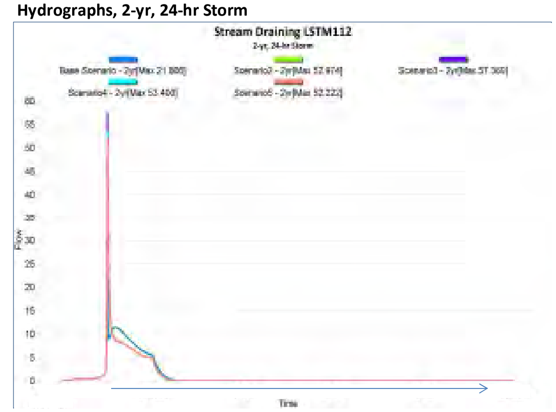

**Total Stream Flow Volume, 2-yr, 24-hr Storm**




**Peak Stream Flow, 2-yr, 24-hr Storm**




**Hydrographs, 2-yr, 24-hr Storm**

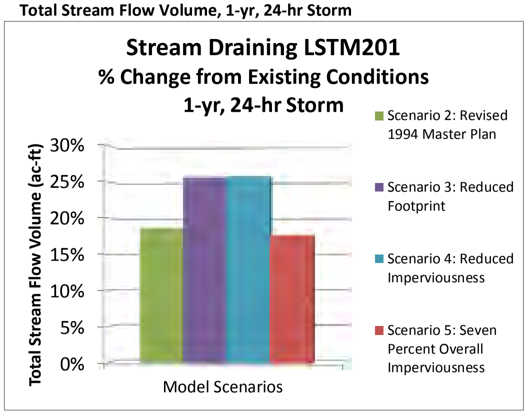


| LSTM201 | | | Existing Conditions | Scenario 2: Revised 1994 Master Plan | | | Scenario 3: Reduced Footprint | | | Scenario 4: Reduced Imperviousness | | | Scenario 5: Seven Percent Overall Imperviousness | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Model Results | Storm 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% |

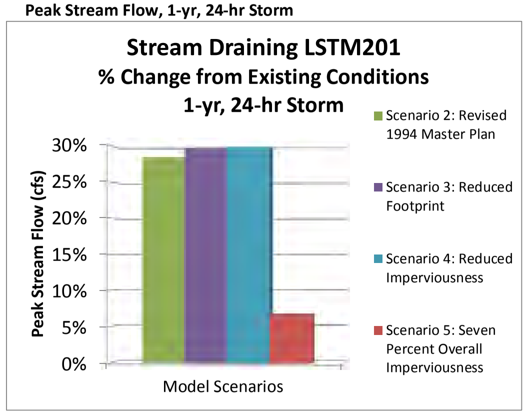
drains to link 110

Change compared to Existing Conditions

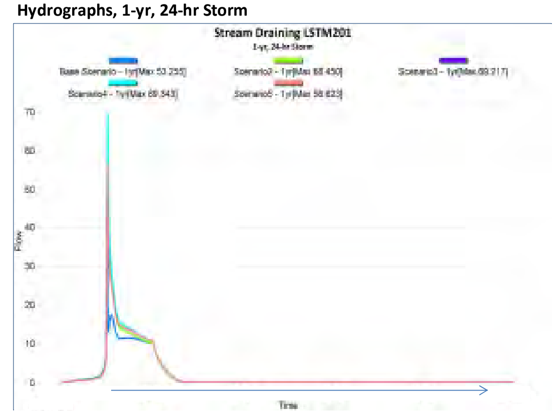
**Total Stream Flow Volume, 1-yr, 24-hr Storm**



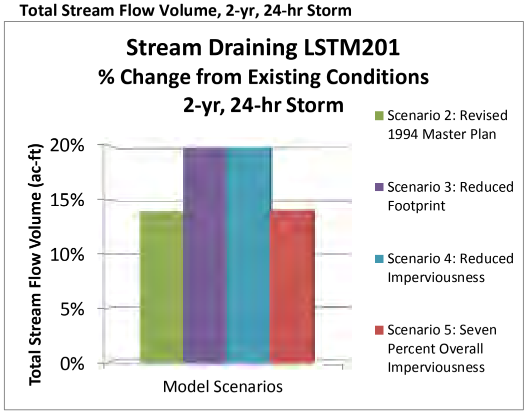

**Peak Stream Flow, 1-yr, 24-hr Storm**



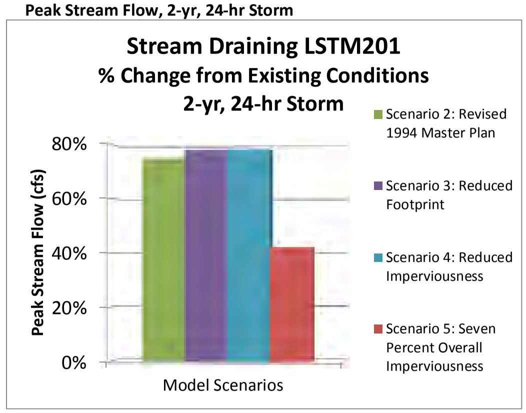

**Hydrographs, 1-yr, 24-hr Storm**



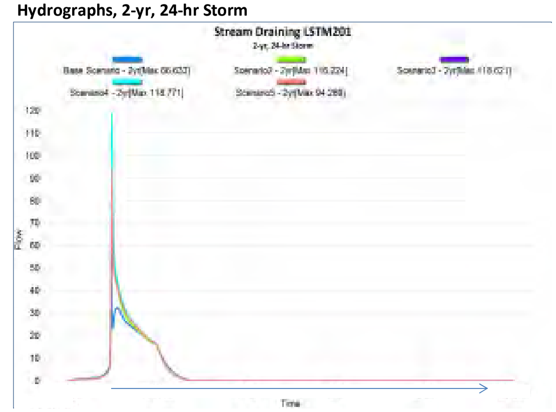

**Total Stream Flow Volume, 2-yr, 24-hr Storm**




**Peak Stream Flow, 2-yr, 24-hr Storm**




**Hydrographs, 2-yr, 24-hr Storm**

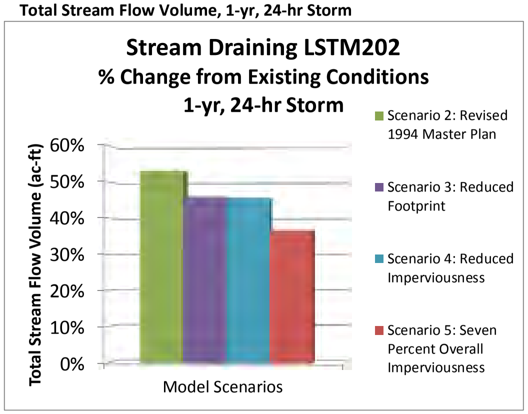


| LSTM202 | | | Existing Conditions | Scenario 2: Revised 1994 Master Plan | | | Scenario 3: Reduced Footprint | | | Scenario 4: Reduced Imperviousness | | | Scenario 5: Seven Percent Overall Imperviousness | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Model Results | Storm 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% |

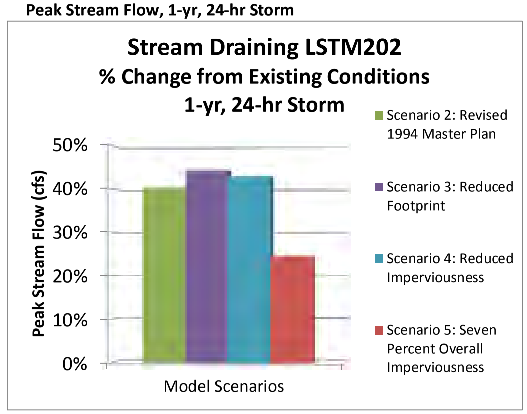
drains to link 101

Change compared to Existing Conditions

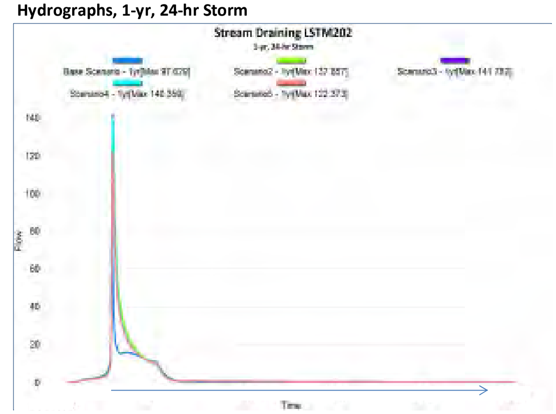
Total Stream Flow Volume, 1-yr, 24-hr Storm



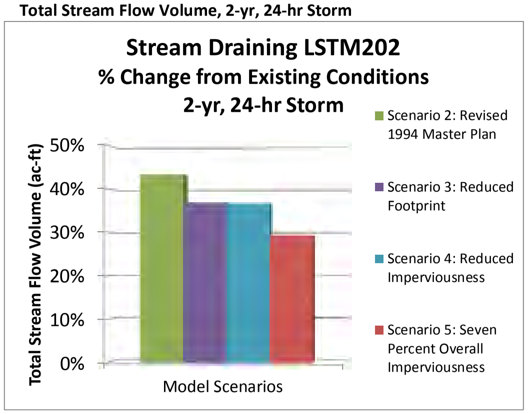

Peak Stream Flow, 1-yr, 24-hr Storm



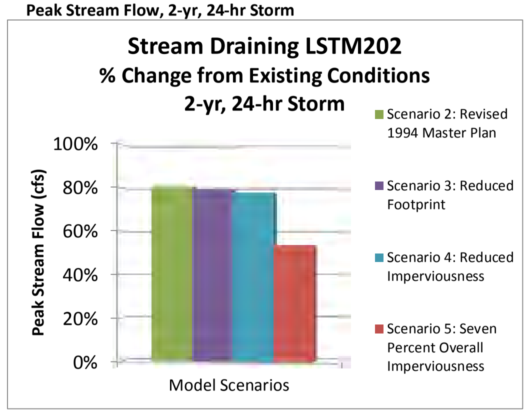

Hydrographs, 1-yr, 24-hr Storm



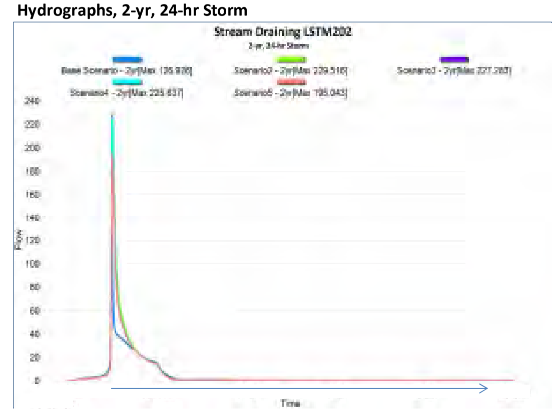

Total Stream Flow Volume, 2-yr, 24-hr Storm




Peak Stream Flow, 2-yr, 24-hr Storm




Hydrographs, 2-yr, 24-hr Storm

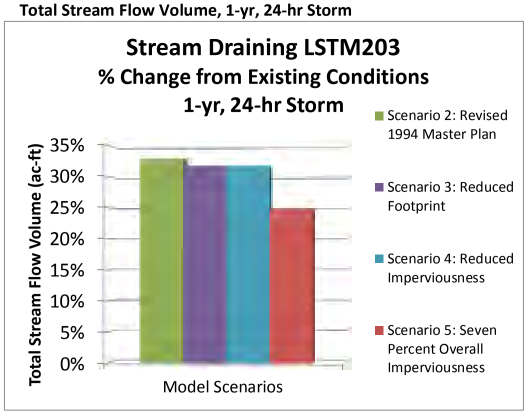


| LSTM203 | | | Existing Conditions | Scenario 2: Revised 1994 Master Plan | | | Scenario 3: Reduced Footprint | | | Scenario 4: Reduced Imperviousness | | | Scenario 5: Seven Percent Overall Imperviousness | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Model Results | Storm 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% |

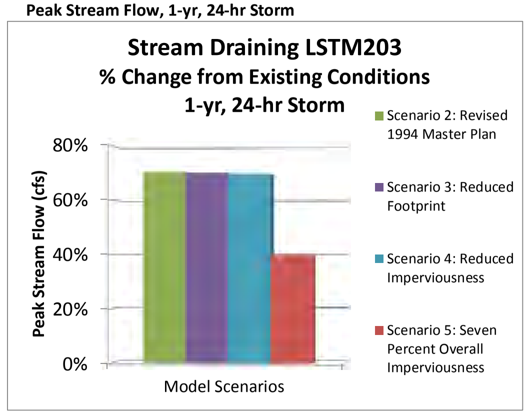
drains to link 90

Change compared to Existing Conditions

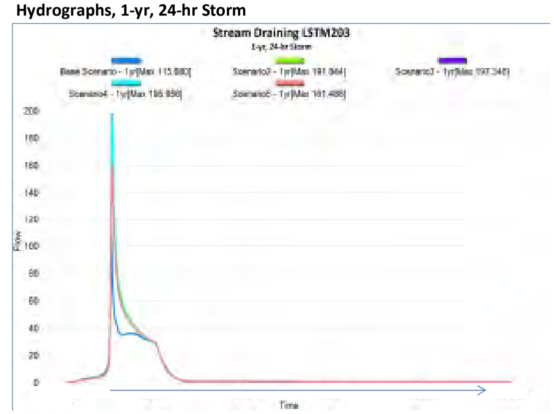
Total Stream Flow Volume, 1-yr, 24-hr Storm



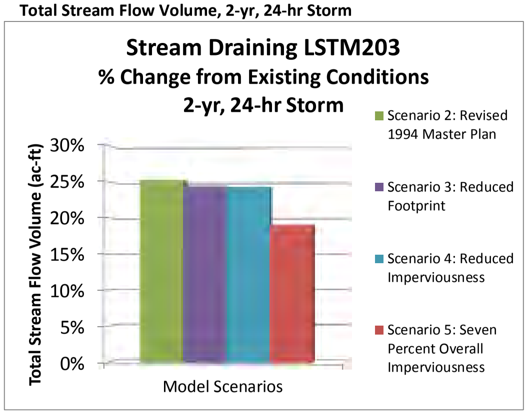

Peak Stream Flow, 1-yr, 24-hr Storm



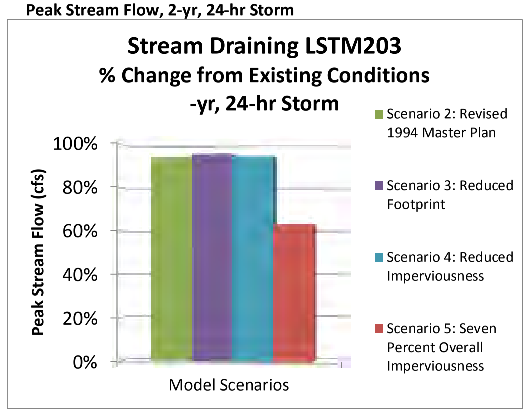

Hydrographs, 1-yr, 24-hr Storm



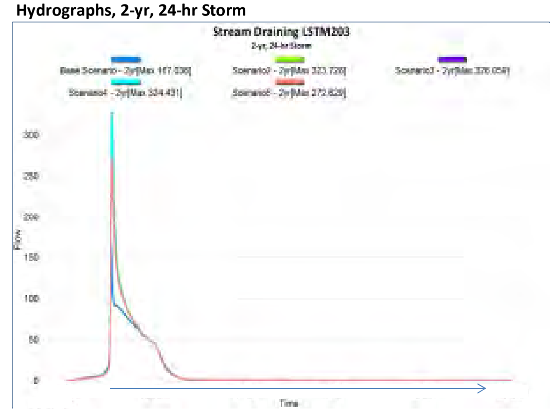

Total Stream Flow Volume, 2-yr, 24-hr Storm




Peak Stream Flow, 2-yr, 24-hr Storm




Hydrographs, 2-yr, 24-hr Storm

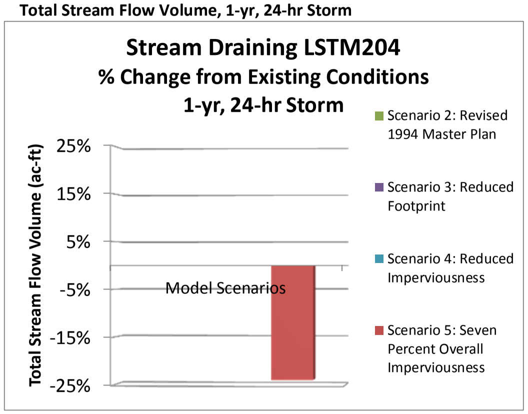


| LSTM204 | | | Existing Conditions | Scenario 2: Revised 1994 Master Plan | | | Scenario 3: Reduced Footprint | | | Scenario 4: Reduced Imperviousness | | | Scenario 5: Seven Percent Overall Imperviousness | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Model Results | Storm 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% |

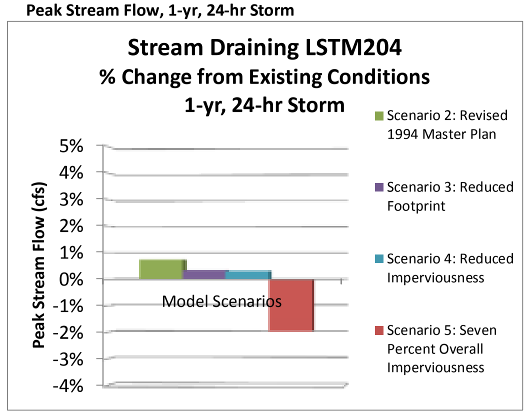
drains to link 041

Change compared to Existing Conditions

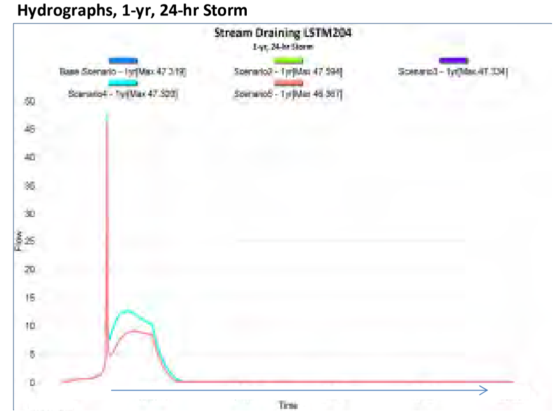
**Total Stream Flow Volume, 1-yr, 24-hr Storm**



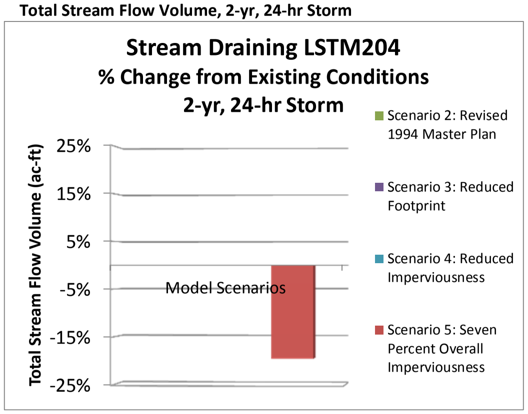

**Peak Stream Flow, 1-yr, 24-hr Storm**



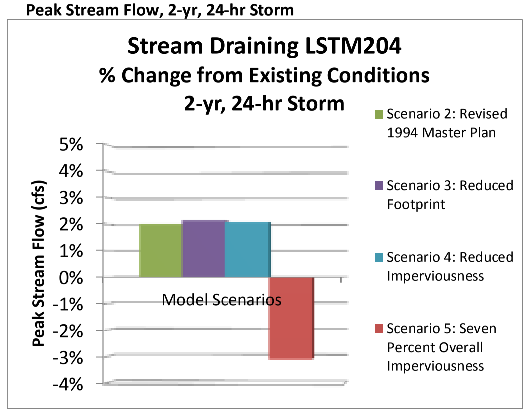

**Hydrographs, 1-yr, 24-hr Storm**



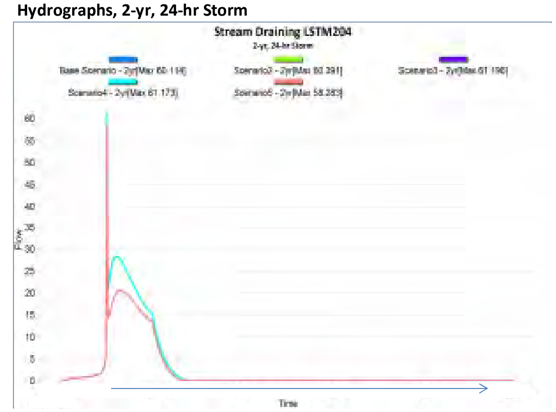

**Total Stream Flow Volume, 2-yr, 24-hr Storm**




**Peak Stream Flow, 2-yr, 24-hr Storm**




**Hydrographs, 2-yr, 24-hr Storm**

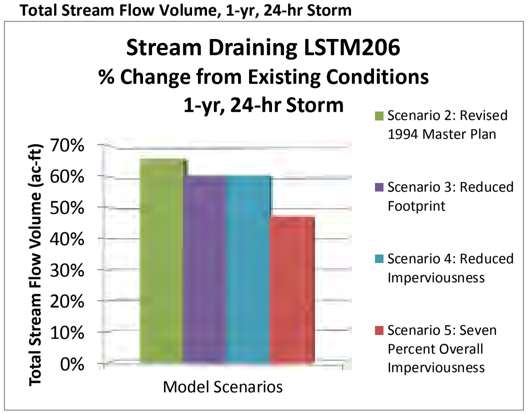


| LSTM206 | | | Existing Conditions | Scenario 2: Revised 1994 Master Plan | | | Scenario 3: Reduced Footprint | | | Scenario 4: Reduced Imperviousness | | | Scenario 5: Seven Percent Overall Imperviousness | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Model Results | Storm 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% |

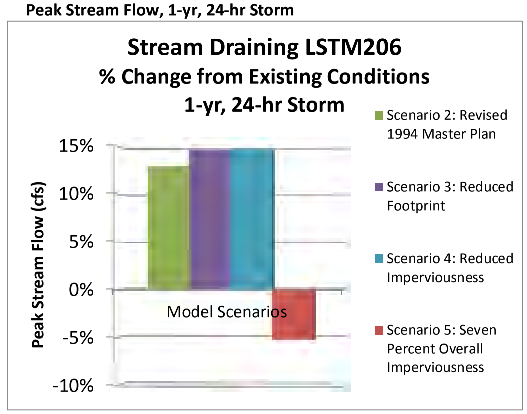
drains to link 102

Change compared to Existing Conditions

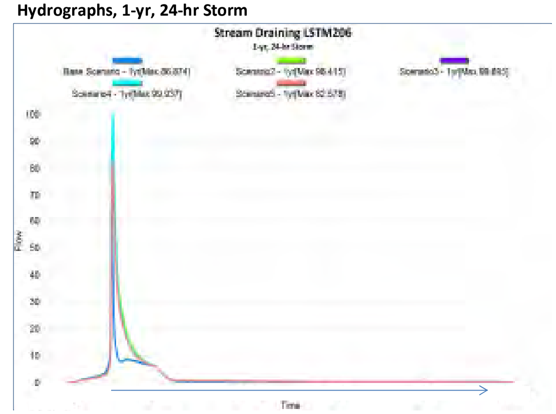
Total Stream Flow Volume, 1-yr, 24-hr Storm



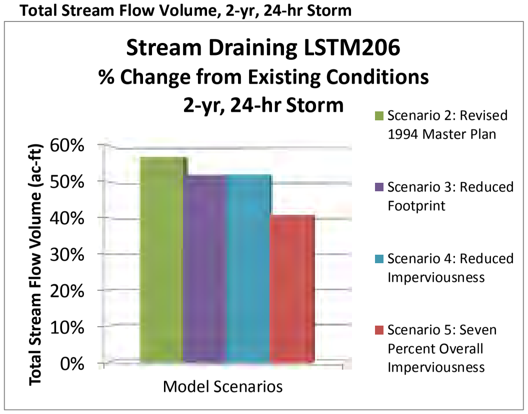

Peak Stream Flow, 1-yr, 24-hr Storm



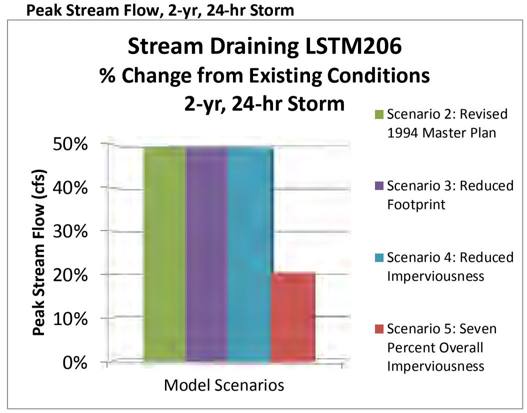

Hydrographs, 1-yr, 24-hr Storm



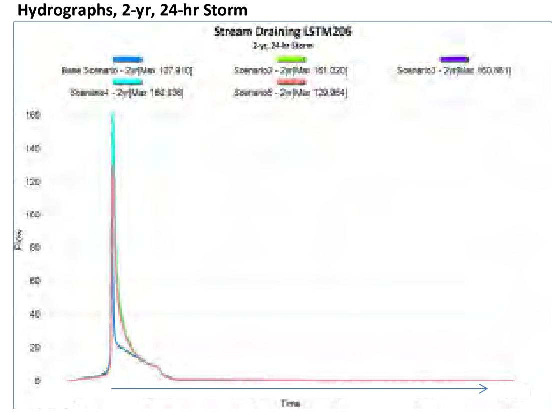

Total Stream Flow Volume, 2-yr, 24-hr Storm




Peak Stream Flow, 2-yr, 24-hr Storm




Hydrographs, 2-yr, 24-hr Storm

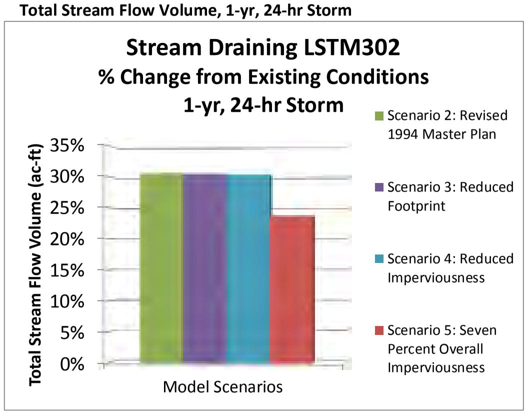


| LSTM302 | | | Existing Conditions | Scenario 2: Revised 1994 Master Plan | | | Scenario 3: Reduced Footprint | | | Scenario 4: Reduced Imperviousness | | | Scenario 5: Seven Percent Overall Imperviousness | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Model Results | Storm 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% |

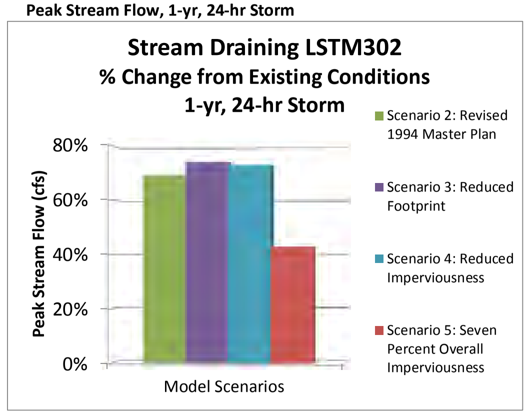
drains to link 80

Change compared to Existing Conditions

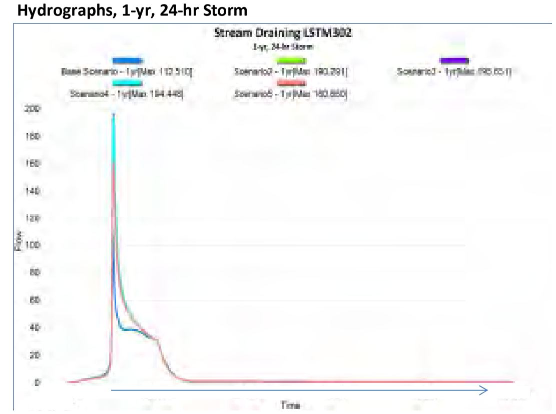
**Total Stream Flow Volume, 1-yr, 24-hr Storm**



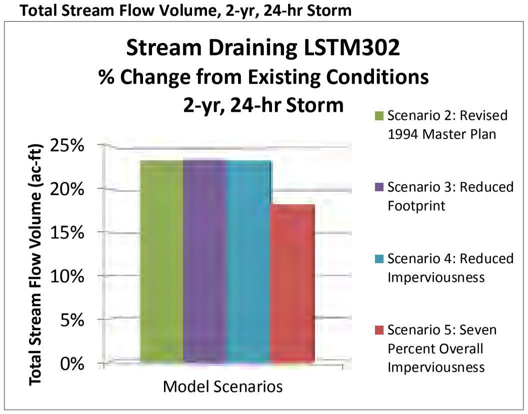

**Peak Stream Flow, 1-yr, 24-hr Storm**



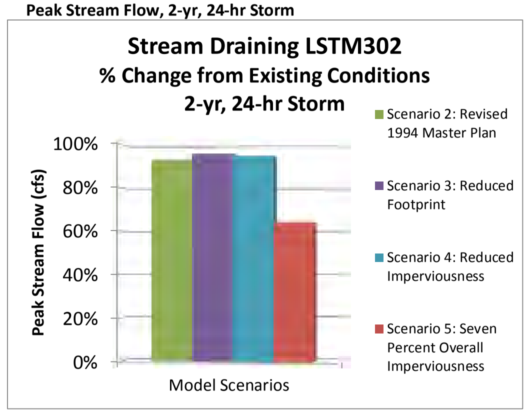

**Hydrographs, 1-yr, 24-hr Storm**



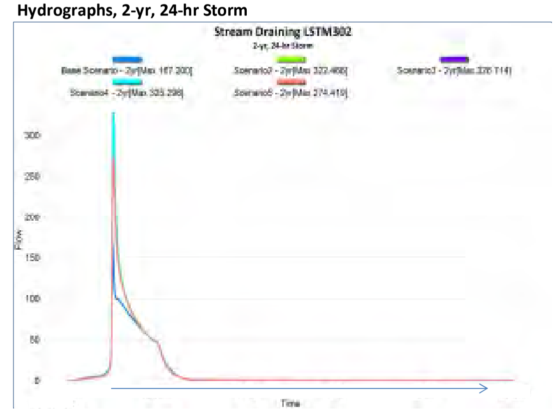

**Total Stream Flow Volume, 2-yr, 24-hr Storm**




**Peak Stream Flow, 2-yr, 24-hr Storm**




**Hydrographs, 2-yr, 24-hr Storm**

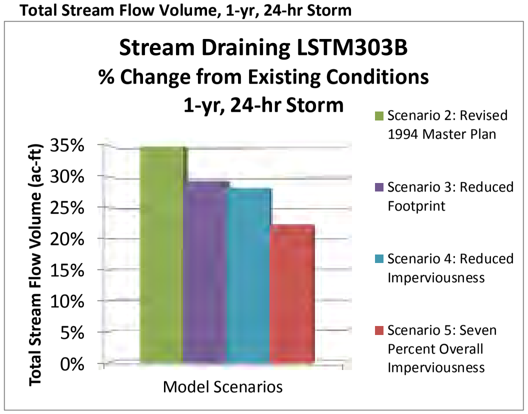


| LSTM303B | | | Existing Conditions | Scenario 2: Revised 1994 Master Plan | | | Scenario 3: Reduced Footprint | | | Scenario 4: Reduced Imperviousness | | | Scenario 5: Seven Percent Overall Imperviousness | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Model Results | Storm 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% |

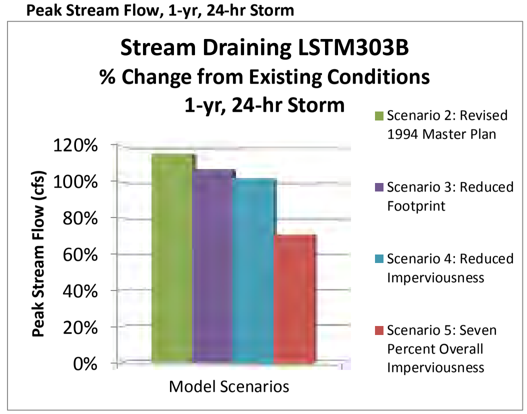
drains to link 50

Change compared to Existing Conditions

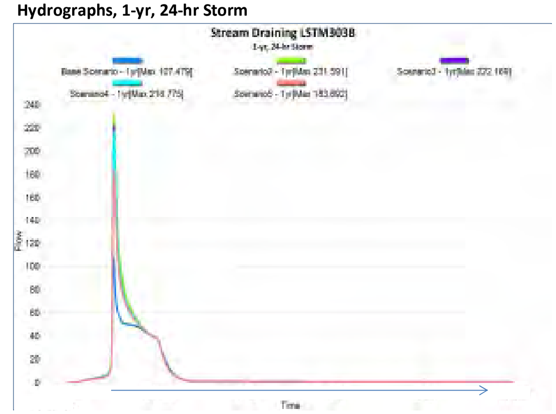
**Total Stream Flow Volume, 1-yr, 24-hr Storm**



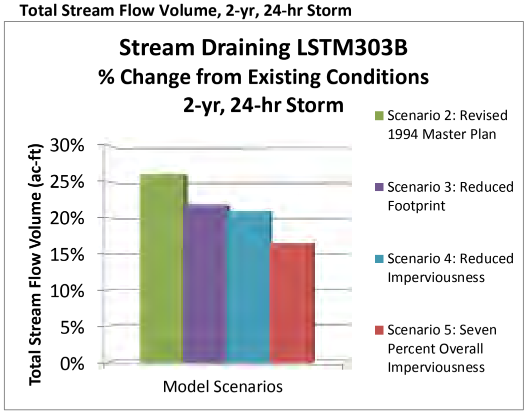

**Peak Stream Flow, 1-yr, 24-hr Storm**



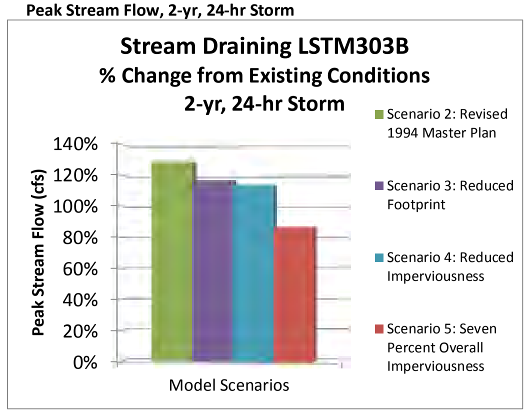

**Hydrographs, 1-yr, 24-hr Storm**



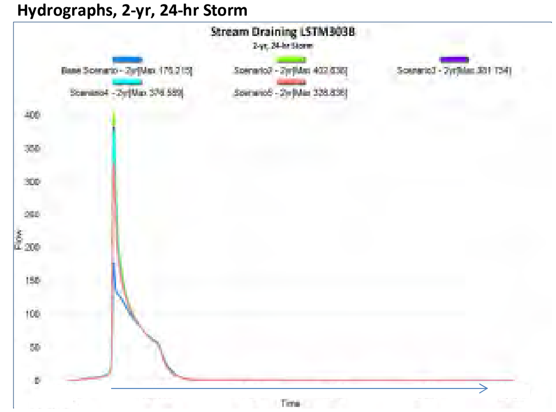

**Total Stream Flow Volume, 2-yr, 24-hr Storm**




**Peak Stream Flow, 2-yr, 24-hr Storm**




**Hydrographs, 2-yr, 24-hr Storm**

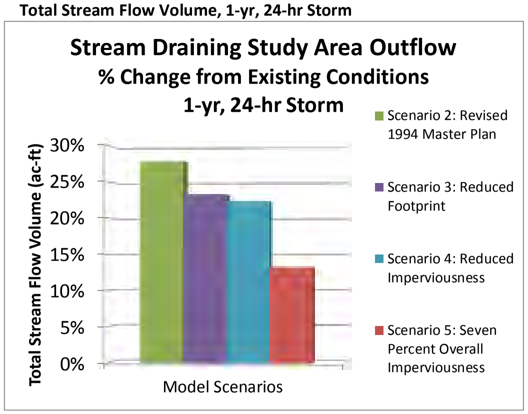


| STUDY AREA OUTFLOW | | | Existing Conditions | Scenario 2: Revised 1994 Master Plan | | | Scenario 3: Reduced Footprint | | | Scenario 4: Reduced Imperviousness | | | Scenario 5: Seven Percent Overall Imperviousness | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Model Results | 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)** | 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% |

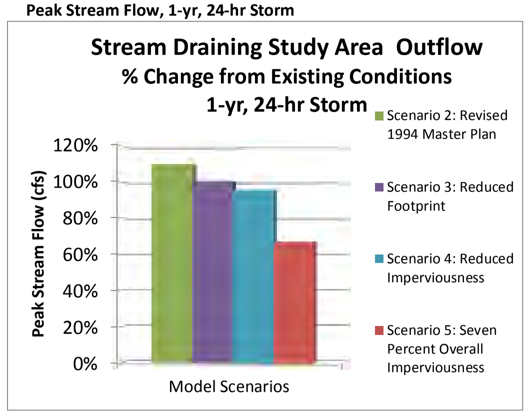
drains to link 30

Change compared to Existing Conditions

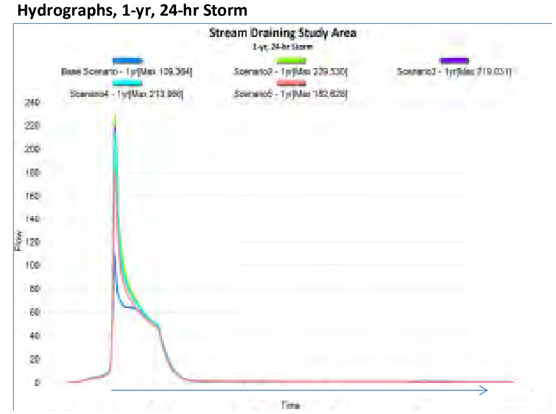
**Total Stream Flow Volume, 1-yr, 24-hr Storm**



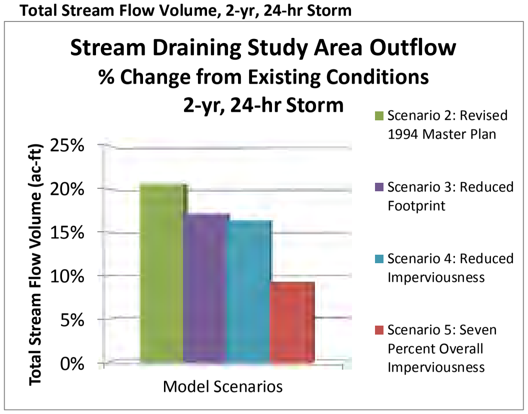

**Peak Stream Flow, 1-yr, 24-hr Storm**



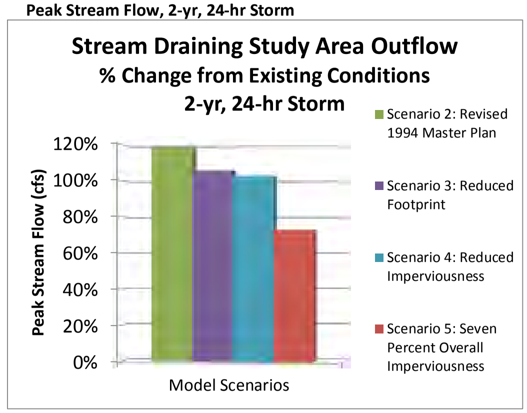

**Hydrographs, 1-yr, 24-hr Storm**



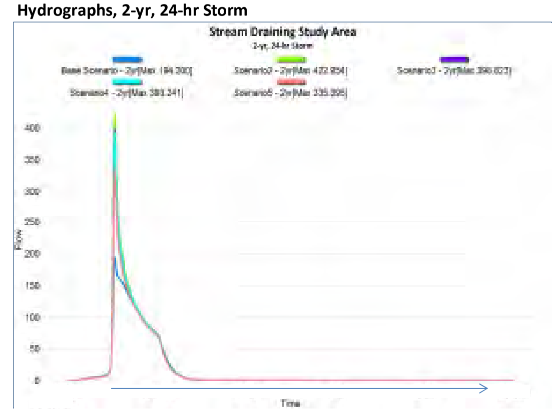

**Total Stream Flow Volume, 2-yr, 24-hr Storm**




**Peak Stream Flow, 2-yr, 24-hr Storm**

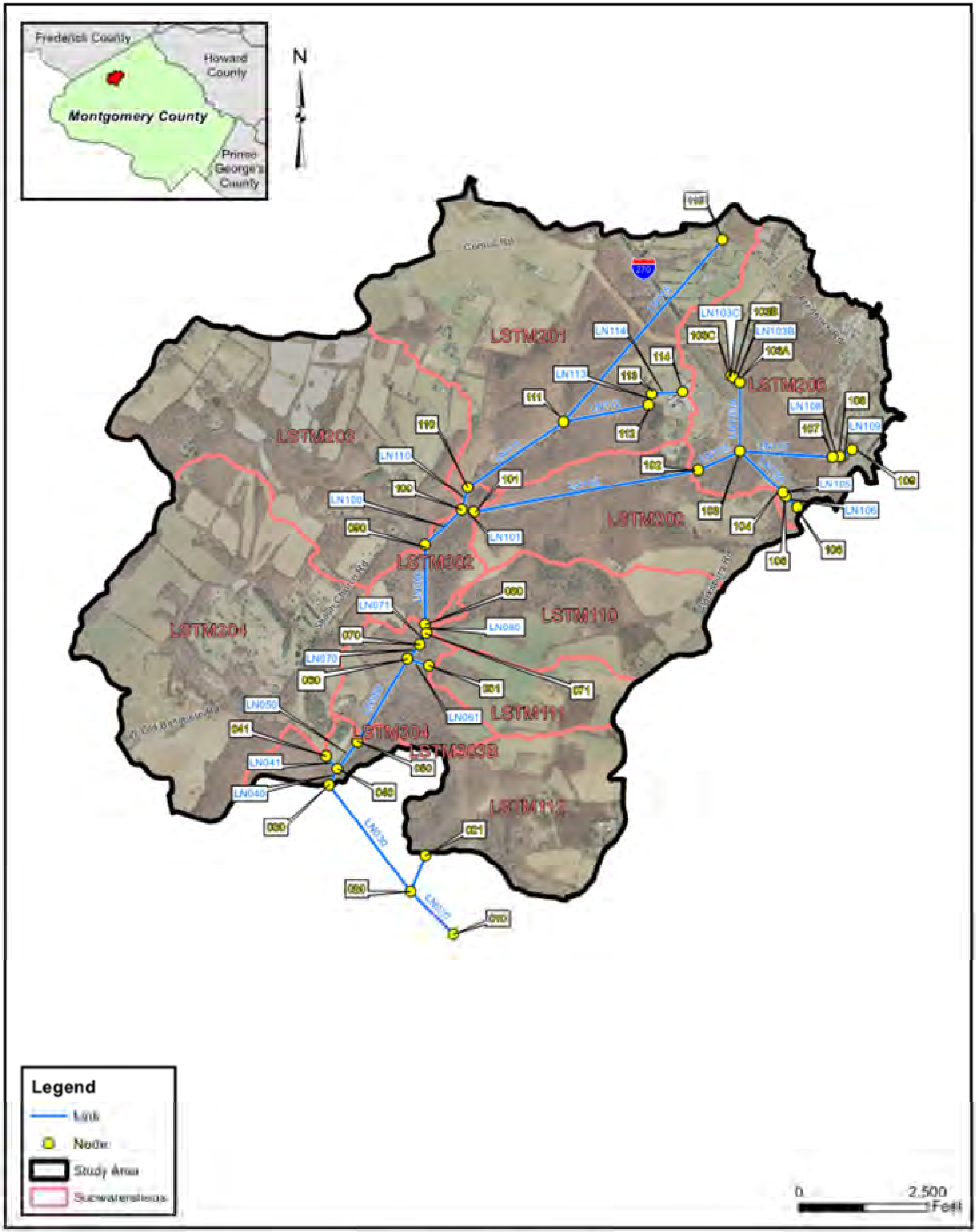



**Hydrographs, 2-yr, 24-hr Storm**



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 | Development | HSG | Area (Acres) | Area (ft2) | RCN | RCN* | Impervious (%) | $R_v$ | $P_e$ (in) | $Q_e$ (in) | $ESD_v$ (ft3) | Af (Mont Co) sf | Total Af (acres)Mont. Co | $A_f$ (Acres) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sub Basin 110 (1 yr 24 hr Storm)** | | | | | | | | | | | | | | |
| Sub-Basin | Development | HSG | Area (Acres) | Area (ft2) | RCN | RCN* | Impervious (%) | $R_v$ | $P_e$ (in) | $Q_e$ (in) | $ESD_v$ (ft3) | Af (Mont Co) sf | Total Af (acres)Mont. Co | $A_f$ (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 (%) | $R_v$ | $P_e$ (in) | $Q_e$ (in) | $ESD_v$ (ft3) | Af (Mont Co) sf | Total Af (acres)Mont. Co | $A_f$ (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 (%) | $R_v$ | $P_e$ (in) | $Q_e$ (in) | $ESD_v$ (ft3) | Af (Mont Co) sf | Total Af (acres)Mont. Co | $A_f$ (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 (%) | $R_v$ | $P_e$ (in) | $Q_e$ (in) | $ESD_v$ (ft3) | Af (Mont Co) sf | Total Af (acres)Mont. Co | $A_f$ (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 (%) | $R_v$ | $P_e$ (in) | $Q_e$ (in) | $ESD_v$ (ft3) | Af (Mont Co) sf | Total Af (acres)Mont. Co | $A_f$ (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 (%) | $R_v$ | $P_e$ (in) | $Q_e$ (in) | $ESD_v$ (ft3) | Af (Mont Co) sf | Total Af (acres)Mont. Co | $A_f$ (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 (%) | $R_v$ | $P_e$ (in) | $Q_e$ (in) | $ESD_v$ (ft3) | Af (Mont Co) sf | Total Af (acres)Mont. Co | $A_f$ (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 (%) | $R_v$ | $P_e$ (in) | $Q_e$ (in) | $ESD_v$ (ft3) | Af (Mont Co) sf | Total Af (acres)Mont. Co | $A_f$ (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 (%) | $R_v$ | $P_e$ (in) | $Q_e$ (in) | $ESD_v$ (ft3) | Af (Mont Co) sf | Total Af (acres)Mont. Co | $A_f$ (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 (%) | $R_v$ | $P_e$ (in) | $Q_e$ (in) | $ESD_v$ (ft3) | Af (Mont Co) sf | Total Af (acres)Mont. Co | $A_f$ (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 | | | | | |

| 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) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **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 (%) | $R_v$ | $P_e$ (in) | $Q_e$ (in) | $ESD_v$ (ft3) | $A_f$ (Mont Co) sf | Total $A_f$ (acres)Mont. Co | $A_f$ (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 (%) | $R_v$ | $P_e$ (in) | $Q_e$ (in) | $ESD_v$ (ft3) | $A_f$ (Mont Co) sf | Total $A_f$ (acres)Mont. Co | $A_f$ (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 (%) | $R_v$ | $P_e$ (in) | $Q_e$ (in) | $ESD_v$ (ft3) | $A_f$ (Mont Co) sf | Total $A_f$ (acres)Mont. Co | $A_f$ (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 (%) | $R_v$ | $P_e$ (in) | $Q_e$ (in) | $ESD_v$ (ft3) | $A_f$ (Mont Co) sf | Total $A_f$ (acres)Mont. Co | $A_f$ (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 (%) | $R_v$ | $P_e$ (in) | $Q_e$ (in) | $ESD_v$ (ft3) | $A_f$ (Mont Co) sf | Total $A_f$ (acres)Mont. Co | $A_f$ (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 (%) | $R_v$ | $P_e$ (in) | $Q_e$ (in) | $ESD_v$ (ft3) | $A_f$ (Mont Co) sf | Total $A_f$ (acres)Mont. Co | $A_f$ (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 (%) | $R_v$ | $P_e$ (in) | $Q_e$ (in) | $ESD_v$ (ft3) | $A_f$ (Mont Co) sf | Total $A_f$ (acres)Mont. Co | $A_f$ (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 (%) | $R_v$ | $P_e$ (in) | $Q_e$ (in) | $ESD_v$ (ft3) | $A_f$ (Mont Co) sf | Total $A_f$ (acres)Mont. Co | $A_f$ (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 (%) | $R_v$ | $P_e$ (in) | $Q_e$ (in) | $ESD_v$ (ft3) | $A_f$ (Mont Co) sf | Total $A_f$ (acres)Mont. Co | $A_f$ (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 (%) | $R_v$ | $P_e$ (in) | $Q_e$ (in) | $ESD_v$ (ft3) | $A_f$ (Mont Co) sf | Total $A_f$ (acres)Mont. Co | $A_f$ (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 (%) | $R_v$ | $P_e$ (in) | $Q_e$ (in) | $ESD_v$ (ft3) | $A_f$ (Mont Co) sf | Total $A_f$ (acres)Mont. Co | $A_f$ (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 | | | | | |