# Loudoun County Stream Assessment: Review of Previous Stream Biological and Habitat Assessments in Loudoun County

Prepared for
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# TABLE OF CONTENTS



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# LIST OF FIGURES

## LIST OF FIGURES (CONTINUED)

**Figure No.** **Page**

## LIST OF FIGURES (CONTINUED)

**Figure No.** **Page**


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# 1 INTRODUCTION

Loudoun County Building and Development is undertaking a countywide stream assessment in 2009 to evaluate the ecological condition of its freshwater stream resources and to provide information for watershed management. Biological and habitat data collected in streams can provide critical information about ecological status and trends. As part of this countywide assessment, Loudoun County seeks to review stream biological and physical habitat data that have been collected in past years by a variety of agencies and organizations. In this report, we review past data for Loudoun County streams and evaluate the utility of this information in light of the county's current stream assessment program.

This report documents our review of prior stream assessments performed in Loudoun County. Stream biological and habitat data have been collected in Loudoun County by a variety of organizations, including governmental, academic, and citizen groups. Data are available for many locations throughout Loudoun County's watersheds (Figure 1-1). The purpose of this report is to provide a detailed summary and evaluation of the information available from these previous field investigations. Chapter 2 provides detailed summaries of all prior reports and data reviewed, with information on monitoring methods, site selection, and findings, including example maps illustrating results. Chapter 3 provides further explanations of particular topics of interest, including a look at trends, data on individual habitat parameters, stream mitigation scores, fish surveys, and field reconnaissance/streamwalk data. Chapter 4 reviews and compares the various protocols and metrics used to score benthic macroinvertebrate data. Chapter 5 provides an integrated assessment, and Chapter 6 includes conclusions that provide the basis for development of the 2009 countywide Loudoun County Stream Assessment. References are in Chapter 7, while graphs depicting year-to-year trends at selected sites are provided in the Appendix.

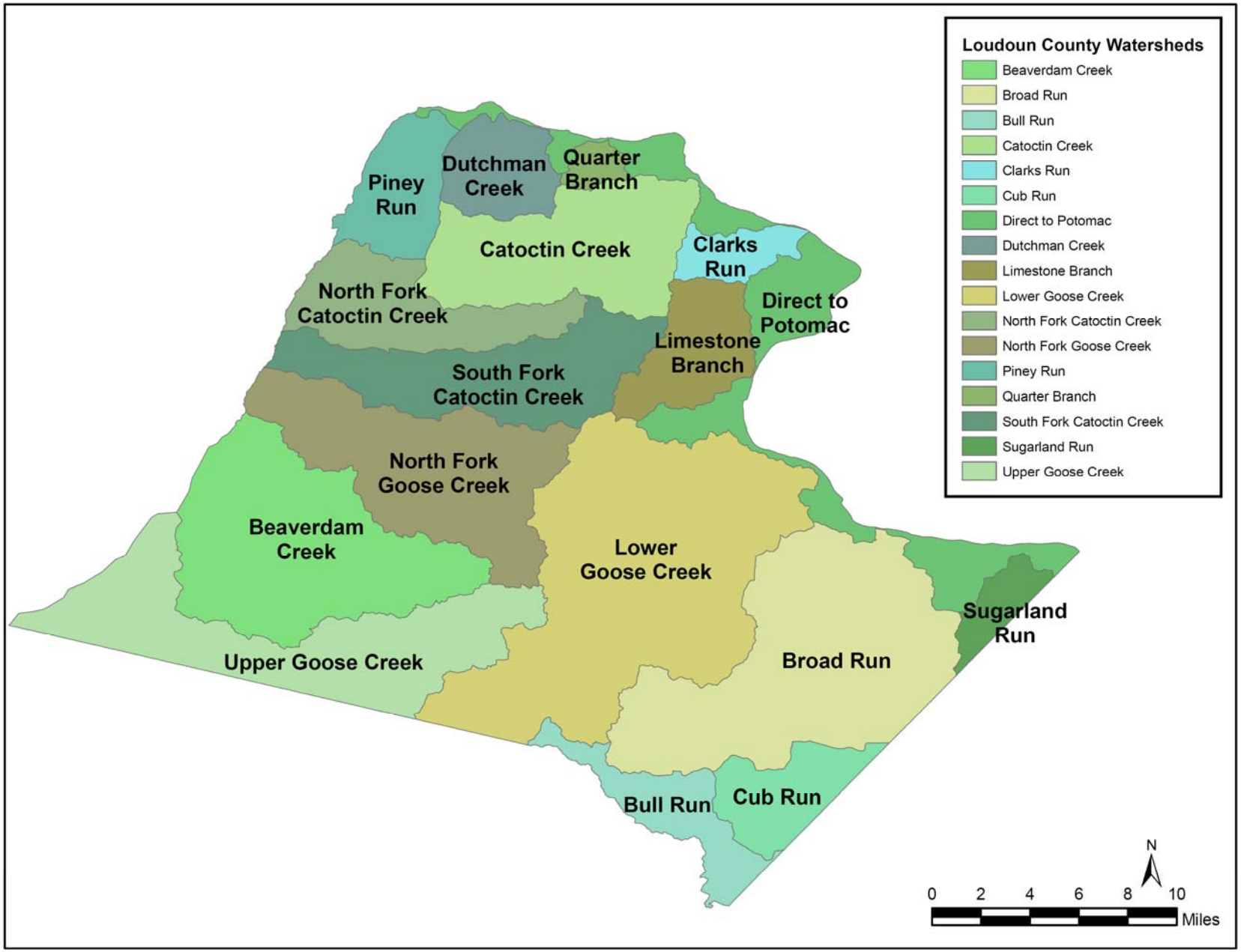


Figure 1-1. Loudoun County watersheds

# 2 DATA AND LITERATURE REVIEW

We conducted a through review of the available reports and stream biological and habitat data for monitoring studies conducted within Loudoun County. Most of these data and reports had been compiled by Loudoun County Building and Development staff and provided as reports and GIS geodatabase files. The review included data on benthic macroinvertebrate monitoring (bioassessment), stream habitat, and streamwalk reconnaissance data collected by numerous parties.

All data and previous reports are summarized independently in the following summary sheets, accompanied by maps and figures. They cover the following:

- Virginia Department of Environmental Quality (DEQ) EDAS Data and DEQ 2008 Impaired Waters fact sheets
- Interstate Commission on the Potomac River Basin. 2004. Benthic Total Maximum Daily Loads (TMDLs) for the Goose Creek Watershed.
- The Louis Berger Group. 2006. Benthic TMDL Development for Bull Run, Virginia.
- Data collected by Virginia Commonwealth University (VCU)'s Center for Environmental Studies
- Loudoun Watershed Watch (LWW). State of Loudoun Streams: 2002. Ecological Assessment of Loudoun County Streams.
- LWW. State of Loudoun Streams Loudoun County: 2005. A Water Quality Assessment.
- Goose Creek Association data.
- Loudoun Wildlife Conservancy (LWC) data.
- Loudoun Soil and Water Conservation District (LSWCD) data.
- Rapid Stream Assessment Technique (RSAT) Survey of the Sugarland Run Watershed Phase I: Sugarland Run Mainstem. Metropolitan Washington Council of Governments.
- RSAT Survey of the Sugarland Run Watershed, Phase II: Sugarland Run Tributaries, Fairfax and Loudoun Counties, Virginia. Metropolitan Washington Council of Governments.
- Loudoun County Baseline Biological Monitoring Survey (2000-2002), Phase I: Broad Run, Goose Creek, Limestone Branch, Dutchman Creek and Piney Run Mainstem Conditions. Metropolitan Washington Council of Governments
- Loudoun County Baseline Biological Monitoring Survey (2004-2006), Phase II: Clarks Run, Catoctin Creek, Quarter Branch, Dutchman Creek and Piney Run Conditions. Metropolitan Washington Council of Governments

- Talbot Farm Tributary RSAT Survey. Metropolitan Washington Council of Governments
- Natural Resource Conservation Service (NRCS). 2001, Using a Regional Index of Biotic Integrity (IBI) to Characterize the Condition of Northern Virginia Streams, with Emphasis on the Occoquan Watershed: A Case Study.
- NRCS. 2005. Aquatic Condition Response to Buffer Establishment on Northern Virginia Streams.
- Center for Watershed Protection (CWP). 2002. Goose Creek Vulnerability Analysis.
- CWP. 2003. Goose Creek Demonstration Subwatershed Plans. Assessment and Recommendation for Three Subwatersheds within the Goose Creek in Northern Virginia.
- CWP. 2007. Tuscarora Creek Field Work and Baseline Assessments.
- Baker Inc. 2003. Goose Creek Source Water Protection Program (SWPP) Vol. 1. Program Summary and Implementation Approach, Vol. 2. Technical Support
- CH2MHILL. Comprehensive Watershed Management Plan 2008

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| **Citation** | Virginia Department of Environmental Quality's EDAS Data provided by Loudoun County; DEQ 2008 Impaired Waters fact sheets (http://gisweb.deq.virginia.gov/FactSheets2008/). |
| **Purpose of Study** | Evaluate stream condition for statewide assessment; determine stream impairments and provide information for TMDL studies; long-term monitoring |
| **Years of Survey** | 1994-2008 |
| **Location** | Statewide sampling |
| **Applicable Location** | Sites in 11 watersheds or subwatersheds in Loudoun County: Broad Run, Catoctin Creek, Cromwells Run, Goose Creek, Little River, North Fork Beaverdam Creek, Trib to Beaverdam Creek, North Fork Goose Creek, North Fork Catoctin Creek, South Fork Catoctin Creek, and Trib to Catoctin Creek |
| **Number of Sites** | 24 sites sampled for benthic macroinvertebrates and/or habitat assessment |
| **Survey Season/Dates** | Spring and fall 1994-2008, varying number of sites monitored per year |
| **Biota** | Benthic macroinvertebrates sampled using EPA's Rapid Bioassessment Protocol and evaluated using RBP and Virginia Stream Condition Index (SCI) methods. Macroinvertebrates were identified to the family taxonomic level. |
| **Stream Reconnaisance/ Habitat** | Habitat sampling in conjunction with biomonitoring following EPA Rapid Bioassessment Protocols. Habitat data have been collected since 2003, with most sampling events in 2005 to present. |
| **Water Quality/Chemistry** | DEQ also collects bacterial and water quality data. Over 5,000 water quality samples have been collected by DEQ since 1968, primarily focused on basic chemical parameters. There a total of 57 monitoring sites in Loudoun County. Nine of these are designated at "trend" sites. |
| **Landscape Assessment** | NA (NA = not applicable or not available) |
| **Site Selection** | Most are targeted sites with known or suspected impairments, some associated with TMDLs. A small number of probability-based sites were also sampled as part of statewide assessment. |
| **Methods** | EPA Rapid Bioassessment Protocol and Virginia Stream Condition Index (SCI). Virginia DEQ methods are documented in its 2008 Biological Monitoring Program Quality Assurance Project Plan for Wadeable Streams and Rivers. |
| **Findings and Conclusions** | Of 124 sampling events for benthic macroinvertebrates from 1994-2008, 13 were rated Excellent (10%), 55 Good (44%), 35 Moderate Stress (28%), and 21 Severe Stress (17%) according to SCI scores. Of 120 sampling events for habitat during this same period, 71 received a habitat assessment rating of Good (59%), 48 Fair (40%), and 1 Poor (1%) according to RBP habitat scores. Benthic monitoring results have been used by DEQ to include the following streams on the state's 2008 Impaired Waters list: 1 segment of North Fork Catoctin Creek, 3 segments of South Fork Catoctin Creek (one was first listed in 2004), 1 segment of Wancopin Creek, 1 segment of North Fork Beaverdam Creek, 1 segment of Goose Creek (first listed 1998), 1 segment of Little River (first listed 1998),and 5 segments of Broad Run (1 first listed in 2006). |
| **Additional Information** | Maps: Figures 2-1 through 2-5. Graphs: Appendix Figures A-1(a-h) and A-2(a-k). See also Section 3.1. |

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| **Citation** | Interstate Commission on the Potomac River Basin. 2004. Benthic TMDLs for the Goose Creek Watershed. Submitted by Virginia Department of Environmental Quality, Virginia Department of Conservation and Recreation. 108 pages. |
| **Purpose of Study** | Benthic impairments were noted in the lower mainstem of Goose Creek and in one of its larger tributaries, Little River. Development of a TMDL to address these impairments was necessary. |
| **Years of Survey** | DEQ benthic macroinvertebrate studies began in 1994. At sites included in this paper, studies from 1997 to 2002 were used. |
| **Location** | Goose Creek and Little River, Rapidan River and Catoctin Creek |
| **Applicable Location** | Goose Creek and Little River in Loudoun County |
| **Number of Sites** | 3, one on Goose Creek with multiple samples, one on Goose Creek with one sample, one on Little River. Compared with Reference sites – Rapidan River and Catoctin Creek |
| **Survey Season/Dates** | Varies, April through September |
| **Biota** | Benthic macroinvertebrates were sampled by DEQ's biological monitoring program (Rapid Bioassessment Protocol RBP II - single habitat 1-meter kick net) and identified to the family taxonomic level. Sites were assessed through a comparison to metric scores obtained at respective reference sites. |
| **Stream Reconnaisance/ Habitat** | DEQ habitat assessment through Rapid Bioassessment Protocols (RBP II). Also consulted habitat data from NRCS (Teels and Danielson 2001) and Metropolitan Washington Council of Government (Trieu et al., 2003) to aid in stressor identification. |
| **Water Quality/Chemistry** | DEQ Ambient Water Quality Monitoring |
| **Landscape Assessment** | Land use patterns were identified from the 1997 Multi-Resolution Land Characteristics (MRLC) Consortium study, and 13 classes of land use were identified in Goose Creek watershed. Pasture represents about 55% of the total watershed area, while forest accounts for about 41%. |
| **Site Selection** | Sites included in this study were DEQ monitoring stations with benthic impairments |
| **Methods** | EPA Rapid Bioassessment Protocol, 1989 version, RBP II (Single habitat 1-meter kick net) |
| **Findings and Conclusions** | The lower mainstem of Goose Creek and a section of one of its larger tributaries (Little River) were listed as impaired on Virginia's 1998 Section 303(d) list due to violations of the General Standard, and were again listed in 2002. Goose Creek's impaired section stretches from the dam for the City of Fairfax's water supply reservoir to Goose Creek's confluence with the Potomac River (4.9 miles). Little River's impaired section stretches from the confluence of Hungry Run and Little River and ends at Little River's confluence with Goose Creek (6.13 mi). The impairments were classified as "Benthic" because they were based on assessments of the benthic macroinvertebrate community performed under DEQ's biological monitoring program. DEQ's assessment of both segments found them to be only slightly impaired and proposed to US EPA that they be removed from the list of impariments in 2001, but EPA did not agree. Stressor identification found sediment loads were the stressor causing the impairment. No other stressors were determined to be significant. The presence of sediment-tolerant species in greater abundance in Goose Creek and Little River represented the clearest difference between the impaired sites and their reference sites. Sites were classified as moderately to slightly impaired. In 7 samples at the Goose Creek sites (GOO002.38 and GOO003.18) between 1997 and 2002, Biological Condition Scores ranged from 20 (RBP II Assessment of "Moderate") to 32 (RBP II Assessment of "Slight") (41 to 75% of reference). In 7 samples at the Little River site (LIV004.78) between 1997 and 2000, Biological Condition Scores ranged from 24 (RBP II Assessment of "Slight") to 40 (RBP II Assessment of "No Impact") (58 – 89% of reference). In 2 surveys (11/98, 5/00), Little River was rated not impacted. The authors note that other biological monitoring studies have been done in the Goose Creek Watershed (Metropolitan Washington Council of Governments - Trieu et al., 2003; NRCS - Teels and Danielson, 2001; Citizen Monitoring Groups, including Loudoun County Soil and Water Conservation District, Loudoun Wildlife Conservancy, North Fork of Goose Creek Watershed Committee, and Friends of Bull Run). They conclude that summarizing the results from these studies is not practical, because they are not comparable with each other. In assessing sediment loads for modeling for TMDL development, the authors estimated that 70% of the sediment in Goose Creek was due to streambank erosion, |

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| | while 60% of the sediment in Little River was from pasture erosion. |
| **Additional Information** | No associated maps or graphs. |

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| **Citation** | The Louis Berger Group. 2006. Benthic TMDL Development for Bull Run, Virginia. Submitted to Virginia Department of Environmental Quality. |
| **Purpose of Study** | A benthic impairment in Bull Run was noted in the Fairfax County portion of watershed. The original reference site degraded in quality, so reference site was moved to Goose Creek in Loudoun County. This report details the steps used to identify and characterize the stressor(s) responsible for biological impairments in Bull Run. |
| **Years of Survey** | Relevant VA DEQ environmental monitoring data from 1976 to 2005. Analysis completed in 2006 |
| **Location** | Bull Run in Loudoun, Prince William, and Fairfax Counties, Cities of Fairfax, Manassas, and Manassas Park. Goose Creek in Loudoun County was used as a reference site. |
| **Applicable Location** | Bull Run in Loudoun County; Goose Creek in Loudoun County was used as a reference site in 2004-05 |
| **Number of Sites** | 1 DEQ Ambient Water Quality Monitoring Station on Bull Run along Loudoun County border (Site 1ABUL025.94): Biological monitoring was conducted here in Fall 2004; 1 Loudoun County Goose Creek site was used as a reference site. |
| **Survey Season/Dates** | For Bull Run Loudoun County station, 1976 to 2005 for water quality data and fall 2004 biological monitoring; spring and fall 2004, and spring 2005 surveys for Goose Creek reference site biological monitoring; spring and fall 2004 for Goose Creek reference site habitat assessment |
| **Biota** | Benthic macroinvertebrates sampled using EPA's Rapid Bioassessment Protocol (RBP II) and evaluated using RBP II and Virginia Stream Condition Index (SCI) methods. Macroinvertebrates were identified to the family taxonomic level. |
| **Stream Reconnaisance/ Habitat** | Habitat sampling in conjunction with biomonitoring following modified Rapid Bioassessment Protocols (RBP II). Habitat parameters examined include channel alteration, sediment deposition, substrate embeddedness, riffle frequency, channel flow and velocity, stream bank stability and vegetation, and riparian zone vegetation. |
| **Water Quality/Chemistry** | DEQ Ambient Water Quality Monitoring at 1ABUL025.94 |
| **Landscape Assessment** | GIS was used to assess physical characteristics of watershed, for stressor identification. Landuse characterization was based on land cover data from Northern Virginia Regional Commission (NVRC) 2000 Land Use Dataset and the 1992 USGS National Land Cover Data (NLCD). Watershed was 38.8% developed lands, 34.2% forested lands, and 22.6% agricultural lands. |
| **Site Selection** | Sites included in this study were DEQ monitoring stations within the watershed of the station of the impaired segment. When the reference site that had been used degraded in quality, a DEQ monitoring station in Loudoun County was selected as the new reference site because of its high-quality conditions. |
| **Methods** | EPA's Rapid Bioassessment Protocol (RBP) II, Virginia Stream Condition Index (SCI). |
| **Findings and Conclusions** | Bull Run is located in the Occoquan Reservoir drainage. Bull Run was originally listed on Virginia's 1994 Section 303(d) list, and was included on Virginia's 1998 and and 2002 list of impaired waters and in the 2004 combined 305(b)/303(d) Integrated Report because of violations of General Standard (benthic impairment). Biological assessments conducted at DEQ monitoring station 1ABUL010.28 indicate a moderately-impaired benthic community. The impaired benthic segment of Bull Run is located outside of Loudoun County, in neighboring Fairfax County. Environmental monitoring data were vital to the identification of pollutant stressors impacting the benthic community in Bull Run. Stressor Identification Analysis identified sedimentation caused by higher runoff flows as a primary stressor impacting benthic macroinvertebrates in the biologically impaired segments of Bull Run. No other stressors were determined to be significant. Potential sources of sediment loading include urban stormwater runoff, stream bank erosion, and sediment loss from habitat degradation associated with urbanization. The Goose Creek watershed draining to the DEQ biomonitoring station 1AGOO022.44 was selected as the reference watershed for Bull Run benthic TMDL development. DEQ has monitored ambient water quality, macroinvertebrate communities, and/or sediment chemistry at 18 locations in the Bull Run watershed; one of these stations (1ABUL025.94) is located on the Loudoun County border. In 2004, no impairment was found when biomonitoring was conducted at this Loudoun County border site (1ABUL025.94) (SCI Score of 69.8, classification of "Good"). Between 2004-2005, Goose Creek reference site 1AGOO022.44 was sampled three times and had an average SCI score of |

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| | 65.1 (classification of "Good"). This site was sampled twice for habitat, once in the spring and once in the fall of 2004, and received an average habitat score of 175 (classification of "Good"). |
| **Additional Information** | No associated maps or graphs. |

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| **Citation** | Data collected by Virginia Commonwealth University (VCU)'s Center for Environmental Studies, Richmond, Virginia. Data provided by Loudoun County and by VCU (http://instar.vcu.edu/). |
| **Purpose of Study** | To compile a georeferenced database with various stream health assessment parameters to support a variety of stream assessment, management, and planning activities aimed at restoring and protecting water quality and aquatic living resources throughout the Commonwealth. The INteractive STream Assessment Resource (INSTAR) application was developed to serve as an on-line mapping and database application to quantitatively assess stream conditions based on comparisons among a suite of integrative, multimetric indices and 'virtual' reference stream models. |
| **Years of Survey** | Unknown |
| **Location** | Statewide sampling |
| **Applicable Location** | Watersheds of Loudoun County, including 4 sites in Upper Goose Creek, 3 sites in Lower Goose Creek, 4 sites in North Fork Goose Creek, 3 sites in Beaverdam Creek, 3 sites in Bull Run, 3 sites in Broad Run, 1 site in Sugarland Run, 4 sites in Direct Drainage, 1 site in Limestone Branch, 3 sites in Catoctin Creek, 1 site in North Fork Catoctin Creek, 2 sites in Clarks Run, 2 sites in Dutchman Creek, and 1 site in Quarter Branch. |
| **Number of Sites** | 35 sites |
| **Survey Season/Dates** | Unknown |
| **Biota** | Benthic macroinvertebrates sampled using modified Rapid Bioassessment Protocols (RBP III) using D-nets, macroinvertebrates are identified to the lowest taxonomic level, usually genus; fish sampled using backpack or barge electrofishing |
| **Stream Reconnaisance/ Habitat** | Habitat assessments conducted using EPA Rapid Bioassessment Protocol's Rapid Habitat Assessment |
| **Water Quality/Chemistry** | in-situ water quality data collected using a Hydrolab water quality sonde. |
| **Landscape Assessment** | NA |
| **Site Selection** | INSTAR employs a probabilistic design. Sites are randomly selected and stratified by stream order. |
| **Methods** | EPA Rapid Bioassessment Protocol (RBP III) for benthic macroinvertebrates. EPA Rapid Habitat Assessment. Modified Rosgen geomorphology measurements. Backpack electrofishing. Scores are calculated for the Modified Index of Biotic Integrity and Virtual Stream Assessment integrating fish, benthic, habitat, and geomorphology data. |
| **Findings and Conclusions** | Due to a lack of high-quality, undisturbed streams that could be considered reference streams in Virginia and lack of agreement between some traditional stream bioassessment protocols, the Center for Environmental Studies at Virginia Commonwealth University (VCU-CES) developed INSTAR, an INteractive STream Assessment Resource in cooperation with VA Department of Conservation and Recreation and the Coastal Program at VA DEQ. This tool uses high-quality archival data along with current data collected by VCU-CES to develop a georeferenced database of stream health information. It includes fish and macroinvertebrate communities, instream and riparian habitat, and geomorphological data. In Loudoun County, modified Index of Biotic Integrity Scores (mIBI) calculated by VCU ranged from 10 to 18, with a mean of 13 out of a possible maximum score of 30. The best-scoring sites were located in the southern portion of the county in Upper Goose Creek, Lower Goose Creek, and Bull Run. Virtual Stream Assessment scores ranged from 42 (Compromised) to 84 (Exceptional), with a mean of 65 (Healthy). The Virtual Stream Assessment score provides ameans of comparing the site sampled to a high-quality virtual reference stream. The score represents how comparable the sampled site is to the virtual reference stream. Similar to the mIBI results, many of the best-scoring sites were located along the southern border of the county, in Upper Goose Creek, Lower Goose Creek, and Bull Run. One "Compromised" site was located in Catoctin Creek watershed. |
| **Additional Information** | Maps: Figures 2-6 through 2-7. See also Section 3.2. |

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| **Citation** | Loudon Watershed Watch. 2002. State of Loudoun Streams 2002: An Ecological Assessment of Loudoun County Streams; and data provided by Loudoun County. |
| **Purpose of Study** | Provides base-line water quality and stream habitat data on Loudoun streams, and an assessment of current stream conditions and long-term trends. |
| **Years of Survey** | Uses existing data gathered by the Virginia Department of Environmental Quality (DEQ), Loudoun Soil and Water Conservation District (LSWCD), North Fork Goose Creek Association (NFGCA) and citizen volunteers from the Loudoun Wildlife Conservancy (LWC). |
| **Location** | All of Loudoun County with watershed profiles for Broad Run/Sugarland Run, Catoctin Creek, Lower Goose Creek/ Little River, North Fork Goose Creek, Middle Goose Creek/ Panther Skin Creek, Beaverdam Creek, Middle Goose Creek, Limestone Branch and Piney Run. Does not include Bull Run, Clarks Run, Dutchman Creek and Quarter Branch. |
| **Applicable Location** | (Same) Loudoun County watersheds: Broad Run/Sugarland Run, Catoctin, Lower Goose Creek/ Little River, North Fork Goose Creek, Middle Goose Creek/ Panther Skin Creek, Beaverdam Creek, Limestone Creek and Piney Run. Does not include Bull Run, Clarks Run, Dutchman Creek and Quarter Branch. |
| **Number of Sites** | 8 streams profiled, including summary benthic macroinvertebrate and habitat information. DEQ has sampled 23 stations, LSWCD has sampled 15 stations, LWC has sampled 12 stations, and the North Fork Goose Creek Watershed Committee has sampled 5 stations. |
| **Survey Season/Dates** | Summarizes existing data gathered prior to 2002. DEQ has sampled 23 stations since the 1970's. The Loudoun Soil and Water Conservation District (LSWCD) has sampled 15 stations since 1999. The Loudoun Wildlife Conservancy (LWC) has sampled 12 stations for at least two years. They have 3 new stations at the time of this publication. The North Fork Goose Creek Watershed Committee has sampled 5 stations since 1993 and has added 3 stations in recent years. |
| **Biota** | This report summarizes data gathered by VA DEQ, LSWCD, LWC and the North Fork Goose Creek Association. The following is broken down by subwatershed as described in this report. Broad Creek: There were no known benthic macroinvertebrate data available on the main stem of Broad Run. Beaverdam Creek: The Loudoun Wildlife Conservancy (LWC) began monitoring the Beaverdam Run tributary in Ashburn for benthic macroinvertebrates in 2000 through 2001. Catoctin Creek mainstem: benthic macroinvertebrates data collected by DEQ from 1996-2001, by LSWCD from 1999-2001 and by LWC from 1997-2001. See Table 1 from report for additional locations on Catoctin Creek. Lower Goose Creek/ Little River: DEQ monitoring of benthic macroinvertebrates was done from 1996-2001 on the Goose Creek main stem, and in Little River from 1997-2000; Rt. 629 was monitored for benthic macroinvertebrates by LSWCD from 1999-2001, LSWCD also monitored Rt. 632 from 1999-2001. North Fork Goose Creek: Benthic macroinvertebrates monitored at various locations (see page 83 of report, Table 1) by LWC and North Fork Goose Creek Association (NFGC) from 1997-2001. Beaverdam Creek: Benthic macroinvertebrates monitored by LSWCD from 1999-2001 along Routes 734 ad 731; and by LWC from 1997-1998 along Route 630, and along Route 831 from 1997-2001. Middle Goose Creek/ Panther Skin Creek: Benthic macroinvertebrates monitored by LWC from 2000-2001. Limestone Branch: Benthic macroinvertebrates monitored by LWC from1997-2001 at Route 661 and in 2001at Route 740. Piney Run: Benthic macroinvertebrates have been monitored by LSWCD from 1999-2001 along Routes 683 and 685. |
| **Stream Reconnaisance/ Habitat** | This report summarizes data gathered by VA DEQ, LSWCD, LWC and the North Fork Goose Creek Association. The following is broken down by subwatersheds described in this report: Broad Run: There are no known habitat data available for the main stem of Broad Run. Beaverdam Creek: The Loudoun Wildlife Conservancy (LWC) began monitoring the Beaverdam Creek tributary in Ashburn for habitat in 2000 through 2001. The data were analyzed using both the EPA criteria and the Izaak Walton SOS criteria. Catoctin Creek: DEQ has been collecting stream habitat data for Catoctin Creek at Taylorstown from 1996-2000. LWC has been collecting stream habitat data for four years in the North and South Forks and at Taylorstown, and for two years in the Milltown Run tributary. Lower Goose Creek / Little River: Main stem has been monitored by DEQ from 1996 - 2001 and Little River has also been monitored by DEQ from 1997-2000. Tuscarora Creek: LWC has been monitoring Tuscarora Creek since 1997 using the Audubon Naturalist Society (ANS) protocol. North Fork Goose Creek: LWC monitored stream habitat from 1997-2001 along Route 782 and 727. Beaverdam Creek: Route 630 and 831 has been monitored by LWC from 1997-2001. Middle Goose Creek/ Panther Skin Creek: Stream habitat has been monitored by LWC from 2000-2001. Limestone Branch: Stream habitat has been monitored by LWC 1997-2001 at Route 661 and in 2001at Route 740. Piney Run: No habitat monitoring has been done at all. |

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| **Water Quality/Chemistry** | This report summarizes historic VA DEQ, LSWCD, LWC and other data for fecal coliform, pH, nitrate, and total phosphorus. |
| **Landscape Assessment** | This report summarizes state and other data including the Loudoun County Environmental Indicators Project (LEIP) which includes mapping of impervious surfaces in the county using LANSAT Imagery. |
| **Site Selection** | See report for details. Methodology for site selection not always indicated. |
| **Methods** | For benthic macroinvertebrate sampling: LWC used EPA's Rapid Bioassessment Protocol and Izaak Walton SOS criteria, the North Fork Goose Creek Association used the Virginia Save Our Streams "Rocky Bottom Method.", LSWCD used the Isaak Walton League Stream Survey Method. For stream habitat monitoring: LWC has used the Audubon Naturalist Society (ANS) protocol, EPA criteria and the Izaak Walton SOS criteria. |
| **Findings and Conclusions** | Conditions for aquatic life remain good at monitoring sites in almost 70% of the streams. Beaverdam Run: These data collected by LWC in 2000-2001 give conflicting assessments in that the EPA criteria indicate the biological conditions were in the excellent range while the SOS criteria indicated the conditions were in the unacceptable range. Major conclusion was that Loudoun County should create a specific water management authority. |
| **Additional Information** | Maps: Figures 2-8 through 2-10 Graphs: Appendix Figures A-3(a-m) and A-4(a-n). See also Section 3.1 |

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| **Citation** | Loudoun Watershed Watch and Loudoun Wildlife Conservancy. 2005. State of Loudoun Streams Loudoun County: 2005. A Water Quality Assessment; Data provided by Loudoun County. |
| **Purpose of Study** | Provides base-line water quality and stream habitat data on Loudoun County streams, and an assessment of current stream conditions and long-term trends. |
| **Years of Survey** | Uses existing historic data gathered by the Virginia Department of Environmental Quality (DEQ), Loudoun Soil and Water Conservation District (LSWCD), North Fork Goose Creek Association (NFGCA) and citizen volunteers from the Loudoun Wildlife Conservancy (LWC) |
| **Location** | All of Loudoun County with stream profiles for Beaverdam Creek, Catoctin Creek, Limestone Branch, Lower Goose Creek/Little River, North Fork Goose Creek and Piney Run. |
| **Applicable Location** | (Same) Loudoun County watersheds: Broad Run/Sugarland Run, Catoctin, Lower Goose Creek/ Little River, North Fork Goose. Does not include Bull Run, Clarks Run, Dutchman Creek and Quarter Branch. |
| **Number of Sites** | 5 streams profiled with summary benthic macroinvertebrate data and habitat info. See tables in report watershed profiles for specific sampling locations. |
| **Survey Season/Dates** | Summarizes existing data gathered previous to 2005. See specifics below. Also note that each stream profile has a Stream Monitoring Data summary table which summarizes dates and organizations doing monitoring for chemical, bacterial, habitat, water flow and benthic macroinvertebrates. |
| **Biota** | This report summarizes benthic macroinvertebrate data gathered by VA DEQ, LSWCD, LWC and NFGCA. The following is broken down by subwatershed as described in this report. Beaverdam Creek: LSWCD has monitored benthic macroinvertebrates from 1999 -2001 and LWC monitored from 1997-2002. Catoctin Creek: Sampling done by LSWCD from 1999-2004 at 3 locations and by LWC from 1997-2004 at 9 locations. Limestone Branch: LWC has monitored benthic macroinvertebrates from 1997-2004. Lower Goose Creek / Little River: DEQ has been gathering data since 1996. North Fork Goose Creek: The NFGCA has been gathering benthic macroinvertebrates from 2000-2004; LSWCD has benthic sampling from 1999-2004 and LWC from 1997-2004. Piney Run: Benthic macroinvertebrate data has been gathered by LSWCD from 1999-2004 and by LWC from 2001-2004. |
| **Stream Reconnaisance/ Habitat** | This report summarizes data gathered by VA DEQ, LSWCD, LWC and the NFGCA. The following is broken down by subwatershed as described in this report. Beaverdam Creek: LWC gathered stream habitat data from 1997-2002, and NFGCA gathered data in 2004. Catoctin Creek: Habitat data have been gathered by LSWCD from 1999-2003 at 2 sites, by DEQ at one site in 2001 and by LWC from 1997-2004 at 9 sites. Limestone Branch: LWC has monitored stream habitat from 1997-2004, DEQ monitored in 2001 and LSWCD monitored from 1999-2003. Lower Goose Creek / Little River: Habitat data have been gathered by DEQ from 1996-2004 and by LWC from 1997-2004. North Fork Goose Creek: Habitat data have been gathered by LWC from 1997-2004 and by NFGCA in 2004. Piney Run: Stream habitat data have been gathered by LWC from 2001-2004. |
| **Water Quality/Chemistry** | This report summarizes water quality chemistry data gathered by VA DEQ, LSWCD, LWC, NFGCA, and USGS. The following is broken down by subwatershed as described in this report. Beaverdam Creek: Chemical data were gathered by DEQ from 1976-2004 (pH, DO, BOD, nitrate and total P), and bacterial data were gathered by DEQ from 1976-2004 and also by LSWCD from 1999-2001. Catoctin Creek: Bacteria data gathered by DEQ from 1973 to 2004 at 10 sites and by LSWCD from 1999-2004 at 3 sites. Chemistry data gathered by DEQ from 1973-2004 at 10 sites and by LSWCD from 4 sites from 1999-2004. USGS collected stream flow data at stations in Catoctin Creek from 1972-2004. Limestone Branch: DEQ has monitored bacteria and water chemistry since 1974 for pH, DO, BOD, nitrate and total P. Lower Goose Creek / Little River: Chemistry data gathered by DEQ from 1973-2004 and by LCSWCD from 1999-2001. USGS collected stream flow data at stations in Lower Goose Creek from 1910-2004. North Fork Goose Creek: Water chemistry was monitored by LSWCD from 1999-2004 and by NFGCA from 1996-2004. USGS collected stream flow data at stations in the North Fork of Goose Creek from 2001-2004. Piney Run: Water chemistry and bacterial data were gathered by DEQ from 1990-2004 and by LSWCD from 1999-2004. |
| **Landscape Assessment** | This report summarizes state and other data including the Loudoun County Environmental Indicators Project (LEIP) which includes mapping of impervious surfaces in the county using Landsat Imagery. |
| **Site Selection** | See report for details. Methodology not always indicated. |

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| **Methods** | LWC monitors benthic macroinvertebrates and stream habitat using the EPA Rapid Bioassessment II methodology. LSWCD uses the Save Our Streams (SOS) protocol for their aquatic insect monitoring. Note that LWW used the DEQ reference streams to assess stream conditions in the 2002 report. However, LWW decided not to use this approach for the 2005 assessments because Catoctin Creek at Taylorstown Bridge (the DEQ monitoring site) is a larger, higher order stream with hydrologic and habitat characteristics dissimilar to the lower and middle order streams in Loudoun that are most often sampled by citizen groups. Instead, criteria to interpret stream habitat and biomonitoring results are taken from EPA's "Volunteer Stream Monitoring: A Methods Manual." |
| **Findings and Conclusions** | The health of stream habitats varies considerably between streams and stream segments. Streams show poor diversity of aquatic insects and have a majority of pollution-tolerant species such as midge larva. Biological conditions can fluctuate considerably from year to year. In 2004 DEQ designated a new benthic impairment in a segment of the South Fork Catoctin Creek that include waters in Purcellville. In addition, DEQ designated waters in the mainstem of Catoctin Creek, the North Fork Catoctin Creek, and in Milltown Branch as having observed effects (threatened). These waters require further study by DEQ to determine if an actual impairment exists. This LWW report recommends the following actions; 1. Creation of watershed management plans to allow the county to implement the Federal Clean Water Act and the Cheseapeake Bay Act requirements as well as Virginia Water Quality Standards. 2. Creation of a water management authority to develop watershed management plans and oversee their implementation. 3. Cost sharing and tax incentives to encouage landowners to install BMPs particularly those which keep livestock out of streams. 4. County-wide stream monitoring. 5. Collaborative monitoring by the state, county, and local watershed groups, and 6. use of a probabilistic sampling plan. |
| **Additional Information** | Maps: Figures 2-8 through 2-10 Graphs: Appendix Figures A-3(a-m) and A-4(a-n). See also Section 3.1 |

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| **Citation** | Goose Creek Association data. No report or publication has been generated. This a summary of raw data provided by Loudoun County and information taken from: http://www.goosecreekassn.org/streammonitoring.html. Much of the history of this data gathering effort has been summarized in the State of Loudoun Streams, 2002 and 2005 reports written by LWW. |
| **Purpose of Study** | The fundamental mission of the Goose Creek Association is to protect and preserve the natural resources of the Goose Creek Watershed. In order to measure progress, the quality of Goose Creek water is regularly tested by volunteers. GCA volunteers monitor 22 stations. |
| **Years of Survey** | 2005-2008 (2006-2008 for those sampling sites within Loudoun County.) |
| **Location** | 22 Sampling stations, 5 in Loudoun County and 17 in Fauquier County. |
| **Applicable Location** | Goose Creek watershed within Loudoun County. |
| **Number of Sites** | 5 sites in Loudoun County portion of Goose Creek. The remainder are in Fauquier County. |
| **Survey Season/Dates** | From June 2005 through June 2008. 2006-2008 at Loudoun County sites. |
| **Biota** | Data is obtained four times a year, using the Virginia Save Our Streams "Rocky Bottom Method." After collection, the data are sent to VASOS, Virginia Department of Environmental Quality, John Marshall Soil, Water, and Conservation District to be rated. |
| **Stream Reconnaisance/ Habitat** | A survey of the habitat surrounding each of the stations is also taken during monitoring using VA SOS Habitat Survey . |
| **Water Quality/Chemistry** | E. coli testing using the Coliscan method is done once a month, year-round. |
| **Landscape Assessment** | Not collected by Goose Creek Association. |
| **Site Selection** | Unknown |
| **Methods** | Virginia Save Our Streams "Rocky Bottom Method." |
| **Findings and Conclusions** | Scores in Loudoun sampling sites averaged between 8 and 11 from 2006-2008. A score of 1 – 7 is Unacceptable, 8 is a Gray Zone and 9 – 12 is an Acceptable score. No conclusions were generated by the Goose Creek Association. Of the 20 benthic sampling events in 2006-2008, the breakdown of scores was 13 Acceptable, 4 Indeterminate (Gray Zone) and 2 Unacceptable. |
| **Additional Information** | Maps: Figure 2-11. Graphs: Appendix Figures A-5(a-e). See also Section 3.1 |

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| **Citation** | Loudoun Stream Quality Project data. This a summary of raw data provided by Loudoun County and the Loudoun Wildlife Conservancy (LWC, www.loudounwildlife.org). Data was taken from http://www.loudounwildlife.org/Stream_Monitoring.htm or provided by Loudoun County Department of Building and Development. Much of the history of this data gathering effort has been summarized in the State of Loudoun Streams, 2002 and 2005 reports written by LWW. No report or publication has been generated for more recent data. |
| **Purpose of Study** | Loudoun Stream Quality Project is a county-wide, stream monitoring program sponsored by LWC and the Audubon Naturalist Society (ANS). The project supports stream monitoring at sites throughout Loudoun County. Monitoring is conducted by teams of citizen volunteers who receive training from the Audubon Naturalist Society in sampling techniques and macroinvertebrate identification. The purpose of LWC is as follows: This 501(3) membership organization's mission is to preserve aquatic and upland wildlife habitat. LWC is the largest unaffiliated conservation group in Loudoun County, and the principal partner with LWW in stream monitoring and educational outreach to the citizens of Loudoun County. |
| **Years of Survey** | 1996-Present |
| **Location** | Loudoun County - selected sites within Piney Run, North Fork Goose Creek, Lower Goose Creek and Little River, Limestone Branch, Catoctin Creek, and Beaverdam Creek watersheds |
| **Applicable Location** | All locations applicable, by definition of project. |
| **Number of Sites** | Approximately 25 sites. However, the number of sites varies per year |
| **Survey Season/Dates** | Surveys conducted twice per year, April – May and again in September – October. |
| **Biota** | According to "State of Loudoun Streams Loudoun County: 2005. A Water Quality Assessment," aquatic insects were monitored from 1997-2005 by LWC citizen volunteers. Monitoring has continued from 2006 to present but has not been summarized or published. LWC continued to sample in 2006-2008, including sampling at 15 sites in 7 watersheds in 2008. |
| **Stream Reconnaisance/ Habitat** | An annual comprehensive stream habitat assessment of selected sites using EPA's Rapid Bioassessment Protocol. For example, in 2004 there were 49 LWC volunteers who monitored 26 different sites on 42 occasions. From 2005 to 2008, LWC has continued its sampling activities. |
| **Water Quality/Chemistry** | In June 2005 LWW and LWC began a bacteria monitoring program in the Catoctin Creek watershed using the Coliscan Easygel method. |
| **Landscape Assessment** | Not collected. |
| **Site Selection** | Unknown |
| **Methods** | Historically LWC has used EPA's Rapid Bioassessment Protocol for stream habitat and benthic macroinvertebrate monitoring. However in 2008 they switched to the Virginia Save Our Streams (SOS) method. Coliscan Easygel method is used for E.coli. |
| **Findings and Conclusions** | LWC's monitoring efforts are integrated into and summarized in the LWW 2002 and 2005 reports but not treated separately. Both LWW reports conclude that the health of stream habitats varies considerably among streams and stream segments. Some streams show poor diversity of aquatic insects and have a majority of pollution-tolerant species such as midge larva. Biological conditions can fluctuate considerably from year to year. Of the 15 sites sampled in 2008, benthic index scores rated 8 sites as Acceptable, 4 Indeterminate (Gray Zone), and 3 Unacceptable. |
| **Additional Information** | Maps: Figure 2-12 |

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| **Citation** | Loudoun County Soil and Water Conservation District (LSWCD). No report has been generated. This a summary of raw data provided by Loudoun County and Loudoun Watershed Watch and from data previously posted on the LSWCD web site. See LWW 2002 and 2005 Reports. |
| **Purpose of Study** | To provide water quality and biological assessment data for selected streams, including some streams subject to TMDL's. |
| **Years of Survey** | 1999-2003 |
| **Location** | LSWCD has gathered data in Piney Run, Goose Creek North Fork, Catoctin Creek, Little River (all in Loudoun County). |
| **Applicable Location** | All locations are within Loudoun County: Piney Run, Goose Creek North Fork, Catoctin Creek, Little River. |
| **Number of Sites** | 12 water quality monitoring locations within 5 subwatersheds and 7 aquatic insect monitoring stations. |
| **Survey Season/Dates** | Water chemistry sampled on inconsistent monthly basis from 1999 until 2003, and also varied by sampling site. Benthic macroinvertebrates sampled once per month in February, May and August 2001 only for North Fork Goose Creek, at Piney Run in August and November 1999, June 2000 and February of 2001 at 2 locations. |
| **Biota** | Benthic macroinvertebrates monitored via North Fork Goose Creek Buffer Project Quarterly Macroinvertebrate Count 2001 and Piney Run in 1999-2001. |
| **Stream Reconnaisance/ Habitat** | Not collected by LWSCD. |
| **Water Quality/Chemistry** | Samples are taken at 15 sites, once per year, by the LSWCD for E. coli measurement (Pers. comm, D. Ward March 2009). E. Coli sampling has been done monthly on an inconsistent basis from 4/19/1999 to 12/9/2003 for Loudoun County TMDL impaired streams. The locations sampled for fecal coliform / E. coli include: 2 locations on Little River, 9 sites on the North Fork of Goose Creek and Beaverdam Creek, 2 sites in Piney Run, and 2 sites on Catoctin Creek main stem. Monthly WQ sampling for pH, water temperature, flow (discharge in CFS), dissolved oxygen (ppm), nitrate (ppm), phosphorus (ppm), and turbidity (NTU) was done inconsistently at 2 sites in the Little River Watershed from 5/6/1999 to 12/10/2003; at Beaver Dam and at North Fork of Goose Creek as part of "North Fork Goose Creek Buffer Project". A monthly water quality survey was done at 7 sites along the North fork of Goose Creek on a monthly basis from June 2000 until September 2001; at Catoctin Creek watershed from 4 sampling locations, with samples taken on an inconsistent monthly basis for the same WQ parameters from 6/29/1999 until 12/10/2003; and at Piney Run at 2 sampling locations on an inconsistent monthly basis from 6/29/1999 until 12/10/2003 for the same WQ parameters. |
| **Landscape Assessment** | Not collected by LWSCD. |
| **Site Selection** | Unknown |
| **Methods** | For benthic macroinvertebrates, LSWCD used Virginia Save Our Streams (SOS) protocol. |
| **Findings and Conclusions** | No conclusions have been generated by LSWCD, however the Loudoun Watershed Watch 2002 and 2005 reports both summarize water quality and benthic macroinvertebrate data gathered in the County, including data specific to the TMDL streams. The first TMDL (for bacteria) was generated in 2002, based on water quality assessments from 1998. The next TMDL, for benthic macroinvertebrates, was in 2005 for Goose Creek because of sediment loading. |
| **Additional Information** | No associated maps or graphs. |

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| **Citation** | Galli, F. J. and K. Corish. 1997. Rapid Stream Assessment Technique (RSAT) Survey of the Sugarland Run Watershed Phase I: Sugarland Run Mainstem. Prepared for Virginia Environmental Endowment. Metropolitan Washington Council of Governments, Washington, DC. 60 pp. |
| **Purpose of Study** | Concern for Sugarland Run recovering from a 1993 oil spill. Intent was to systematically evaluate conditions, identify problems, and provide recommendations for future efforts |
| **Years of Survey** | 1996-1997 |
| **Location** | Sugarland Run Mainstem, Loudoun and Fairfax Counties |
| **Applicable Location** | Sugarland Run Mainstem in Loudoun County |
| **Number of Sites** | 13 total, 4 in Loudoun County (Lower Mainstem sites) |
| **Survey Season/Dates** | Nov 1996 to Feb 1997 |
| **Biota** | Macroinvertebrates sampled using RSAT biosurvey protocol. Identified in field to taxonomic order or family, wherever possible. |
| **Stream Reconnaisance/ Habitat** | RSAT survey rated Channel Stability, Channel Scouring/Sediment Deposition, Physical Instream Habitat, and Riparian Habitat |
| **Water Quality/Chemistry** | Baseflow water quality readings taken with a Horiba U-10 water quality meter, Hach total dissolved solids meter, and Hach nitrate and fluoride pocket colorimeters. 12 parameters measured at every 4th or 5th transect |
| **Landscape Assessment** | Drainage Area, Existing Imperviousness |
| **Site Selection** | Targeted to road crossing or adjacent streets |
| **Methods** | Rapid Stream Assessment Technique (RSAT); RSAT biosurvey protocol involved turning over 10 cobble-sized stones (or larger) and a minimum of three one-square-foot 30-second kick-samples per riffle. |
| **Findings and Conclusions** | The Sugarland Run mainstem was surveyed to systematically evaluate existing physical, chemical, and biological stream quality conditions along the mainstem using RSAT. Four of the 13 sites evaluated were in the Loudoun County portion of Sugarland Run, the lower portion of the mainstem. This portion of the stream has a drainage area consisting of 16% impervious cover. Three of these four lower mainstem sites had an overall RSAT stream quality rating of "Fair", while one site rated "Good". For the Physical Instream Habitat metric, 3 of the 4 Loudoun County sites rated "Good" while one rated "Fair". The weighted mean Physical Instream Habitat score was 4.6 (Good). Riparian Habitat Condition ranged from 5 (Good) to 7 (Excellent), with a weighted mean of 6.1 (Excellent). Pollution intolerant macroinvertebrate groups or taxa, including stoneflies, mayflies, and caddisflies, were all found in Sugarland Run's mainstem; only mayflies were found in the Loudoun County portion and occured in all lower mainstem reaches surveyed. For the Biological Indicators metric, 3 of the 4 Loudoun County sites rated "Good" while one rated "Fair". Erosion was most pronounced in this portion of Sugarland Run. Some downcutting is occuring, and 3 exposed sewer lines were found. No residual oil from the 1993 spill was observed in the streambed. The authors provide some preliminary recommendations for guiding possible future watershed restoration/protection efforts. Since water quality appears to be compromising biological conditions, they suggest a comprehensive, watershed-wide stormwater management retrofit/stream restoration inventory be performed. Additional water chemistry, macroinvertebrate, fisheries, physical habitat and channel morphology monitoring should be performed in the mainstem of Sugarland Run, along with an RSAT-type survey of the tributaries to Sugarland Run. |
| **Additional Information** | Maps: Figure 2-13 |

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| **Citation** | Galli, F. J., K. Corish and P. Trieu. 1999. Rapid Stream Assessment Technique (RSAT) Survey of the Sugarland Run Watershed, Phase II: Sugarland Run Tributaries, Fairfax and Loudoun Counties, Virginia. Prepared for Virginia Environmental Endowment. Metropolitan Washington Council of Governments, Washington DC. 61 pp. |
| **Purpose of Study** | To systematically evaluate physical, chemical, and biological stream quality conditions. Also, to extend work done in Phase I in order to provide a comprehensive picture of Sugarland Run |
| **Years of Survey** | 1998 |
| **Location** | Sugarland Run Tributaries in Loudoun and Fairfax Counties |
| **Applicable Location** | Lower and Middle Tributaries to Sugarland Run in Loudoun County |
| **Number of Sites** | 30 total, 10 in Loudoun County |
| **Survey Season/Dates** | May to October 1998 |
| **Biota** | Macroinvertebrates sampled using RSAT Level II procedures. Two types of samples were taken for each tributary: every survey reach: 10 stones and 3 1-sq. foot kick samples (30 sec.) were taken. The lower mainstem of each tributary was also sampled with 9 (30 sec.) kick samples in 1-sq. meter, identified to genus |
| **Stream Reconnaisance/ Habitat** | RSAT survey rated Channel Stability, Channel Scouring/Sediment Deposition, Physical Instream Habitat, and Riparian Habitat |
| **Water Quality/Chemistry** | Baseflow water quality readings taken with a Horiba U-10 water quality meter, Hach total dissolved solids meter, and Hach nitrate and fluoride pocket colorimeters. 12 parameters measured at every 4th or 5th transect |
| **Landscape Assessment** | Drainage Area, Existing Imperviousness |
| **Site Selection** | Not specified |
| **Methods** | Rapid Stream Assessment Technique (RSAT) Level II survey, additional benthic sampling also performed |
| **Findings and Conclusions** | Tributaries of Sugarland Run in Loudoun and Fauquier Counties were surveyed as a follow-up to surveys previously performed in Sugarland Run's mainstem. Nine of the ten sites surveyed in the Loudoun County portion of the Sugarland Run watershed received a Total RSAT score of "Fair" (range 23-29), while one site was rated "Good" (32). For the Physical Instream Habitat metric, 8 of the 10 Loudoun County sites rated "Fair" while one rated "Poor". 70% of the sites rated "Good" for the Bank Stability metric, while 30% rated "Excellent". Biological Indicators were "Fair" in all but one segment surveyed. Fair-rated streams were characterized by generally low total numbers of taxa, and the taxa present were generally pollution tolerant. In these ten sites, the Water Quality metric ranged from 3 to 6 (Fair to Good), while Riparian Habitat ranged from 1 to 6 (Poor to Excellent). The authors note that Muddy Branch was experiencing some severe erosion. They found 3 exposed sewer lines in Muddy Branch and Hughes Branch, high embeddedness at site 13 (the northernmost site), and 14 fish barriers. They also note that Hughes Branch had a dissolved oxygen (DO) violation of DEQ Water Quality Criteria as well as a lot of trash. Unlike the mainstem, the tributary branches were mostly more non-clay soils and were thus more stable. There were low to moderate amounts of organic loading and nutrient enrichment, as evidenced by the Hillsenhoff Biotic Index. Riffle quality was not affecting the macroinvertebrate community, but water quality or other physical habitat factors were likely limiting the health of aquatic biota. The authors suggest a comprehensive, watershed-wide stormwater retrofit/stream restoration inventory be performed, and it should be combined with results of this study and its predecessor, as well as Fairfax County's biological monitoring program to serve as the basis of a comprehensive watershed restoration/protection plan for Sugarland Run. |
| **Additional Information** | Maps: Figure 2-13 |

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| **Citation** | Trieu, P., J. Galli, J. Dittman, M. Smith and C. Vatovec. 2003. Loudoun County Baseline Biological Monitoring Survey (2000-2002), Phase I: Broad Run, Goose Creek, Limestone Branch, Dutchman Creek and Piney Run Mainstem Conditions. Prepared for the National Fish and Wildlife Foundation. Metropolitan Washington Council of Governments, Washington DC. |
| **Purpose of Study** | To systematically evaluate physical, chemical, and biological stream quality conditions. Also, to obtain baseline data as part of a comprehensive and phased evaluation of existing stream quality conditions |
| **Years of Survey** | 2000-2002 |
| **Location** | Broad Run, Goose Creek, Limestone Branch, Catoctin Creek, Dutchman Creek, Piney Run |
| **Applicable Location** | Loudoun County portions of Broad Run, Goose Creek, Limestone Branch, Catoctin Creek, Dutchman Creek, and Piney Run |
| **Number of Sites** | 26 sites, total of 112 transects |
| **Survey Season/Dates** | September 2000 to December 2002; macroinvertebrates were sampled in summer/fall of 2002 |
| **Biota** | Macroinvertebrates sampled using RSAT Level III procedures. Two types of samples were taken: at every survey reach, 2 one-foot kick and 2 one-foot jab samples were composited. At RSAT segments with riffles present (25 sites), macroinvertebrates were quantitatively sampled by compositing 1-square meter of best habitat, which was used for Fairfax County Stream Protection Strategy (SPS) IBI scoring evaluations. |
| **Stream Reconnaisance/ Habitat** | RSAT survey rated Channel Stability, Channel Scouring/Sediment Deposition, Physical Instream Habitat, and Riparian Habitat. At 10 selected RSAT stations, additional channel morphology data were collected including pebble counts and modified Rosgen Level I and II channel morphology characterization, due to Loudoun County's desire for additional channel morphology data. |
| **Water Quality/Chemistry** | RSAT Level III including measurements with water quality handheld meters. Also, one-time fecal coliform grab samples were collected to provide Loudoun County with additional bacteriological data. |
| **Landscape Assessment** | Drainage area, existing imperviousness, and general landuse/landcover for each watershed using 2000 LandSat7 Imagery |
| **Site Selection** | Strategically located to be representative of conditions in each watershed |
| **Methods** | RSAT Level III; modified Rosgen Level I and II channel morphology analysis at 10 sites; Fairfax County's Stream Protection Strategy (SPS) IBI |
| **Findings and Conclusions** | This study was the first phase of a multi-phased study conducted to evaluate stream quality conditions and obtain baseline data for watersheds in Loudoun County. In this study, watershed imperviousness ranged from 6 to 18%. Overall RSAT Stream Quality Ratings were "Good" or "Fair" at all sites surveyed, and "Good" at all mainstem segments. Biological Indicators metrics were rated "Good" or "Excellent" in all sites surveyed, and all sites in Dutchman and Piney Run were rated "Excellent". Water Quality was rated "Fair" at 22 sites, and "Good" at 3 sites, and was not rated at 1 site. Riparian Conditions overall were rated the lowest in Limestone Branch and rated the highest in Dutchman Creek and Piney Run. Fairfax County Stream Protection Survey (SPS) Index of Biotic Integrity (IBI) scores were calculated to provide an additional assessment of the macroinvertebrate communities in these watersheds. Dutchman Creek and Piney Run IBI scores ranged from 93 to 100 and all were rated "Excellent". In Limestone Branch, all sites received an IBI score of 100 (Excellent). Catoctin Creek IBI scores ranged from 57.8 (Fair) to 91.1 (Excellent), and in Goose Creek, all sites were rated "Excellent" based on their IBI score (ranged from 88.8 to 99.2). Overall health of Loudoun County's streams will require protection of currently undeveloped areas and environmentally-sensitive development. The authors provide a series of recommendations, including county-wide recommendations and watershed-specific recommendations for each watershed included in this study. They recommend that similar studies should be conducted throughout the entire county and suggest that baseline fisheries studies could provide further valuable information. They suggest that one Goose Creek site that had high bacteria levels may have some human input, or levels may be elevated due to cows just upstream of the site. Futher investigation is recommended. Their recommendations also include adopting a county-wide Stream Protection Strategy (SPS) similar to that of Fairfax County, VA and Montgomery County, MD. Also, they suggest that the county should begin to employ an MBSS-type survey for macroinvertebrates, identifying |

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| | specimens to the lowest practical level. |
| **Additional Information** | Maps: Figure 2-13 |

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| **Citation** | Trieu, P., K. Levendosky, and J. Galli. 2006. Loudoun County Baseline Biological Monitoring Survey (2004-2006), Phase II: Clarks Run, Catoctin Creek, Quarter Branch, Dutchman Creek and Piney Run Conditions. Prepared for the National Fish and Wildlife Foundation. Metropolitan Washington Council of Governments, Washington DC. |
| **Purpose of Study** | To systematically evaluate physical, chemical, and biological stream quality conditions. Also, to obtain baseline data as part of a comprehensive and phased evaluation of existing stream quality conditions |
| **Years of Survey** | 2005-2006 |
| **Location** | Clarks Run, Catoctin Creek, Quarter Branch, Dutchman Creek, Piney Run |
| **Applicable Location** | Clarks Run, Catoctin Creek, Quarter Branch, Dutchman Creek, Piney Run |
| **Number of Sites** | 16 sites, each with 3 transects |
| **Survey Season/Dates** | Oct 2005 to Apr 2006, macroinvertebrates during Fall and Spring |
| **Biota** | Macroinvertebrates sampled using RSAT Level III procedures. Two types of samples were taken: at every survey reach, 2 one-foot kick and 2 one-foot jab samples were composited, and 10 cobble-sized stones were overturned and sampled. In addition, at 16 RSAT stream segments and two Catoctin Creek tributaries with riffle areas present, 20 jabs were taken in best habitat with 600 micron D- net for use in Fairfax County Stream Protection Strategy (SPS) IBI scoring evaluations. RSAT samples were identified in the field to the family level. For the 20-jab surveys, all organisms were identified in the field to the lowest practical level, usually genus. |
| **Stream Reconnaisance/ Habitat** | RSAT survey rated Channel Stability, Channel Scouring/Sediment Deposition, Physical Instream Habitat, and Riparian Habitat. This study also included Catoctin Creek Riparian Analysis. At 7 selected RSAT stations, additional channel morphology data were collected including pebble counts and modified Rosgen Level I and II channel morphology characterization, due to Loudoun County's desire for additional channel morphology data. |
| **Water Quality/Chemistry** | Baseflow water quality readings taken with a Horiba U-10 water quality meter, Hach total dissolved solids meter, and Hach nitrate and fluoride pocket colorimeters. |
| **Landscape Assessment** | Drainage area, existing imperviousness extracted from RESAC 2000 LandSat 7 ETM imagery analysis |
| **Site Selection** | Strategically located to be representative of conditions in each watershed |
| **Methods** | RSAT Level III, Modified Rosgen Level I and II morphology analysis, Fairfax County's Stream Protection Strategy (SPS) IBI, remote-sensed imagery analysis for Catoctin Buffer Study |
| **Findings and Conclusions** | This study was the second phase of a multi-phased study conducted to evaluate stream quality conditions and obtain baseline data for watersheds in Loudoun County. In this study, watershed imperviousness ranged from 1.4 to 3.2%. Sites in Clarks Run, Quarter Branch, Dutchmans Creek and Piney Run received Overall RSAT Stream Quality ratings of "Good", while Catoctin Creek sites rated "Good" and "Fair." All sites but 1 rated "Excellent" for the RSAT "Biological Indicator" metric. Fairfax County Stream Protection Strategy (SPS) IBI Ratings were all "Good" or "Excellent." 271 possible sites for buffer enhancement were identified in Catoctin Creek watershed. The authors note that pressure on the county's undeveloped areas and aquatic systems will continue to increase with increased growth in the region. They provide county-wide recommendations as well as specific recommendations in individual watersheds. The authors suggest that a comprehensive environmental database is necessary. Landuse management measures should be implemented in Quarter Branch, Dutchman Creek, and Piney Run. As was suggested in the first phase of this study, comprehensive fisheries surveys are needed to complement macroinvertebrate survey work already conducted. In addition, the authors recommend that the county begin to employ an MBSS-like survey for macroinvertebrates, and identify macroinvertebrates collected to the lowest taxonomic level possible. |
| **Additional Information** | Maps: Figure 2-13 |

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| **Citation** | Trieu, P., F. J. Galli and K. Corish. 1998. Talbot Farm Tributary Rapid Stream Assessment Technique (RSAT) Survey. Prepared for Loudoun County Soil and Water Conservation District. Prepared by Metropolitan Washington Council of Governments, Washington, DC. |
| **Purpose of Study** | To characterize physical, chemical, and biological conditions in the Talbot Farm tributary prior to planned stream bank stabilization and riparian reforestation projects. |
| **Years of Survey** | 1998 |
| **Location** | Northeastern Corner of Catoctin Creek Watershed |
| **Applicable Location** | Catoctin Creek Watershed (South Fork Catoctin Subwatershed), Talbot Farm Tributary, upstream of confluence with South Fork Catoctin |
| **Number of Sites** | 1 site, including 10 transects |
| **Survey Season/Dates** | April 8th, 1998 |
| **Biota** | Macroinvertebrates were sampled using RSAT procedures. Larvae were identified to the genus taxonomic level, others were identified to the family taxonomic level. |
| **Stream Reconnaisance/ Habitat** | RSAT survey rated Channel Stability, Channel Scouring/Sediment Deposition, Physical Instream Habitat, and Riparian Habitat. Additional channel morphology data were also collected. |
| **Water Quality/Chemistry** | Baseflow water quality readings taken with a Horiba U-10 water quality meter, Hach total dissolved solids meter, and Hach nitrate and fluoride pocket colorimeters |
| **Landscape Assessment** | The predominant land use in the subwatershed was cow pasture (82%). Forest accounted for 17% and Singe-Family Residential accounted for 1% of the land use in the subwatershed. Cattle farming had recently been discontinued at Talbot Farm, but continued in upstream and downstream reaches, where cattle had direct access to the stream. |
| **Site Selection** | Targeted, at site selected for a stream and riparian restoration project |
| **Methods** | Rapid Stream Assessment Technique (RSAT) |
| **Findings and Conclusions** | This study was undertaken to characterize the conditions of the Talbot Stream Tributary prior to a stream bank stabilization and riparian reforestation effort planned at the Talbot Farm. This site received an Overall RSAT Stream Quality rating of "Fair," with a total RSAT score of 28. Results from the macroinvertebrate sampling suggest that the Talbot Farm Tributary presently supports a healthy and diverse macroinvertebrate community. Pollution intolerant taxa, including mayflies, stoneflies, and caddisflies were found throughout the tributary. The tributary received a ranking of "Excellent" for the RSAT Biological Indicators metric (score of 7). For the Channel Scour/Deposition, Instream Habitat, and Water Quality RSAT metrics, the site received a "Good" rating (scores of 5 for each metric). Bank Stability rated "Fair" while Riparian Habitat Condition rated "Poor." Substrate fouling throughout the entire study area was consistently high, ranging from 55 to 83%. Fouling was greatest in the upper portion of the tributary, and coupled with high nitrogen values, suggests that the cattle pasture may be responsible for high nutrient loads. The authors note that the stream channel is narrowing and deepening. Also, they note that the grassy riparian areas make poor riparian habitat, providing no stream canopy coverage, and adding very little root depth to augment bank stability. The authors recommend that another RSAT survey be performed at this site within 3 to 5 years after the bank stabilization and riparian reforestation project has been completed to better quantify changes in stream quality. They also suggest that the agencies should investigate the possibility of working with other landowners in the subwatershed to restore riparian corridors and limit direct access of cattle to streams. |
| **Additional Information** | No associated maps or graphs. |

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| **Citation** | Teels, B.M., and T.J. Danielson. 2001. Using a Regional IBI to Characterize the Condition of Northern Virginia Streams, with Emphasis on the Occoquan Watershed: A Case Study. USDA, NRCS, Wetland Science Institute, Laurel, MD. |
| **Purpose of Study** | Development of fish IBI |
| **Years of Survey** | 1997-1999 |
| **Location** | Tributaries of Occoquan River, upper Rappahannock River, and Goose Creek |
| **Applicable Location** | Loudoun County portion of Goose Creek |
| **Number of Sites** | 157 in entire survey, 42 in Goose Creek watershed, 27 in Loudoun County |
| **Survey Season/Dates** | Late May through mid-September |
| **Biota** | Fish |
| **Stream Reconnaisance/ Habitat** | Stream Visual Assessment Protocol |
| **Water Quality/Chemistry** | |
| **Landscape Assessment** | Percent of drainage above each sample reach in cropland, pasture, or urban land uses; proximity of the sample reach to fish barriers |
| **Site Selection** | Targeted, based on drainage area and site condition (Human Disturbance Index); Upstream or downstream of road crossings |
| **Methods** | Seine: 2.4 m length by 1.8 m depth minnow seine; 2 hour time limit, generally >300 meters |
| **Findings and Conclusions** | This study describes the development of a fish IBI for streams in the Occoquan watershed in Northern Virginia. The Goose Creek and Rappahannock watersheds were included to broaden the pool of reference conditions. An IBI can be a useful tool to assess conditions of streams and to assess conditions of contributing watersheds, including the impacts of human disturbances on watershed health. Projected growth in this area is significant and its effects on stream health are a concern. Twenty-seven sites were sampled in the Loudoun County portion of the Goose Creek watershed. The mean fish IBI at these sites was 33 (Fair). Of these sites, 4 rated Very Poor (15%), 10 rated Poor (37%), 8 rated Fair (30%), and 5 rated Good (18%). There appeared to be a continuing trend of stream degradation in the Occoquan watershed. Suburban sprawl was identified as one component affecting stream quality and it is expected to continue to increase. Sprawl around the city of Leesburg is probably responsible for low IBI scores in the Tuscarora system and Cattail Branch. Livestock are also likely playing a role in stream degradation in other parts of Goose Creek watershed. |
| **Additional Information** | Maps: Figure 2-14 |

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| **Citation** | Teels, B.M., C. Rewa, and J. Myers. 2005. Aquatic Condition Response to Buffer Establishment on Northern Virginia Streams. USDA, NRCS, Wetland Science Institute, Laurel, MD. |
| **Purpose of Study** | Assessment of the effects of riparian restoration by examining aquatic condition before and after buffer establishment |
| **Years of Survey** | 2000 - 2003 |
| **Location** | Tributaries of Occoquan River, upper Rappahannock River, and Goose Creek, |
| **Applicable Location** | Loudoun County portion of Goose Creek |
| **Number of Sites** | 36 sites in entire project, but different sites entered the program in different years. 20 sites were sampled in 2000, 29 in 2001, 33 in 2002, and 36 in 2003. In addition, 12 reference sites; 6 sites plus 1 less-disturbed reference site located in Goose Creek Watershed. |
| **Survey Season/Dates** | Late May through mid-September, during daylight hours, during periods of low flow |
| **Biota** | Fish |
| **Stream Reconnaisance/ Habitat** | Stream Visual Assessment Protocol |
| **Water Quality/Chemistry** | |
| **Landscape Assessment** | In the entire study area, Agricultural landuse ranged from 2-72%, Cropland ranged from 0-43%, and Pasture ranged from 1.6-41%. |
| **Site Selection** | Targeted – Sites NRCS Recommended with landowner interest in buffer program. Sites were added to the study if lands were associated with streams large enough to support fish assemblages capable of producing a meaningful IBI (i.e., with > 5 km2 (1.9 mi2) drainage area). Reference sites targeted – 6 less-disturbed and 6 moderately-disturbed |
| **Methods** | Seine: 2.4 m length by 1.8 m depth minnow seine; 2 hour time limit, generally >300 meters |
| **Findings and Conclusions** | This study investigates the effects of riparian buffer planting on the health of streams in Northern Virginia. It uses the fish IBI and Stream Visual Assessment Protocol (SVAP) as an integrated assessment for watershed and local influences that combine to determine the aquatic condition of a site. Prior to restoration, SVAP scores ranged from 3.4 (Poor) to 8.8 (Good) on a 1 to 10 scale, with an average of 6.8 (Fair). 67% of the sites rated Fair or Poor. At the less-disturbed reference sites, SVAP scores ranged from 8.1 (Good) to 9.3 (Excellent), with an average of 8.7 (Good). The moderately-disturbed reference sites predictably had lower scores than the less-disturbed reference sites, and ranged from 4.9 (Poor) to 8.4 (Good), with an average of 6.9 (Fair.) Fish IBI scores followed a similar pattern. The baseline IBI scores prior to restoration ranged from 20 (Very Poor) to 48 (Good) out of a maximum of 60, with an average of 34.8 (Fair). At the less-disturbed reference sites, fish IBI scores ranged from 42 (Good) to 48 (Good), with an average score of 46.3 (Good). The moderately-disturbed reference sites ranged from 18 (Very Poor) to 46 (Good), with an average fish IBI score of 37.3 (Fair). Streamside vegetative buffers were established after baseline data were collected. Following restoration, streams were assessed over multiple years. SVAP scores improved from a mean of 6.8 (Fair) pre-restoration, to a mean of 7.2 (Fair) the first year after restoration, 7.21 (Fair) the second year, and 7.63 (Good) the third year. Only half of the sites' SVAP scores remained higher than baseline after a few years post-restoration. Fish IBI scores also improved after restoration, from a baseline mean of 35.27 (Fair) to 35.33 (Fair) the first year after restoration, 36.28 (Fair) the second year, and then decreased to 35.8 (Fair) the third year. Only one-third of the sites remained improved after a few years post-restoration. This study found a direct correlation between the biological integrity of the fish community (as measured by the IBI) with the physical attributes of the stream reaches. The benefits of a vegetated riparian zone to the ecology of a stream are many, and include shade, cover, temperature regulation, organic inputs, bank protection and stabilization, and a decrease in nutrient and sediment inputs to the stream. The authors found that smaller sites showed the most improvement in this study. They suggest that most initial improvements seen were likely due to a lack of grazing. They suggest that local conditions probably have a greater influence on these streams than overall watershed and landscape features. Riparian restoration should be carried out along with other practices at a watershed scale to provide a comprehensive solution to water quality problems and maximize the benefits the buffers provide. |

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| **Additional Information** | No associated maps or graphs. |
| **Citation** | Center For Watershed Protection. 2002. Goose Creek Vulnerability Analysis. Submitted to Piedmont Environmental Council and Goose Creek Association. 40 pages. |
| **Purpose of Study** | Evaluate baseline conditions of subwatershed for vulnerability to current and future development. |
| **Years of Survey** | Completed in 2002, using GIS data from 2001 county coverages |
| **Location** | Goose Creek Watershed, Loudoun and Fauquier Counties |
| **Applicable Location** | Goose Creek Watershed, Loudoun County |
| **Number of Sites** | |
| **Survey Season/Dates** | |
| **Biota** | Used fish IBI data (Virginia Monitoring Data, source not specified) to assign vulnerability points |
| **Stream Reconnaisance/ Habitat** | |
| **Water Quality/Chemistry** | Used WQ data from DEQ stations to assign vulnerability points |
| **Landscape Assessment** | Used 2001 Loudoun County and Fauquier County GIS to delineate watersheds and assess impervious cover. To predict future impervious cover, used zoning and Comprehensive Plans. Used 1997 MRLC landuse data for forest area. |
| **Site Selection** | |
| **Methods** | Impervious cover analysis, Rural Watershed Quality Point Method, High Quality Point Method |
| **Findings and Conclusions** | This report summarizes the first phase of the Center for Watershed Protection's work in the Goose Creek Watershed, evaluating their vulnerability to current and future land development, and impacts of land management practices on rural subwatersheds. In an initial impervious cover analyses, 2 Loudoun County Goose Creek subwatersheds (Tuscarora Upper Direct Drainage, Tuscarora Lower Direct Drainage) were classified as "Impacted" (10-25% impervious cover), while all others were classified as "Sensitive" (<10% Impervious Cover). Based on future impervious cover, the two Tuscarora watersheds were projected to be "Non-Supporting" (>25% impervious cover), and four other Loudoun County Goose Creek subwatersheds were classified as "Impacted". All others were "Sensitive". A combination of current and future impervious cover, in-stream factors, and other subwatershed factors was then used to reclassify the subwatersheds. Reclassification involved the development of the Rural Watershed Quality Point Method, which assigned favorable and unfavorable rural watershed quality points based on in-stream and subwatershed factors. Sites were classified as "High Quality," "Rural Impacted," "Urban Impacted," and "Non-Supporting." Using these data and the High Quality Point Method, 12 Goose Creek subwatersheds were classified as "Most Vulnerable." Three of these, one high quality (Goose Headwater 105), one rural impacted (North Fork 102), and one future urban impacted subwatershed (North Fork Upper Direct Drainage) were selected for further study in Phases 2 and 3. North Fork 102 and North Fork Upper Direct Drainage are located in Loudoun County. The authors concluded that impervious cover is one indicator of watershed health but that in-stream and subwatershed factors are also important in characterizing conditions. |
| **Additional Information** | No associated maps or graphs. |

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| **Citation** | Center For Watershed Protection. 2003. Goose Creek Demonstration Subwatershed Plans. Assessment and Recommendation for Three Subwatersheds within the Goose Creek in Northern Virginia. Submitted to Piedmont Environmental Council and Goose Creek Association. |
| **Purpose of Study** | Assess baseline condition of 3 subwatersheds, provide recommendations, provide framework for other watersheds |
| **Years of Survey** | 2002, 2003 |
| **Location** | selected Goose Creek Subwatersheds defined by the Center for Watershed Protection: Goose Headwater 105 in Fauquier County, and Goose North Fork 102 and Goose North Fork Upper Direct Drainage in Loudoun County |
| **Applicable Location** | selected subwatersheds of Goose Creek in Loudoun County: Goose North Fork 102, and Goose North Fork Upper Direct Drainage |
| **Number of Sites** | 37 total, 16 in Loudoun County: 8 in North Fork 102, 8 in North Fork Direct Drainage |
| **Survey Season/Dates** | October, 2002 |
| **Biota** | |
| **Stream Reconnaisance/ Habitat** | RBP, Riparian Inventory Tracking. Contiguous Forest Assessment in Goose North Fork 102 |
| **Water Quality/Chemistry** | |
| **Landscape Assessment** | Upland features and landuse, used Loudoun County and Fauquier County GIS |
| **Site Selection** | Not specified |
| **Methods** | Rapid Bioassessment Protocol for Habitat (RBP), Riparian Inventory Tracking, Contiguous Forest Assessment |
| **Findings and Conclusions** | This study is the third part of a three-part study conducted by Center for Watershed Protection in the Goose Creek Watershed. Phase 1 of the study was the Vulnerability Analysis. The second phase of the study consisted of field analyses in three specific subwatersheds. The results of these field analyses and a review of programs that may impact the protection and restoration of these three watersheds are included in this third and final phase. Two of the subwatersheds included in this phase of the study are in the Loudoun County portion of the Goose Creek Watershed, North Fork 102, and North Fork Upper Direct Drainage. North Fork 102 had an estimated 5% impervious cover, and was projected to increase to 9% in the future. In this subwatershed, 5 sites (63%) had good physical habitat, 2 sites (25%) had fair physical habitat, and one site had poor physical habitat (12%) according to RBP results. There were some isolated areas of erosion and inadequate buffer, likely due to livestock access. Contiguous forest was present along the Round Hill ridgetop and other areas, a marshy area was identified above a beaver dam, and 3 man-made fish barriers were found. North Fork Upper Direct Drainage had an estimated 7% impervious cover, and was projected to increase to 11% in the future. In this subwatershed, 5 sites (63%) had good physical habitat, 2 sites (25%) had fair physical habitat, and one site had poor physical habitat (12%) according to RBP results. More than 50% of the stream miles had inadequate buffers, and cattle and horse access and stream erosion were more problematic in this watershed than the others. Some significant resources, including some very old trees, were found in this subwatershed. Goals for subwatershed management plans for each of the individual subwatersheds and for Goose Creek Watershed as a whole were included. Over 140 recommendations for improving the quality of the subwatersheds were made. One over-arching, county-wide goal was to minimize impacts of new development and to encourage stewardship among the residents. |
| **Additional Information** | No associated maps or graphs. |

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| **Citation** | Center for Watershed Protection. 2007. Summary of Findings from Tuscarora Creek Field Work and Baseline Assessments. Protecting Human Health and Water Quality in the Town of Leesburg and its Watersheds. March 2007. |
| **Purpose of Study** | This study was recommended as a result of the Goose Creek Vulnerability Analysis of 2006. This is one part of the larger Goose Creek Watershed Study. |
| **Years of Survey** | 2006 |
| **Location** | Tuscarora Creek, Town of Leesburg VA, Loudoun County. Was divided into the Tuscarora Upper Direct Drainage and Lower Direct Drainage subwatersheds for the study. |
| **Applicable Location** | All within Loudoun County. |
| **Number of Sites** | Twenty-seven stream reaches were evaluated in the Tuscarora Upper DD and Lower DD subwatersheds. |
| **Survey Season/Dates** | Aug 7-9 2006 |
| **Biota** | Not done for this study. |
| **Stream Reconnaisance/ Habitat** | Center for Watershed Protection's Unified Stream Assessment implemented for Tuscarora Creek. Unified Subwatershed and Site Reconnaissance ("windshield tour", USSR) results also included in this report. |
| **Water Quality/Chemistry** | Not done for this study. |
| **Landscape Assessment** | Imperviousness calculated. CWP Unified Subwatershed and Site Reconnaissance results also included in this report. |
| **Site Selection** | NA |
| **Methods** | Unified Stream Assessment and USSR |
| **Findings and Conclusions** | USA Results: Fourteen of stream reaches were found to be in good to fair condition and the remaining 13 were found to be in poor to very poor condition. "Good reaches often had better quality riparian buffer and floodplain connectivity than streams scoring in the fair or poor range". Recommendations at 100 sites surveyed include such things as infrastructure repair, discharge investigations, stream restoration, trash clean up, and buffer reforestation. USSR Results: Neighborhood source assessments yielded the following results: "None of the neighborhoods in the study area met the definition of a high pollution generator; one was considered to have little to no pollution severity, and the rest were classified as moderate pollution generators. All but one site were identified as having moderate restoration potential. The top priorities for all of the neighborhoods include tree planting, landscaping with native vegetation, and downspout disconnection." Hotspot investigations at 20 locations yielded no confirmed hotspots, but six sites were cited as potential hotspots and two others had practices that represented a possible pollution source. Conclusions: Numerous recommendations made including; 1. Add landscaping criteria to stormwater design standards (i.e., Dry ponds). 2. Forest existing dry ponds 3. Maintain existing condition of areas that improve water quality (existing wetlands and grass channels). 4. Encourage Better Site Design through credits in the stormwater requirements. 5. Create a field-verified GIS layer of existing stormwater facilities. |
| **Additional Information** | No associated maps or graphs. |

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| **Citation** | Baker Inc. 2003. Goose Creek Source Water Protection Program. Vol 1 (of 2) Program Summary and Implementation Approach; and Vol 2 (of 2) Technical Support |
| **Purpose of Study** | This is a compendium of tools (guidelines, partnership actions, practices) written for the Loudoun County Sanitation Authority (LCSA), Loudoun County and the City of Fairfax to protect the reservoir from sedimentation and eutrophication. It is required under the Clean Water Act 1996 Clean Water Drinking Act amendment. This is the Source Water Protection Program (SWPP) which is the second step, the first being generation of a Source Water Assessment Program (SWAP completed Fall 2002). This SWPP focuses on the 348 square mile Goose Creek "intake watershed" that are within 5 miles upstream of the Goose Creek water supply intake. This "is a complement to the proposed county-wide watershed plan" generated by CH2MHILL (see CH2MHILL 2008). Volume 1 addresses the planning and implementation issues. Volume 2 is the technical support volume and includes data, tables and figures upon which the SWPP was developed plus recommendations. |
| **Years of Survey** | Not specified. |
| **Location** | This SWPP focuses on the 348 square mile Goose Creek "intake watershed" upstream of the Goose Creek water supply intake. This includes land in Loudoun County and a small piece of Fauquier County. This study does not include the Sycolin Creek (which includes the Town of Leesburg) because its confluence with Goose Creek is downstream of the Goose Creek Water Treatment Plant water intake and does not affect drinking water quality. The entire Goose Creek watershed encompasses 386 square miles. Note that Fairfax City draws its water from Goose Creek at a point just north of the Beaverdam Reservoir hence their involvement in this project. |
| **Applicable Location** | Loudoun County, watershed area upstream of the Goose Creek water supply intake. |
| **Number of Sites** | 68 reaches (See Vol 2. Technical Support, for details.) |
| **Survey Season/Dates** | Not specified. |
| **Biota** | Benthic macroinvertebrate sampling not done by Baker Inc. However, Baker Inc. summarizes a benthic macroinvertebrate study done by Loudoun SWCD as part of North Fork Goose Creek Watershed Study in 2001 (samples collected Feb, May, August) using Izaak Walton League's Save Our Streams Survey Protocol. Invertebrates were collected and identified to the family level and assigned a pollution tolerance rating. Taxa were counted and categorized at 7 sampling sites. Note: No obvious patterns were evident from the water quality data and macroinvertebrate data to support the water quality scores that were generated. Four stream assessment sites and Loudon SWCD benthic sampling sites overlapped. Professor Margaret Palmer at University of Maryland has gathered extensive data on the meiofauna community of Goose Creek, which has been found to be diverse compared to other area streams most likely due to the rural nature of the watershed. Previously unknown species of copepods were also discovered by Palmer in Goose Creek. |
| **Stream Reconnaisance/ Habitat** | Baker Inc. assessed 7 subwatersheds, 45 miles (10% of total length) of stream, broken into 14 stream segments, 68 reaches, using the habitat assessment method of EPA's Rapid Bioassessment Protocol. Problem areas such as deficient riparian buffer, erosion, stream obstructions and dump sites were also recorded. See Vol 2. Technical Support for details. |
| **Water Quality/Chemistry** | 30 sites have been monitored from 1968 to present by VADEQ. USGS monitored 1 site for 1 year, Loudoun SWCD monitored 9 sites for 1 year. See Vol 2. Technical Support, for details. |
| **Landscape Assessment** | 1992 USGS National Land Cover Data used (NLCD 92). See Vol 2 for details. |
| **Site Selection** | Stream locations were chosen based upon stream confluences to provide representative data for subwatersheds, as well as to provide proximity to road crossings and easy access as well as minimal encroachment on private property. See Vol 2. Technical Support, for details. |
| **Methods** | Habitat assessment method of EPA's Rapid Bioassessment Protocol. See Vol 2 for details. |
| **Findings and Conclusions** | This stream and watershed characterization by Baker Inc. included various efforts. The first was a stream habitat assessment using EPA's Rapid Bioassessment Protocol. Lack of vegetative cover on stream banks and within stream buffers, and general stream instability had the greatest negative effect on stream habitat scores. RBP habitat scores ranged from 65 to 180.5 out of a maximum of 200 points where 80 or less was rated as |

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| | "poor", 80-125 was rated as "fair" and scores greater than 125 were considered "good". In the final analysis, 36 reaches (~54%) were rated as "good"; 27 as "fair" (~41%), and 4 as "poor" (~5%). Of the 68 stream reaches evaluated and inventoried as part of this study (which comprised 10% of all stream miles in the watershed), 29 deficient buffer areas were found, 54 erosion impact areas were found, 53 stream obstructions were found and one appliances dumping site was found. No exposed public utility lines were encountered. The other major endeavor of this effort was modeling of nutrient and sediment loads, by subwatershed, using EPA's PLOAD. Results of the PLOAD modeling exercise showed a general increase in total phosophorus, total nitrogen and total suspended sediments loading from 1979-1998. Recommendations generated from PLOAD modeling included: The need to control any increase in pollutant loading from future developments, the need to reduce pollutant loads from critical subwatersheds even if there is no potential change in land use as well as the need to maintain the models developed in this effort to make sure recommended tools are meeting goals of this program. General conclusions generated by the report include the following: The primary sources of stream habitat impairment are a lack of adequate stream buffer and bank erosion in all subwatersheds. Secondarily, because the primary landuse in the greater watershed is pasture for livestock, increased E. coli and fecal coliform levels can be partially attributed to stream access by livestock. The last part of the Baker Inc. effort was generation of a series of source water protection "tools." |
| **Additional Information** | Maps: Figure 2-15 |

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| **Citation** | CH2MHill 2008. Comprehensive Watershed Management Plan. Prepared for Loudoun County Department of Building and Development. September. |
| **Purpose of Study** | The purpose of this project was to develop a comprehensive watershed management program (CWMP) based on detailed analysis of the information available to date. Focus was on hydrologic, hydraulic, and water quality data. |
| **Years of Survey** | This report summarizes historic water quality data gathered for Loudoun County. |
| **Location** | Loudon County watersheds |
| **Applicable Location** | All within Loudoun County. |
| **Number of Sites** | No stream habitat or benthic monitoring was done for this report nor were any such data summarized. |
| **Survey Season/Dates** | No stream habitat or benthic monitoring done or summarized. All historic water quality data summarized. |
| **Biota** | No stream habitat or benthic monitoring done or summarized. |
| **Stream Reconnaisance/ Habitat** | No stream habitat or benthic monitoring done or summarized. |
| **Water Quality/Chemistry** | The Virginia Department of Environmental Quality's (DEQ) database includes 94 monitoring stations located either in Loudoun County or on streams that drain into the County. Forty-three stations were used to collect ambient water quality data, 4 were used to collect biological data, 44 were citizen monitoring stations that collected benthic macroinvertebrate data, and 3 involved other types of monitoring. Most of the ambient stations contained limited data in terms of number of samples, period of record, and pollutants analyzed. Only 16 stations could be considered to have long-term data. All data sets and analyses were provided by the County to CH2M Hill for further analyses, evaluation, and interpretation to establish baseline conditions, characterize the County's groundwater and surface water quantity and quality, and identify and discuss areas of concern and pertinent trends that may exist. Water quality parameters available include: total nitrogen, ammonia, nitrate, nitrite, total phosphorus, orthophosphorus, chloride, sulfate, fluoride, arsenic, lead, zinc, manganese, specific conductance, turbidity, BOD, chemical oxygen demand, pH, total organic carbon. Data are available from the 1970s until present depending on the parameter. |
| **Landscape Assessment** | Not done for this study. |
| **Site Selection** | Not indicated in report. |
| **Methods** | Scores of 1 to 4 were assigned to each of the 161 subwatersheds for each of the 13 independent metrics. |
| **Findings and Conclusions** | A matrix of 87 watershed management activities was developed. Each activity included a likeliness rank of 2-6 based on relative cost and relative effectiveness. Benthic macroinvertebrate monitoring was suggested as a management activity to be implemented immediately because "The collections are considered to be a truer depiction of stream health as compared to water quality monitoring". In terms of additional data requirements, benthic macroinvertebrate monitoring and basic stream assessments were suggested. |
| **Additional Information** | No associated maps or graphs. |

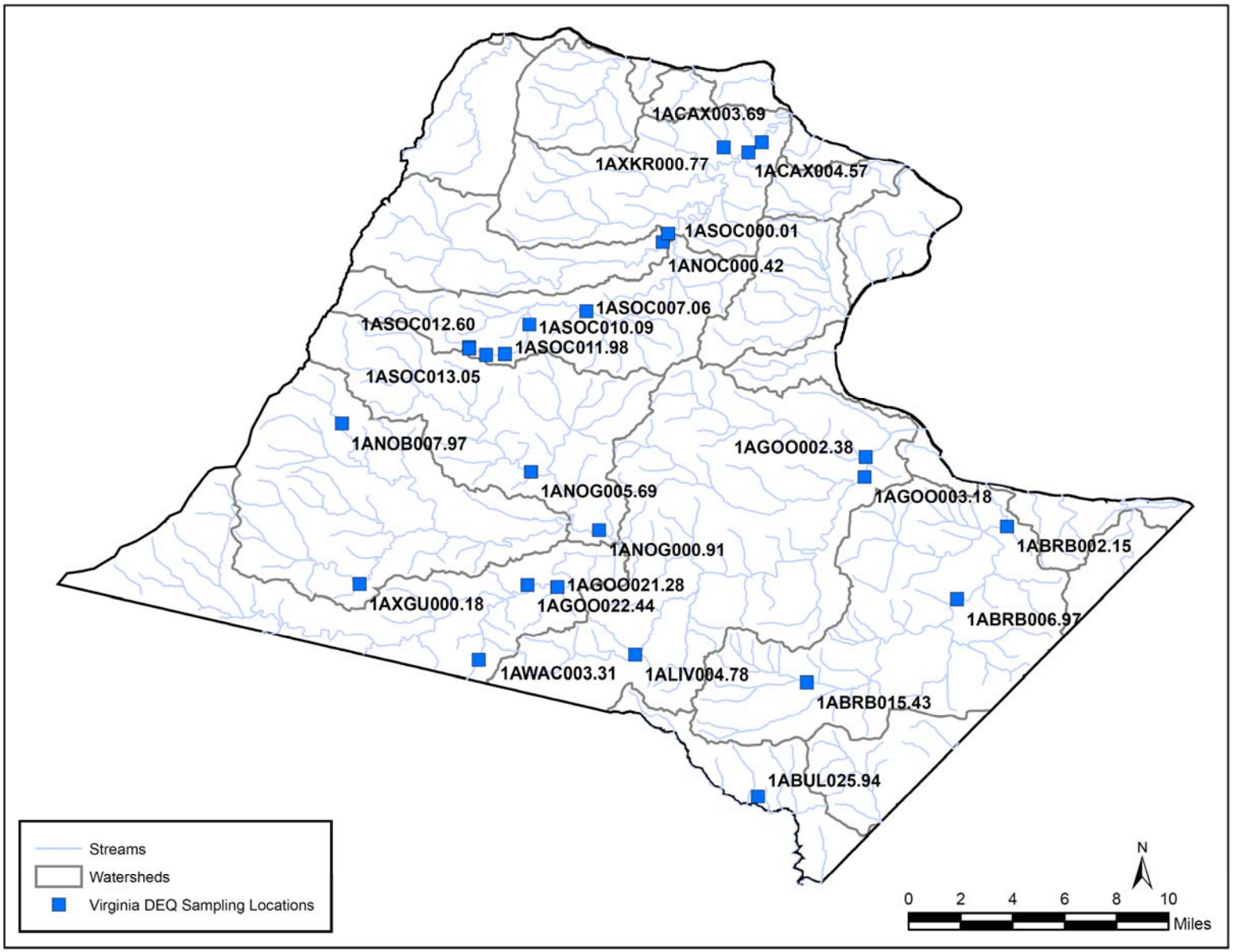


Figure 2-1. Locations of Virginia DEQ stream sampling sites in Loudoun County

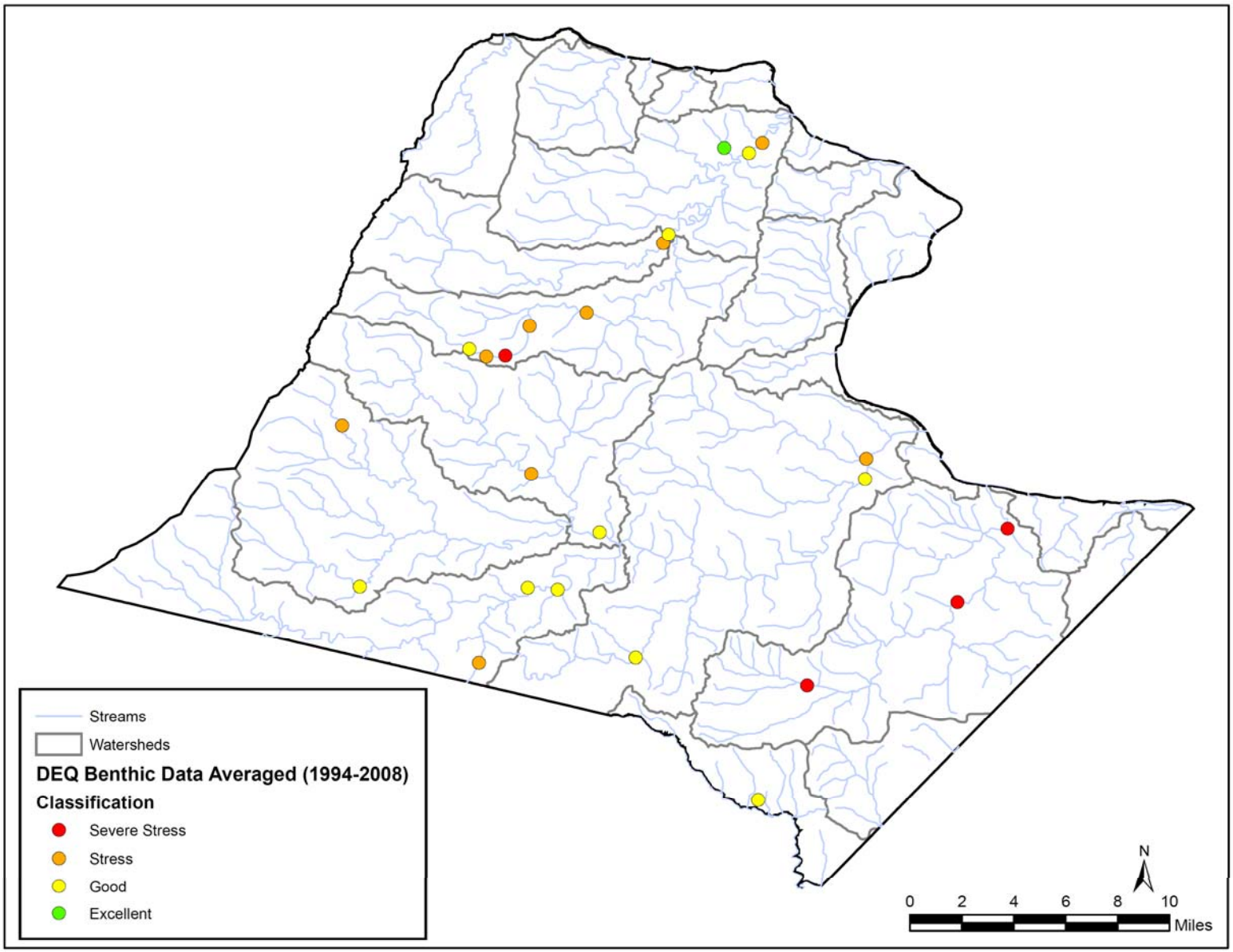


Figure 2-2. Average Benthic Stream Condition Index (VSCI) score classification at Virginia DEQ stream sampling sites (1999-2008)

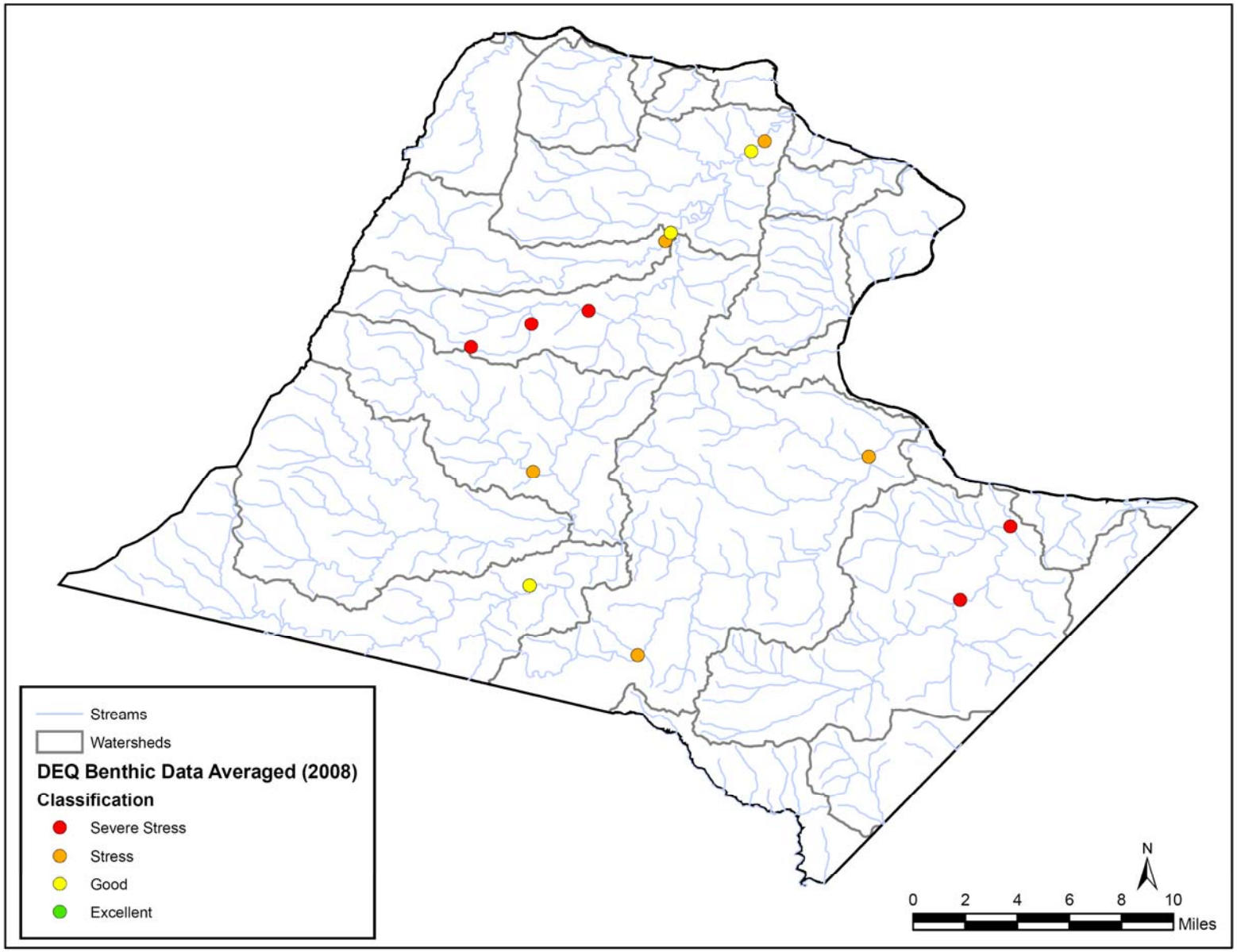


Figure 2-3. Average Benthic Stream Condition Index (VSCI) score classification at Virginia DEQ stream sampling sites (2008)

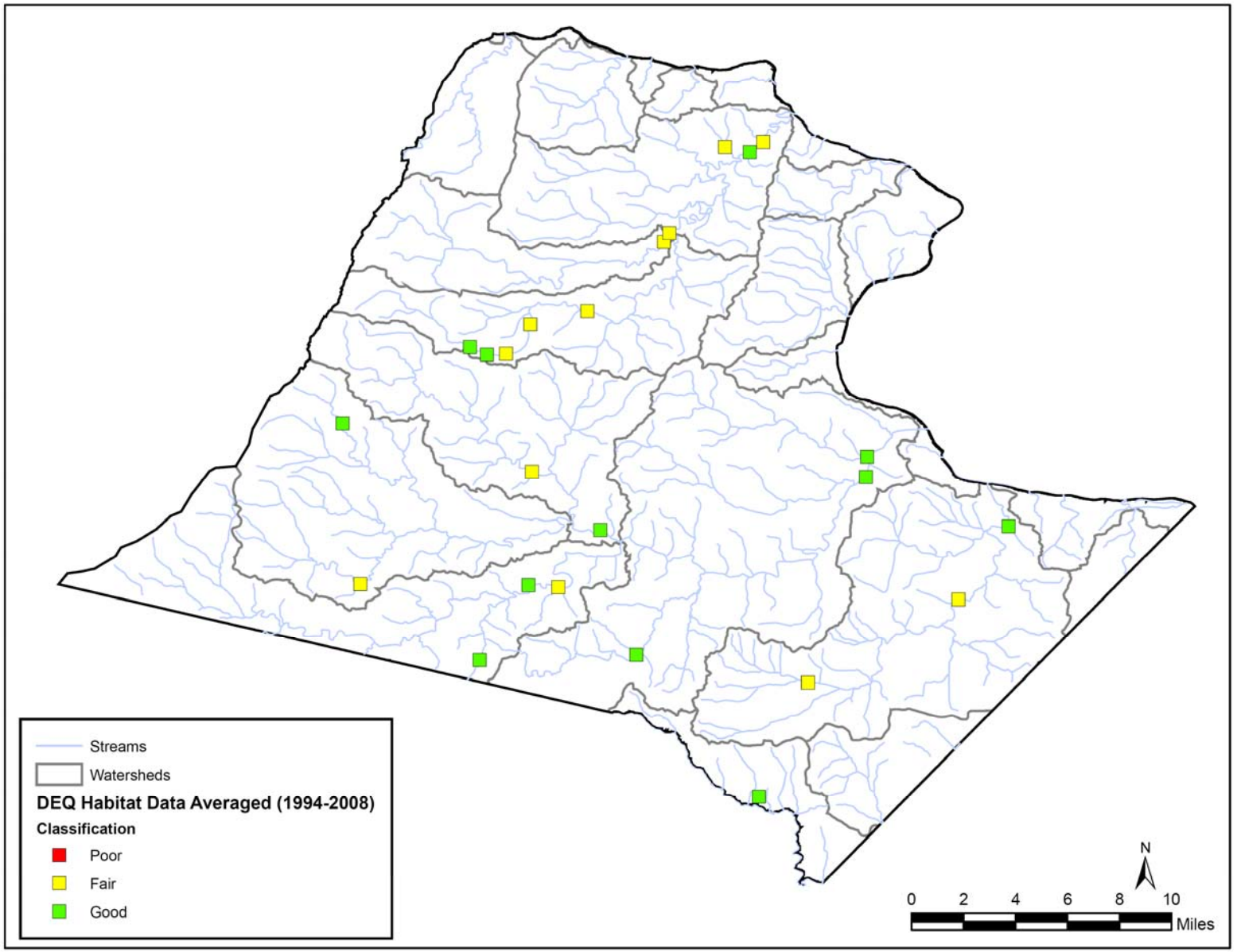


Figure 2-4. Average habitat score classification at Virginia DEQ stream sampling sites (1999-2008)

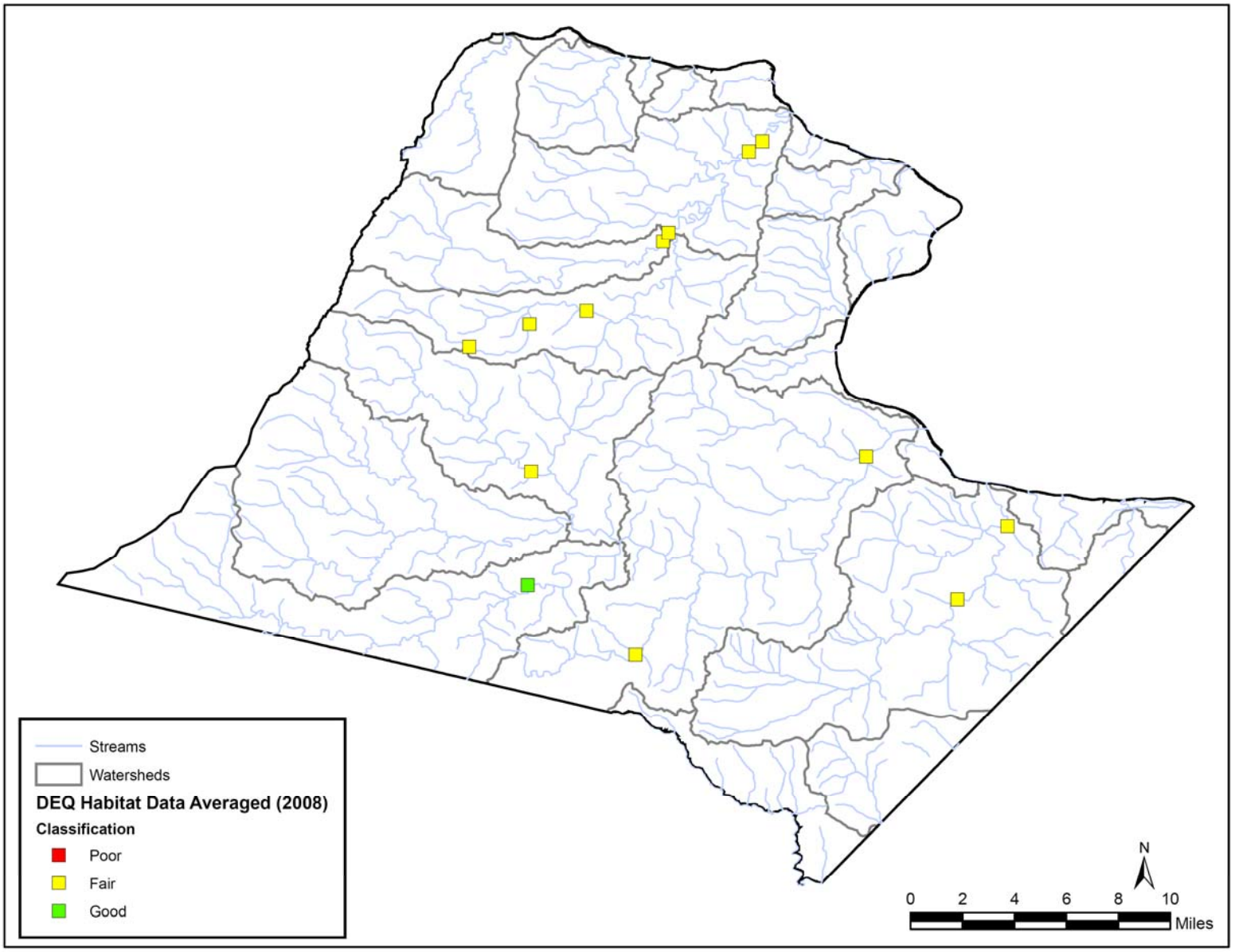


Figure 2-5. Average habitat score classification at Virginia DEQ stream sampling sites (2008)

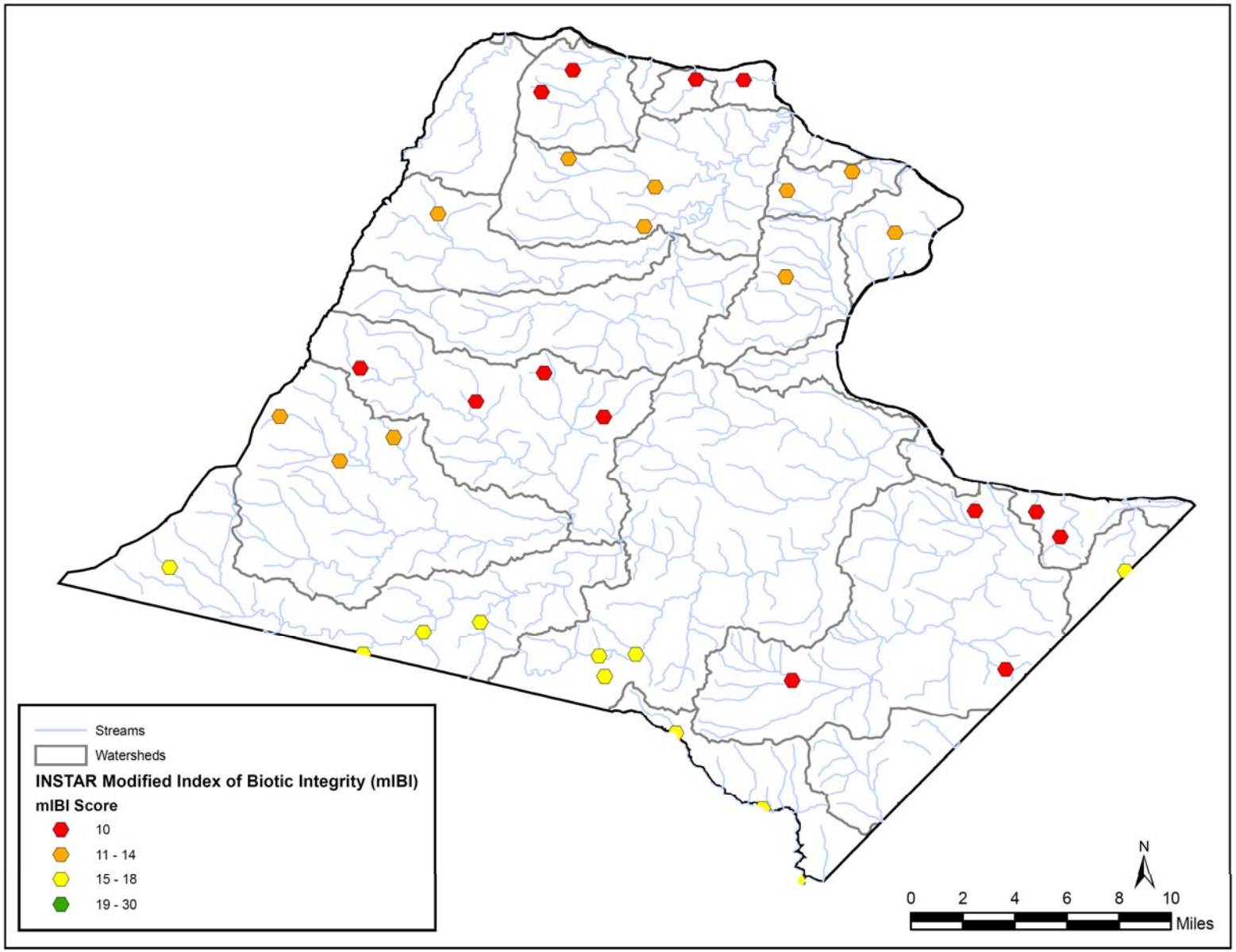


Figure 2-6. Modified Index of Biotic Integrity (mIBI) scores for stream sampling locations from Virginia Commonwealth University's (VCU) Interactive Stream Assessment Resource (INSTAR; Data compiled by Loudoun County Department of Building and Development from INSTAR, May 2008)

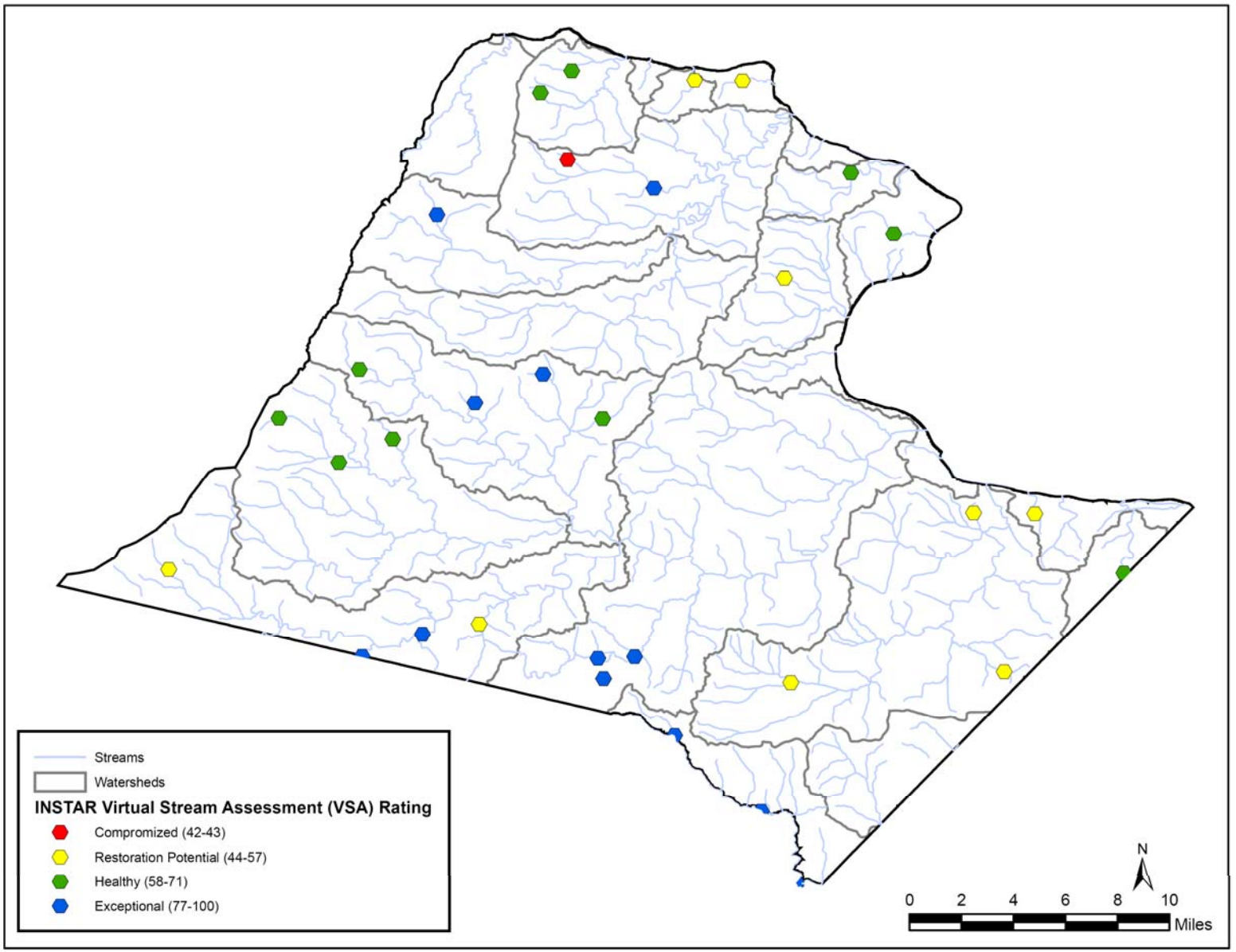


Figure 2-7. Visual Stream Assessment (VSA) ratings for stream sampling locations from Virginia Commonwealth University's (VCU) Interactive Stream Assessment Resource (INSTAR; Data compiled by Loudoun County Department of Building and Development from INSTAR, May 2008)

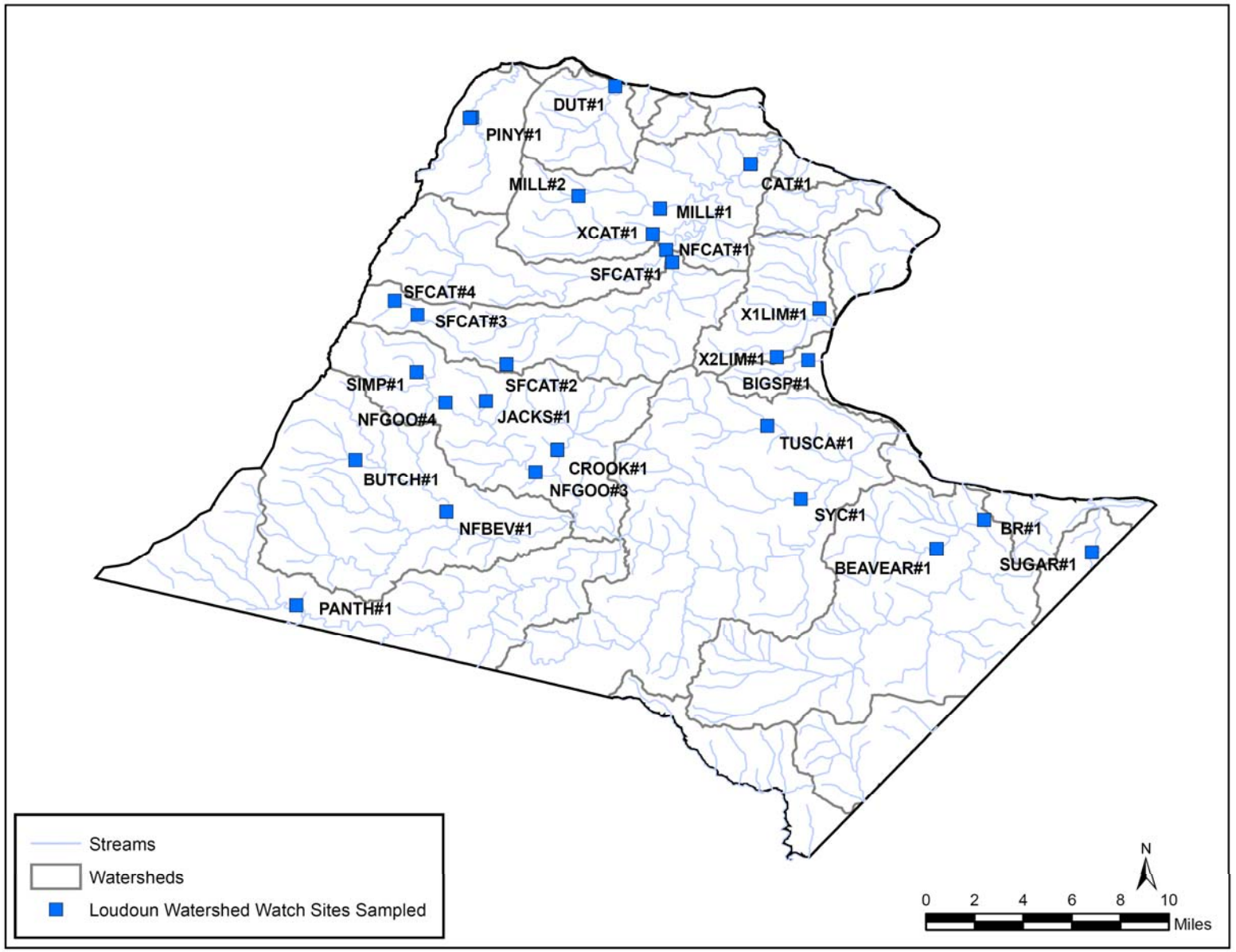


Figure 2-8. Locations of Loudoun Watershed Watch stream sampling sites

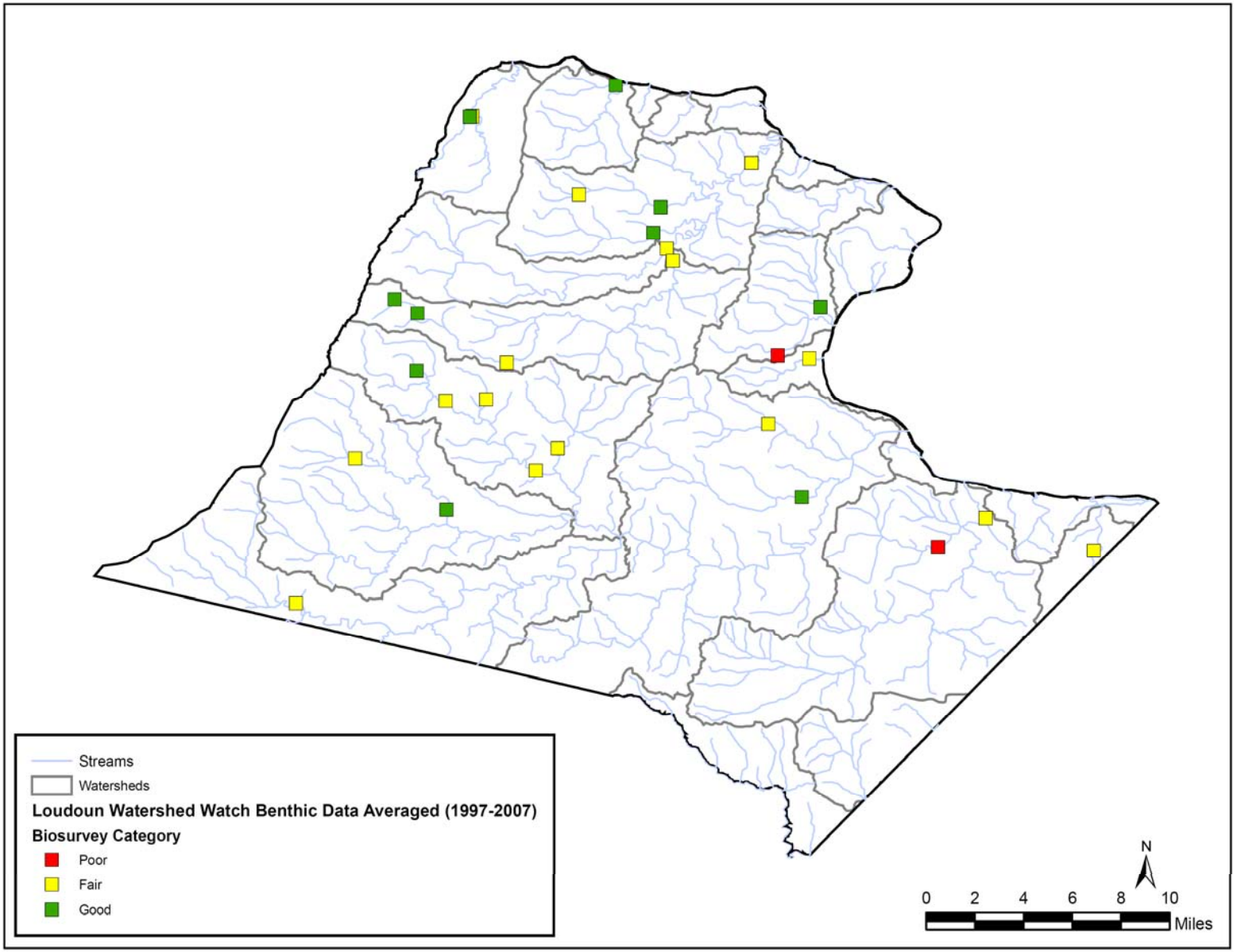


Figure 2-9. Average benthic condition at sites monitored by Loudoun Watershed Watch members (1997-2007), using data collected following EPA's Rapid Bioassessment Protocols (RBP)

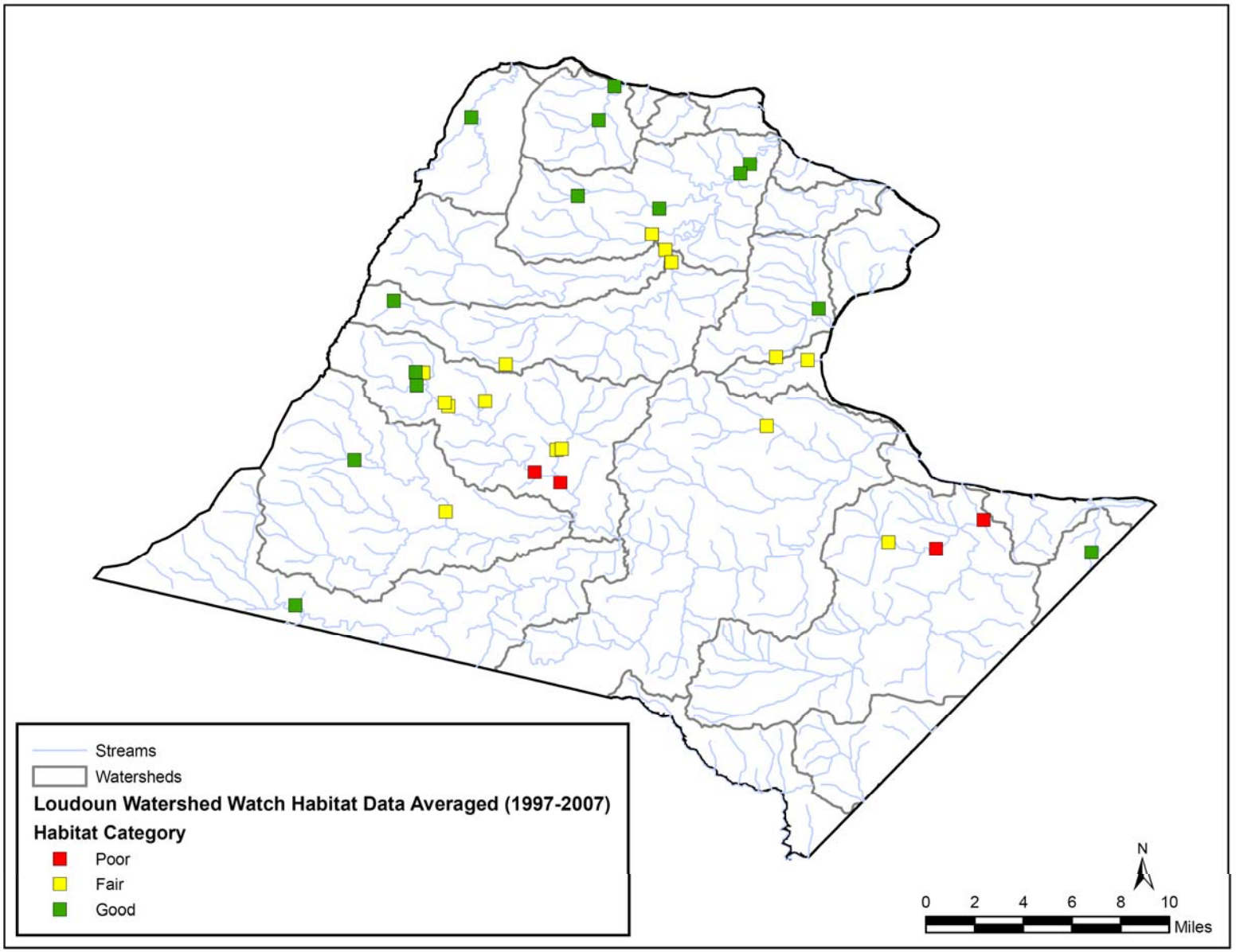


Figure 2-10. Average habitat condition at sites monitored by Loudoun Watershed Watch members (1997-2007), using data collected following EPA's Rapid Bioassessment Protocols (RBP)

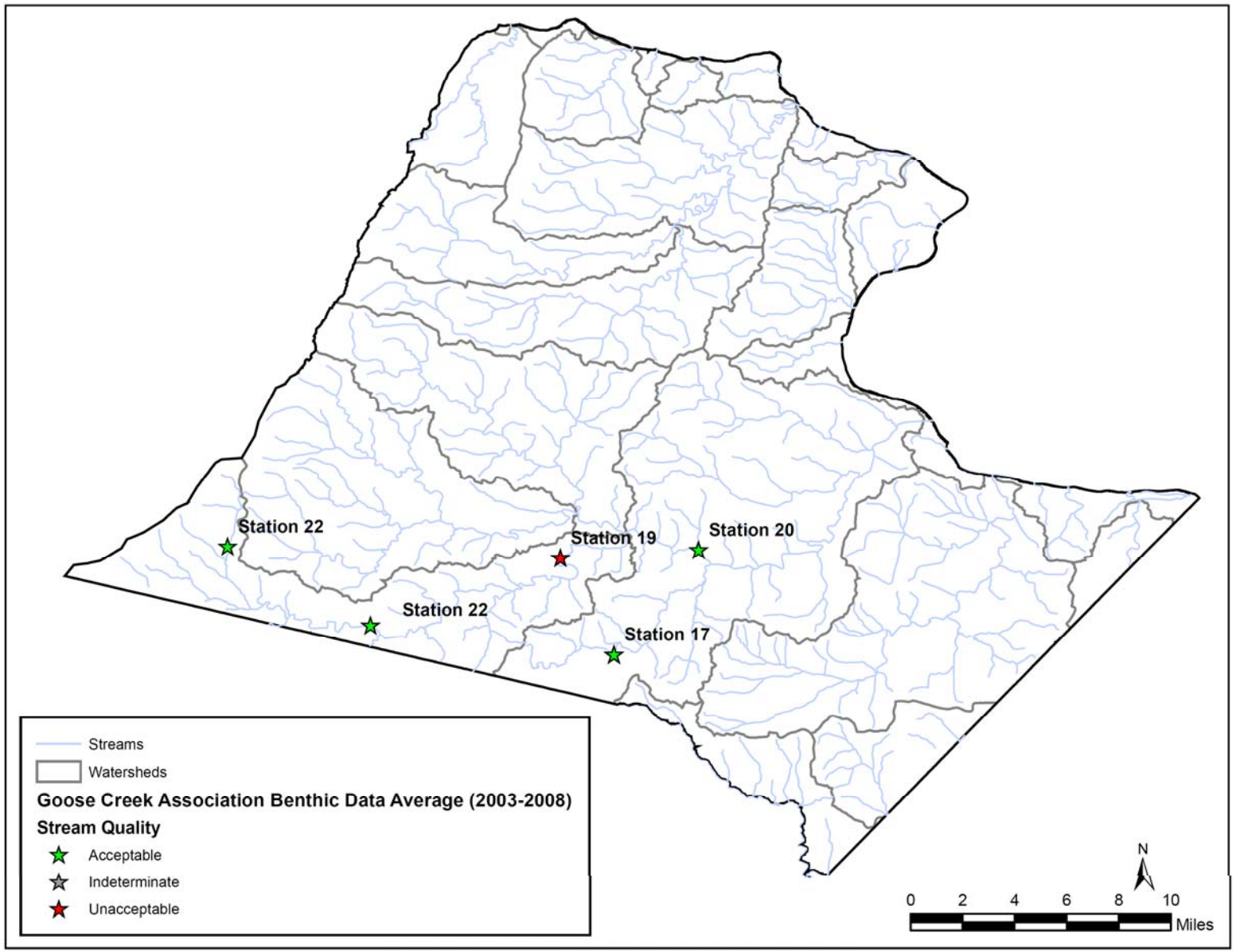


Figure 2-11. Average benthic condition at sites monitored by Goose Creek Association (2003-2008), using data collected following Virginia Save Our Streams (VA SOS) protocols

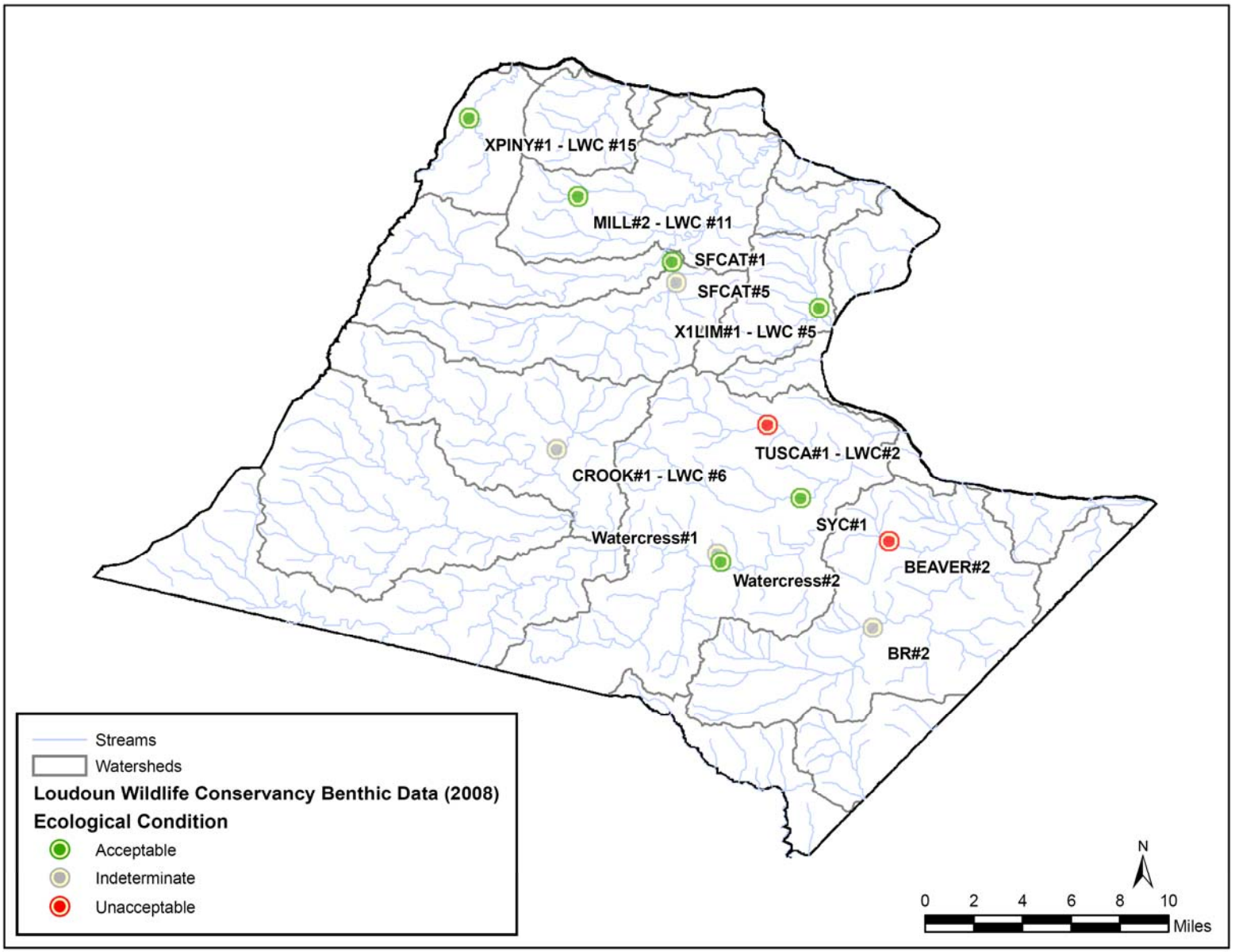


Figure 2-12. Benthic conditions at sites monitored by Loudoun Wildlife Conservancy (2008), using data collected following Virginia Save Our Streams (VA SOS) protocols

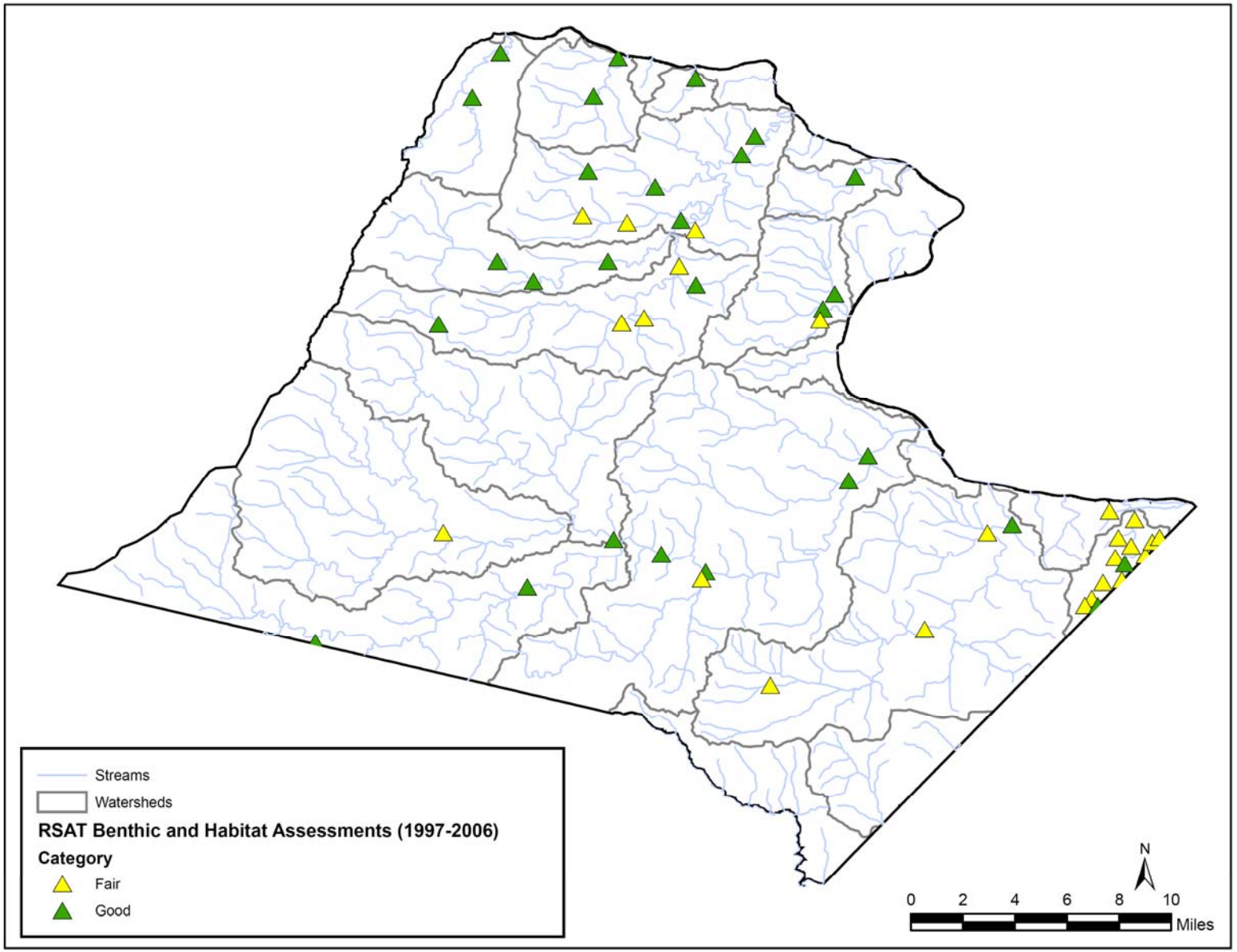


Figure 2-13. Benthic and habitat conditions at sites monitored by Metropolitan Washington Council of Governments (COG) for the Virginia Environmental Endowment (1997-2006), using data collected following Rapid Stream Assessment Techniques (RSAT)

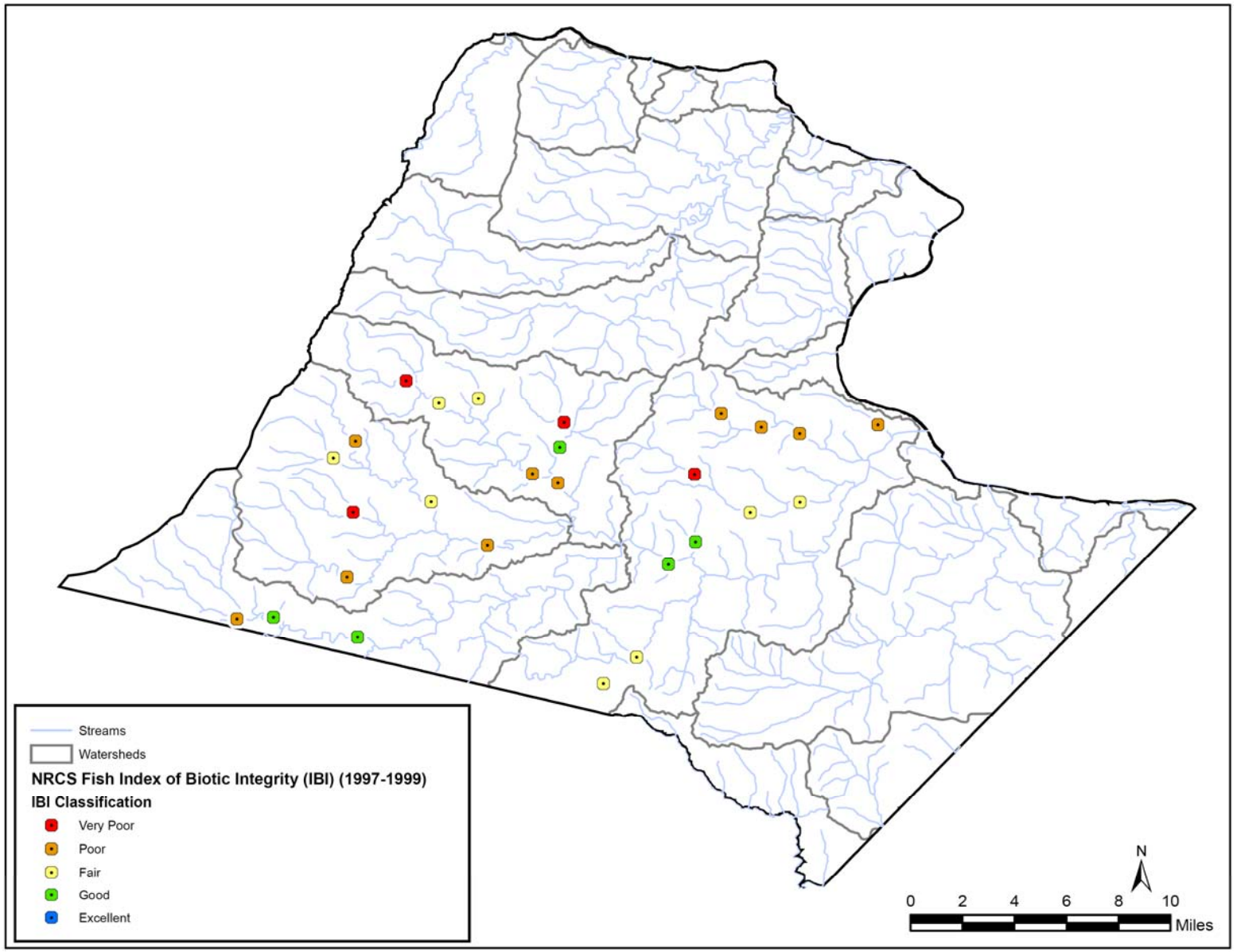


Figure 2-14. Fish Index of Biotic Integrity (IBI) ratings for sites sampled by the Natural Resources Conservation Service (NRCS; 1997-1999)

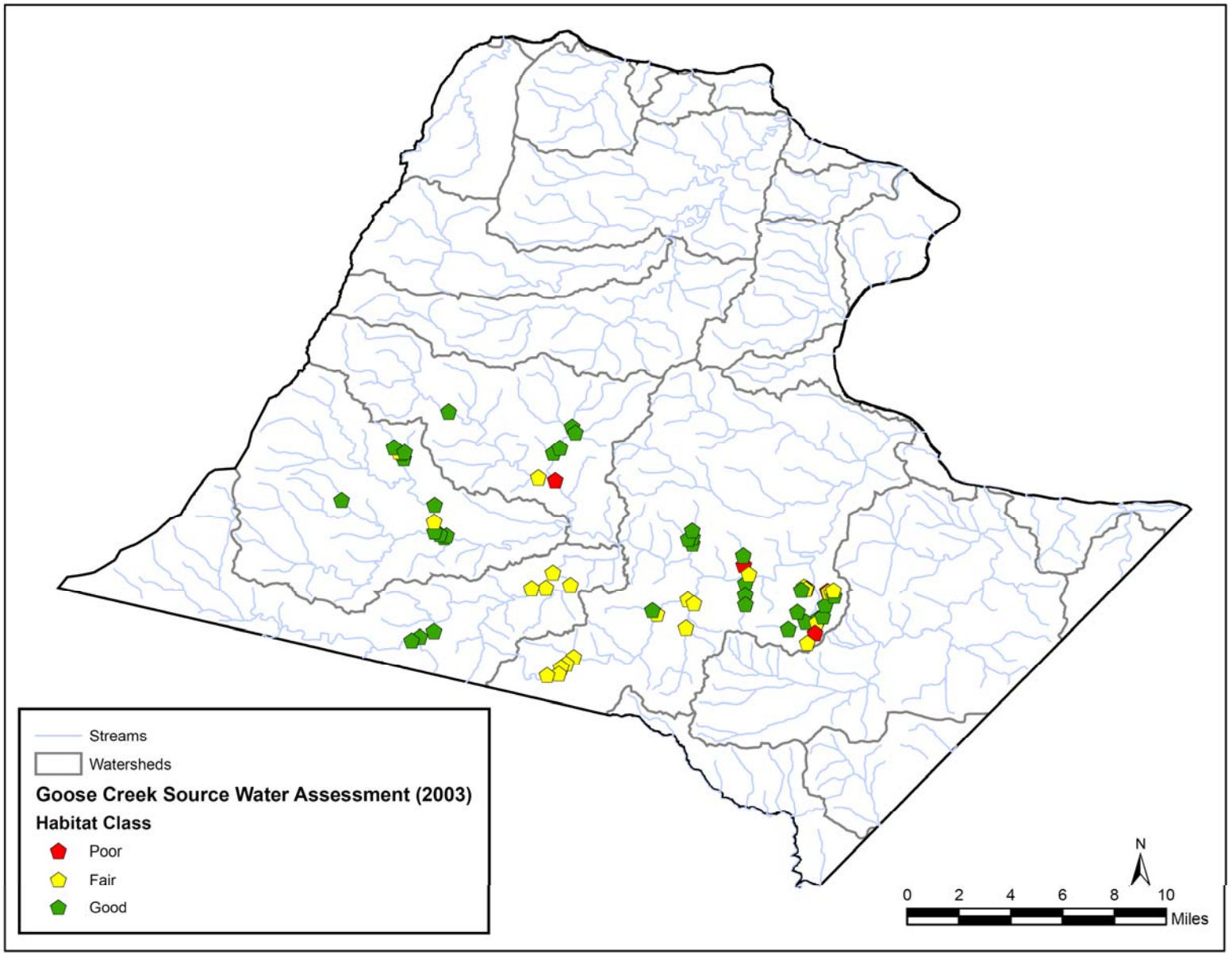


Figure 2-15. Habitat ratings at sites monitored during the Goose Creek Source Water Assessment (2003), using data collected following EPA's Rapid Bioassessment Protocols

# 3 SPECIAL TOPICS

## 3.1 STREAM IMPAIRMENTS

Virginia DEQ routinely monitors stream water quality throughout the Commonwealth. Water samples are collected from a suite of locations on a multi-year, rotating-watershed basis. Water samples are analyzed for temperature, chemistry, microbiology, benthic macroinvertebrate and stream habitat characteristics. Over 100,000 measurements have been collected since the early 1970's. Every two years, DEQ assesses water quality for various uses. Stream monitoring results are compared to numerical water quality standards. Streams that do not meet minimum standards are investigated further to identify the location of the stream, the parameter of concern (e.g., high bacteria counts), and the likely sources of the problem (e.g., failing septic systems). These streams are listed in Virginia's 305(b) and 303(d) reports (the Water Quality Assessment Report and the Report on Impaired Waters). Since 2004, DEQ has combined these two reports into the Virginia Water Quality Assessment 305(b)/303(d) Integrated Report. Over the long term, DEQ must work in cooperation with other governmental agencies to develop and implement cleanup plans to restore the health of these listed streams, based on Total Maximum Daily Loads (TMDLs) of pollutants that can enter a stream without harming it.

In Loudoun County, all streams are designated for recreational uses including swimming and boating, and for the support of aquatic life. These designated uses determine the water quality criteria applicable to Loudoun County streams. These standards can be found online at www.deq.state.va.us/wqs/, or in 9 VAC 25-260-5 et seq. Water Quality Standards. Some Loudoun County stream segments have been listed by DEQ as having impairments (Figures 3-1 through 3-3). These include benthic impairments (red segments in Figure 3-1), bacteriological impairments (red segments in Figure 3-2), and PCB impairments (red segments in Figure 3-3).

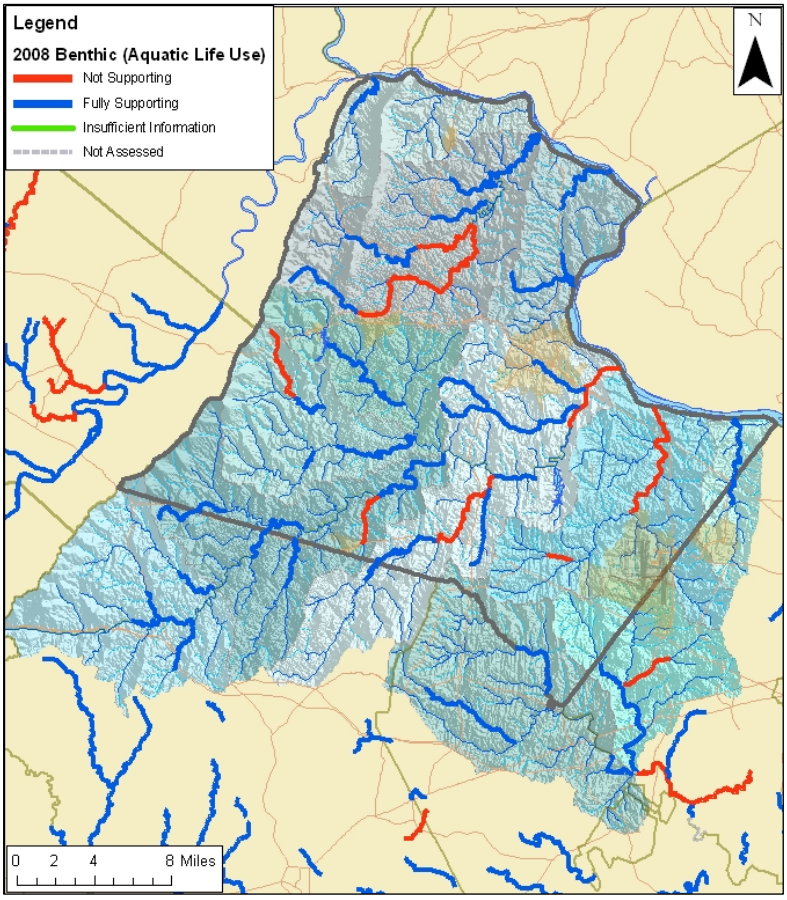


Figure 3-1. Status of benthic impairments in Loudoun County streams (DEQ 2008 Water Quality Assessment; map provided by Loudoun County, www.loudoun.gov)

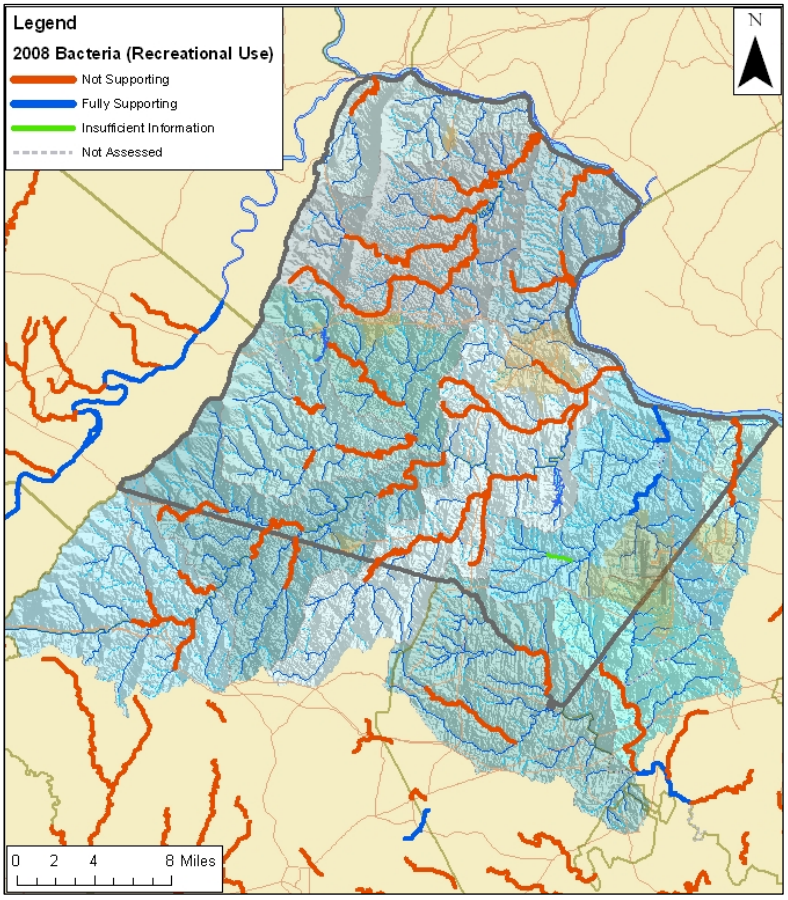


Figure 3-2. Status of bacteria impairments in Loudoun County streams (DEQ 2008 Water Quality Assessment; map provided by Loudoun County, www.loudoun.gov)

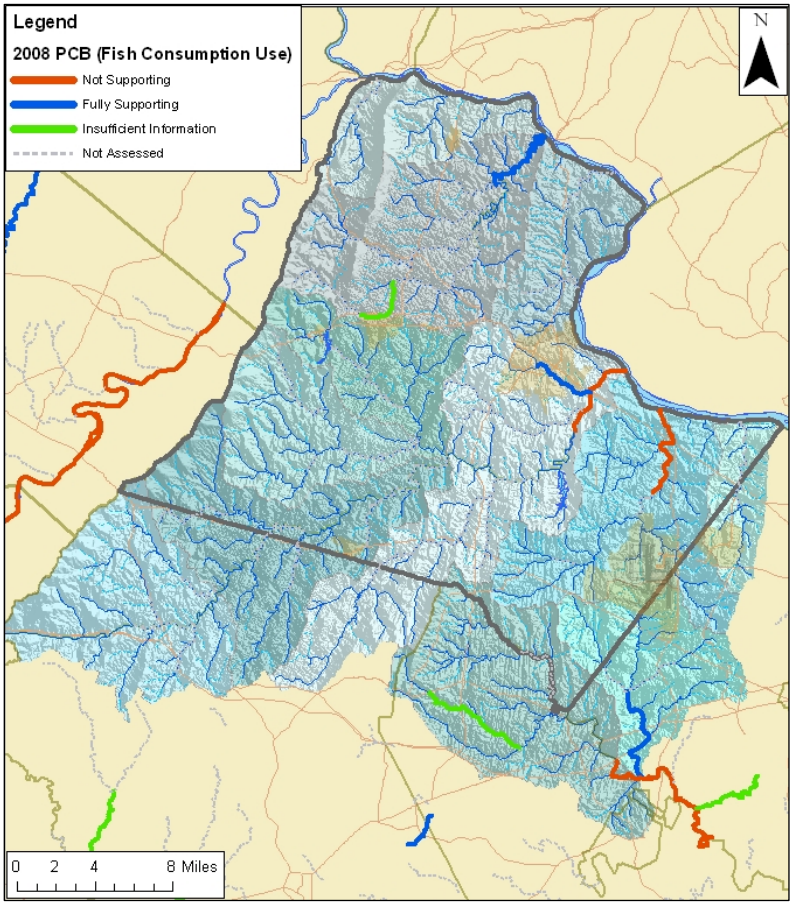


Figure 3-3. Status of PCB impairments in Loudoun County streams (DEQ 2008 Water Quality Assessment; map provided by Loudoun County, www.loudoun.gov)

## 3.2 TEMPORAL TRENDS

Several sets of data were examined for year-to-year patterns in stream condition. These included Virginia DEQ's Virginia Stream Condition Index (VSCI) benthic results and habitat assessment data, Loudoun Watershed Watch benthic and habitat assessments, and Goose Creek Association benthic results. The reasons for observed differences across years may include observer variation and/or actual change in condition.

Virginia DEQ stream benthic and habitat data are available for surveys conducted since 1994. Because DEQ has resampled many of the same sites over multiple years, these data provide an opportunity to examine potential trends in stream condition over time. The sites sampled by DEQ are a combination of locations selected because of suspected or known problems (i.e., TMDL streams) and other sites chosen through probability-based sampling. Therefore, they do not, as a group, provide an unbiased representation of conditions or trends

throughout the county in any given year. However, the data are very useful in seeking patterns that might indicate temporal trends at any of the sampled sites.

We examined data for DEQ sites with one or more samples over three or more years. See Appendix, Figures A-1(a-h) for benthic macroinvertebrate VSCI scores and Figures A-2(a-k) for habitat assessments. In general, mean yearly VSCI scores at most sites tended to remain in the same narrative category or change only by one category rating across different years. For three TMDL sites, VSCI scores over multiple years were always in the Stress and Severe Stress categories. One potential regional reference site (1AGOO022.44) was rated Good to Stress; another reference site (1ASOC013.05) had scores ranging from Stress to Excellent, but its 2008 score fell into the Severe Stress category. For six of eight sites, VSCI scores decreased in 2008, compared with previous years, perhaps indicative of increased pressure from stressors acting upon those stream systems. Across 11 sites with stream habitat assessments over multiple years, scores tended to remain roughly the same (3 sites) or decline (8 sites) over time.

Sampling in 2009 will continue to provide data for many of the DEQ sites. The Loudoun County Stream Assessment plans to sample 23 of the 24 sites previously monitored by DEQ (Table 3-1). DEQ is sampling 10 sites in 2009. Long-term monitoring of DEQ sites will continue in future years.

Loudoun Watershed Watch (LWW) has compiled data collected by volunteer monitors beginning in 1997. We examined data for sites with one or more samples over four or more years within the period of 1997-2007. See Appendix, Figures A-3(a-m) for benthic macroinvertebrate scores and Figures A-4(a-n) for habitat assessments. For 13 sites examined, mean annual benthic invertebrate ratings varied to a moderate degree across years, but still provided a fairly consistent characterization. That is, sites that scored Poor for the aquatic macroinvertebrate rating tended to remain in the Poor to Fair range in other years. Sites rated as Good in any year did not, for the most part, drop into the Poor range. No data for 2007 or 2008 were included in this evaluation. Habitat scores also were fairly consistent across time, generally remaining in the same narrative category or only fluctuating by one category rating across years.

The Goose Creek Association has collected volunteer monitoring data since 2006. We examined all available data for the five sites in Loudoun County, sampled for macroinvertebrates over 2006-2008 and rated using Virginia SOS methods. See Appendix, Figures A-5(a-e). Results for individual sampling events are shown. Scores for three sites were consistent over time, while scores for the other two sites ranged from acceptable to unacceptable.

Table 3-1. Virginia DEQ sites in Loudoun County, sampled in various years through 2008. Figures depicting results over multiple years are in the Appendix.

| Virginia DEQ Station ID | Latitude | Longitude | Stream Name | Site Name | Land Use | DEQ's Survey Reason |
|---|---|---|---|---|---|---|
| 1ABRB002.15 | 39.04667 | -77.43278 | Broad Run | Broad Run at Route 7 | Urban/Residential | Citizen Request |
| 1ABRB006.97 | 39.00583 | -77.46064 | Broad Run | Broad Run Upstream from Waxpool Run | Urban | TMDL |
| 1ABRB015.43 | 38.95958 | -77.54428 | Broad Run | Broad Run Upstream from Route 621 | Urban | TMDL |
| 1ABUL025.94 | 38.88944 | -77.57056 | Bull Run | Bull Run at Route 705 | agriculture | TMDL |
| 1ACAX003.69 | 39.26055 | -77.5692 | Catoctin Creek | Catoctin Creek downstream from Route 663 | Agricultural | 2008 Probabilistic Site - VAW05547-190 |
| 1ACAX004.57 | 39.255 | -77.57667 | Catoctin Creek | Catoctin Creek at Route 663 | Forest | This station is used as one of the reference sites. |
| 1AGOO002.38 | 39.085556 | -77.511389 | Goose Creek | Goose Creek at Route 7 | Cropland | This station is an EPA Core Monitor Station. |
| 1AGOO003.18 | 39.07428 | -77.51208 | Goose Creek | Goose Creek Above Route 7 | Rural | TMDL Study |
| 1AGOO021.28 | 39.01264 | -77.6831 | Goose Creek | Goose Creek Downstream from Route 734 | Pasture/Hay | Probabilistic site - VAW05547-126 |
| 1AGOO022.44 | 39.01361 | -77.69972 | Goose Creek | Goose Creek at Route 734 | Forest | Prospective ecoregional reference |
| 1ALIV004.78 | 38.975 | -77.63972 | Little River | Little River at Route 50 | Suburban | Expand coverage in the suburban Potomac River watershed |
| 1ANOB007.97 | 39.10389 | -77.80306 | North Fork Beaverdam Creek | North Fork Beaverdam Creek at Route 831 | Rural/Forest | Prospective ecoregional reference |
| 1ANOC000.42 | 39.205 | -77.62444 | North Fork Catoctin Creek | North Fork Catoctin Creek at Route 681 | Agriculture | Citizen Request |
| 1ANOG000.91 | 39.04457 | -77.65984 | North Fork Goose Creek | North Fork Goose Creek Upstream from Route 733 | Forest | Probabilistic Site - VAEQ99-455 |
| 1ANOG005.69 | 39.07722 | -77.69778 | North Fork Goose Creek | North Fork Goose Creek at Route 722 | Rural, Agriculture | Nutrient Criteria Pilot Program |
| 1ASOC000.01 | 39.2098 | -77.62138 | South Fork Catoctin Creek | South Fork Catoctin Creek above Confluence with North Fork | Agriculture/Rural | Citizen Request |
| 1ASOC007.06 | 39.16656 | -77.66697 | South Fork Catoctin Creek | South Fork Catoctin Creek at Route 738 | Agriculture/Rural | TMDL |
| 1ASOC010.09 | 39.15914 | -77.69869 | South Fork Catoctin Creek | South Fork Catoctin Creek at Route 711 | Agriculture/Rural | TMDL |
| 1ASOC011.98 | 39.14278 | -77.71222 | South Fork Catoctin Creek | South Fork Catoctin Creek Downstream of Route 611 | Rural | Assess impacts on water quality from Town of Purcellville |
| 1ASOC012.60 | 39.14222 | -77.72278 | South Fork Catoctin Creek | South Fork Catoctin Creek Above Route 690 | Rural | Assess impacts on water quality from Town of Purcellville |
| 1ASOC013.05 | 39.14639 | -77.73222 | South Fork Catoctin Creek | South Fork Catoctin Creek Above Route 7 Bypass | | Selected for reference condition study |
| 1AWAC003.31 | 38.97206 | -77.72683 | Wancopin Creek | Wancopin Creek Downstream of Route 50 | Rural/Residential | Probabilistic Station |
| 1AXGU000.18 | 39.01434 | -77.79316 | Tributary to Beaverdam Creek | Unnamed Tributary to Beaverdam Creek Downstream from Route 790 | Agricultural | 2006 Probabilistic Site - VAW05547-062 |
| 1AXKR000.77 | 39.25784 | -77.59046 | Tributary to Catoctin Creek | Unnamed Tributary to Cactoctin Creek Downstream from Route 663 | Forest/Agriculture | Probabilistic Site, VAEQ99-615 |

## 3.3 SPECIFIC STREAM HABITAT PARAMETERS

In addition to overall stream habitat condition indicators, as summarized in Chapter 2, we also reviewed data on specific habitat parameters including embeddedness, bank stability, channel flow, riffle frequency, riparian conditions and other factors. Our review of available data found that most of the datasets did not include these specific data, but only summary-level habitat indicators. Detailed habitat parameter data were available from Virginia Commonwealth University's (VCU) INteractive STream Assessment Resource (INSTAR) program. From the INSTAR website http://instar.vcu.edu/ (accessed March 13, 2009), we obtained habitat data collected using EPA's semi-quantitative Rapid Habitat Assessment (RBP Protocol) for 30 sites in Loudoun County. This included 28 sites sampled by VCU's Center for Environmental Science, 1 site sampled by Virginia Department of Environmental Quality's probabilistic monitoring (ProbMon) program, and 1 site sampled by Fairfax County. VCU-sampled sites were selected on a random basis by 12-digit Hydrologic Unit Code (HUC) which in some cases cross county boundaries. The INSTAR habitat dataset contains scores for a variety of stream habitat parameters. For all stream gradients, the dataset contains site ratings for metrics including Epifaunal Substrate/Available Cover, Channel Alteration, Sediment Deposition, Channel Flow Status, Channel Stability, Vegetative Protection, and Riparian Vegetative Zone Width. For low-gradient streams (17 sites), data available also include Pool Substrate Characterization, Pool Variability, and Stream Sinuosity. For high-gradient streams (13 sites), data available also include Frequency of Riffles (or bends), Velocity/Depth Regime, and Embeddedness. Each metric is evaluated on a 0-20 scale. Based on these scores, classes are assigned as follows:

| Habitat Rating | Score Range |
|---|---|
| Optimal | 16 to 20 |
| Suboptimal | 11 to 15 |
| Marginal | 6 to 10 |
| Poor | 0 to 5 |

Maps depicting INSTAR habitat assessment results are provided in Figures 3-4 through 3-16. Scores for habitat parameters indicated a broad range of conditions across Loudoun County, from Optimal to Poor, for the various aspects of habitat quality assessed. Sediment Deposition ratings indicated pockets of problems at sites in Catoctin Creek, as well as North Fork and South Fork Catoctin Creek. Pool Substrate scores were predominantly in the Marginal category. The Sinuosity of low-gradient streams was low, with many streams rated Poor to Marginal.

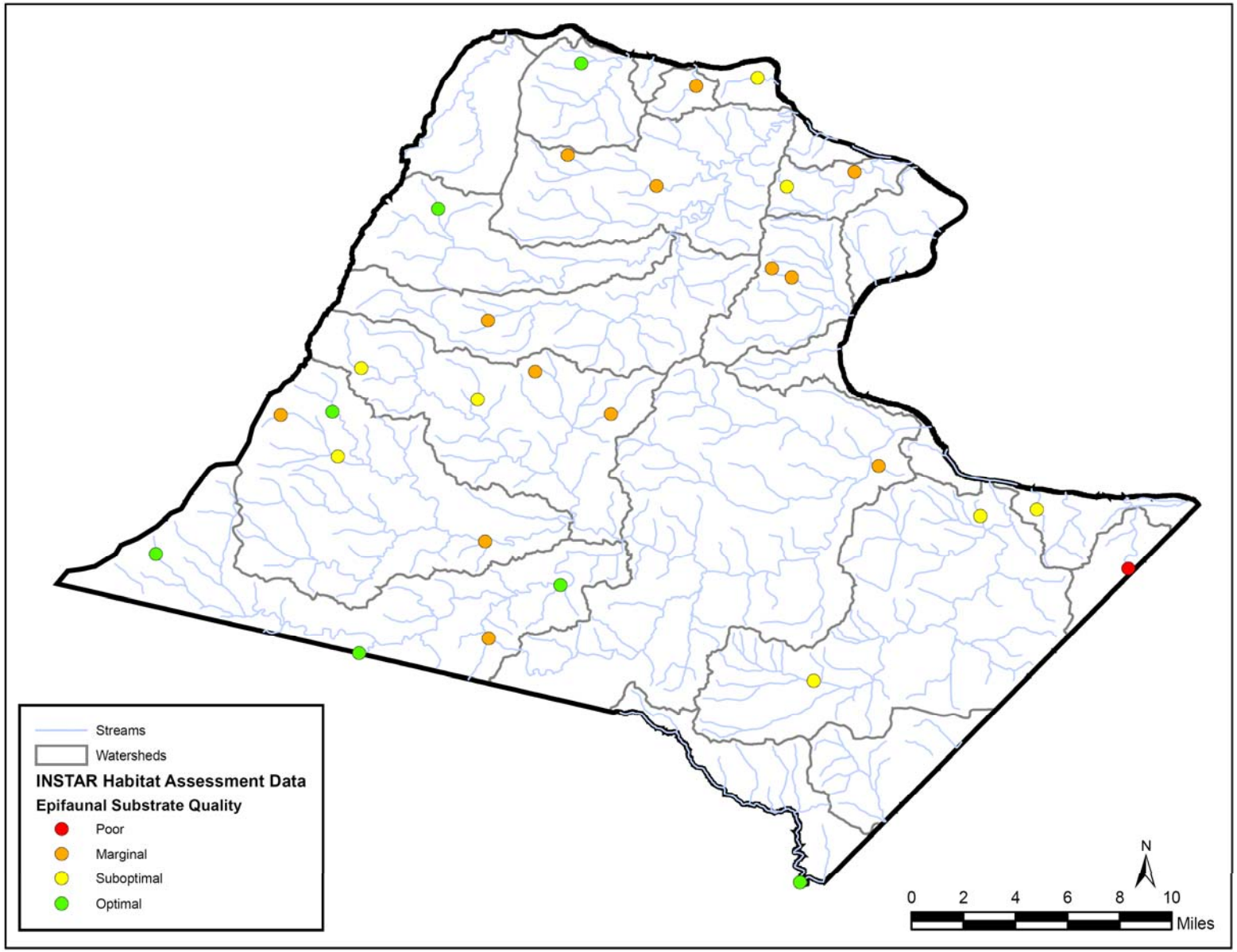


Figure 3-4. Epifaunal substrate scores for stream sampling locations from Virginia Commonwealth University's (VCU) Interactive Stream Assessment Resource (INSTAR; Data compiled by Versar, 2009)

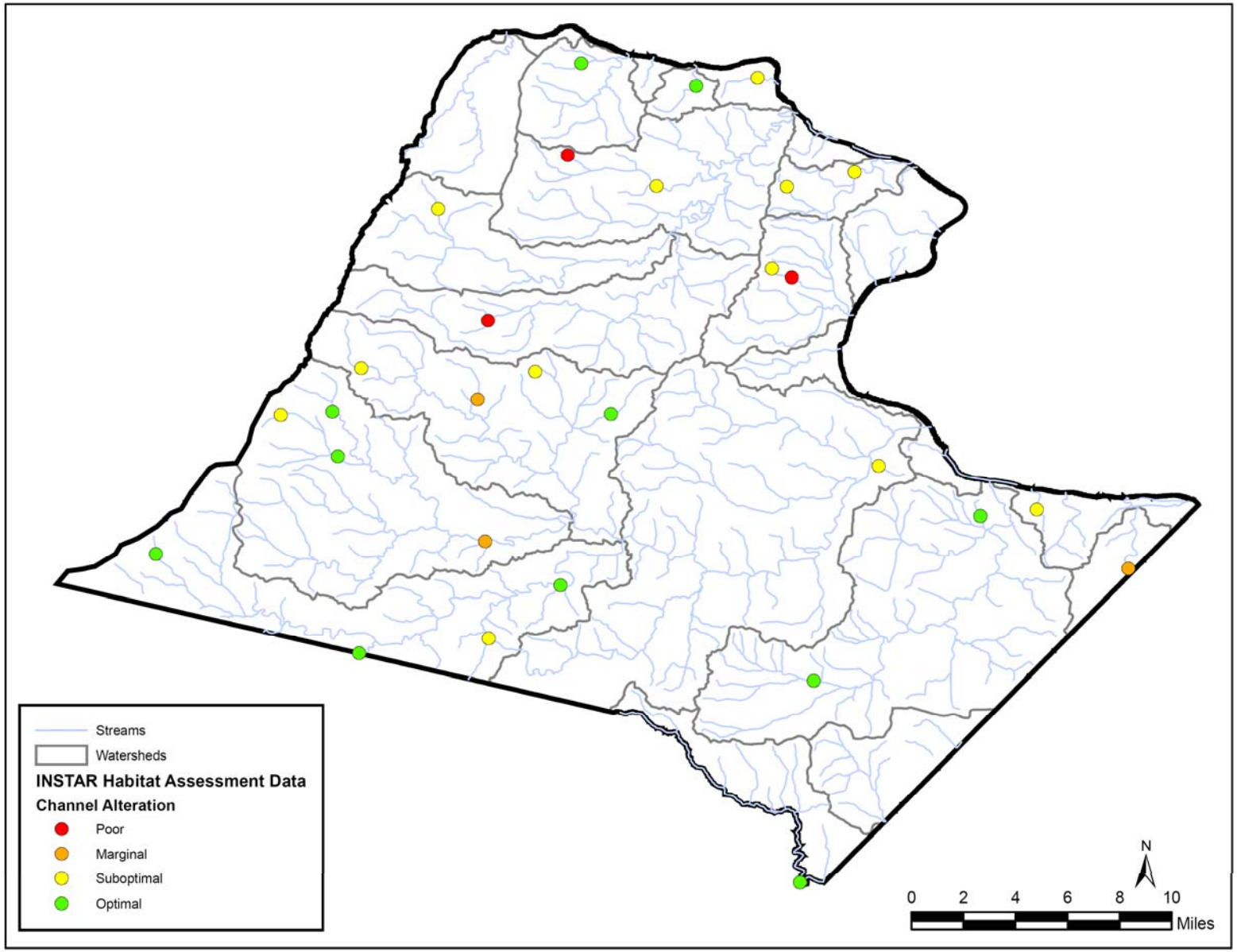


Figure 3-5. Channel alteration scores for stream sampling locations from Virginia Commonwealth University's (VCU) Interactive Stream Assessment Resource (INSTAR; Data compiled by Versar, 2009)

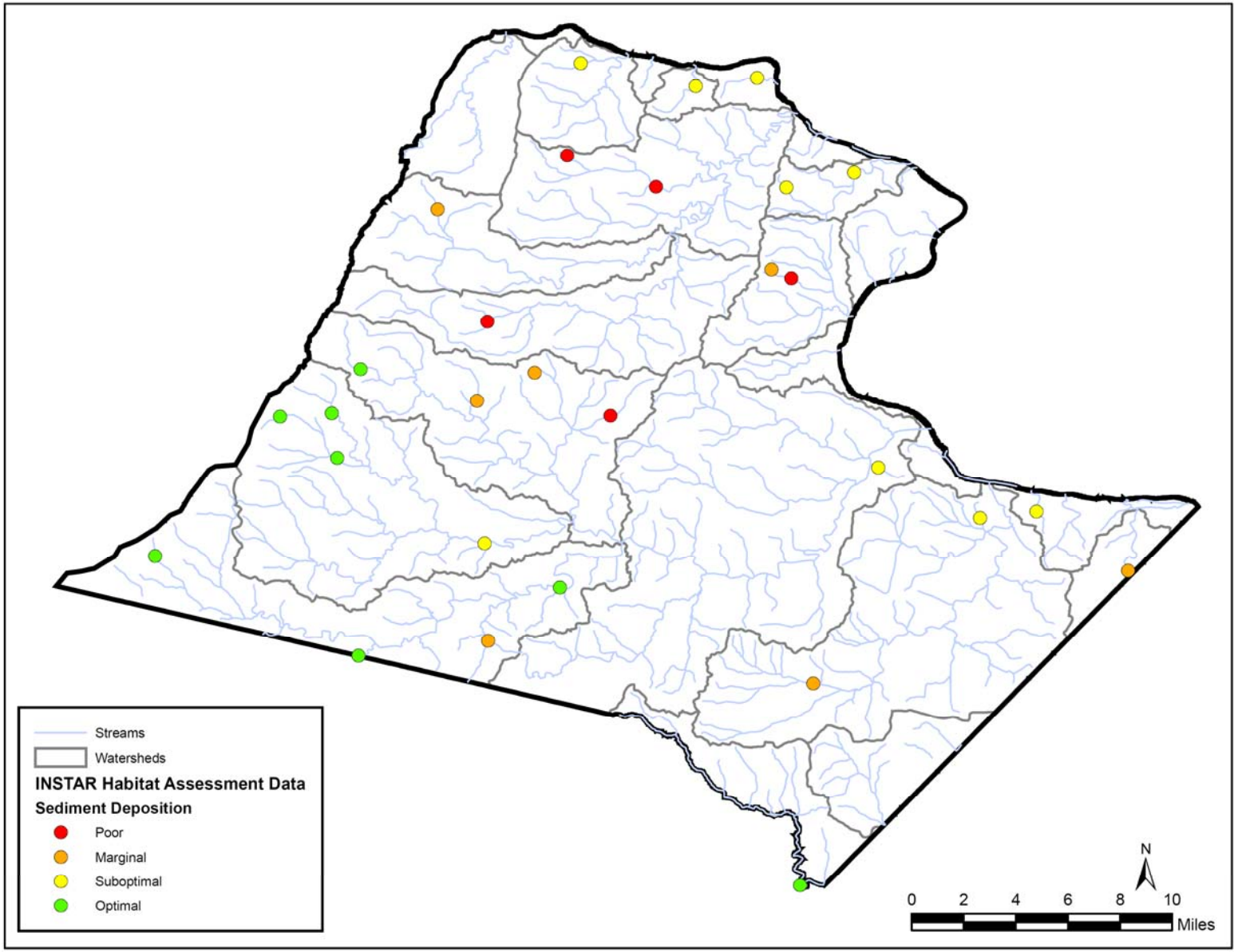


Figure 3-6. Sediment deposition scores for stream sampling locations from Virginia Commonwealth University's (VCU) Interactive Stream Assessment Resource (INSTAR; Data compiled by Versar, 2009)

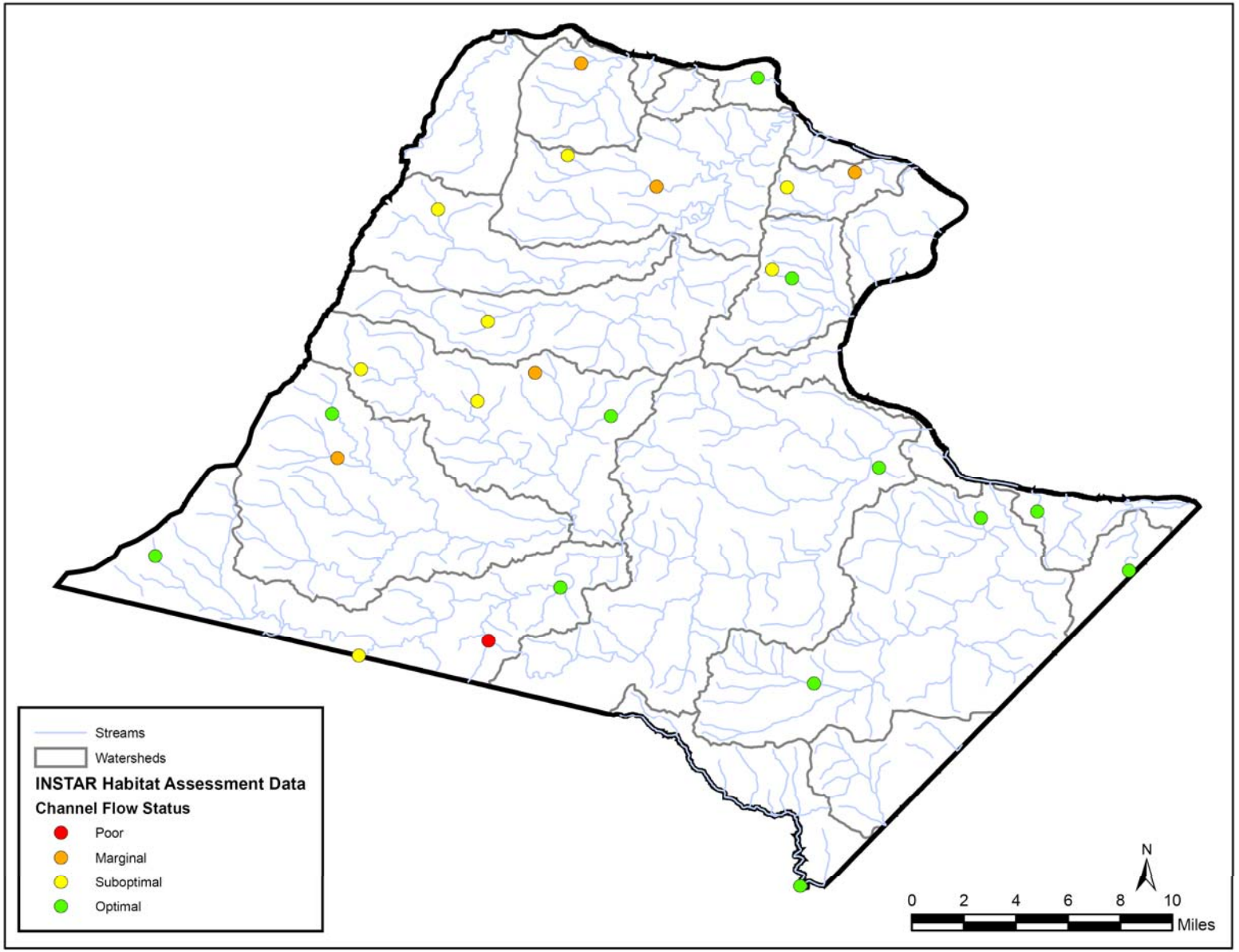


Figure 3-7. Channel flow status scores for stream sampling locations from Virginia Commonwealth University's (VCU) Interactive Stream Assessment Resource (INSTAR; Data compiled by Versar, 2009)

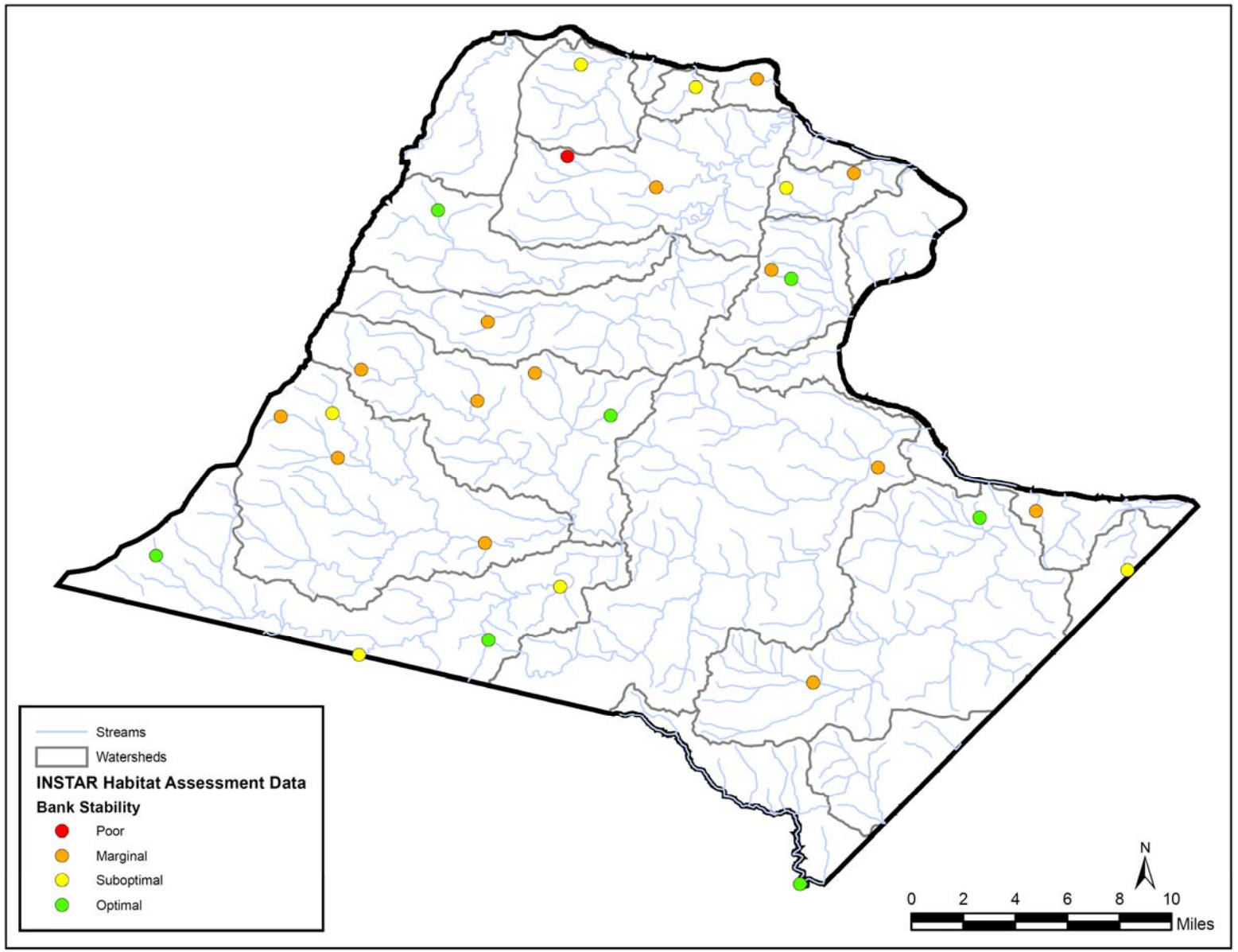


Figure 3-8. Bank stability scores for stream sampling locations from Virginia Commonwealth University's (VCU) Interactive Stream Assessment Resource (INSTAR; Data compiled by Versar, 2009)

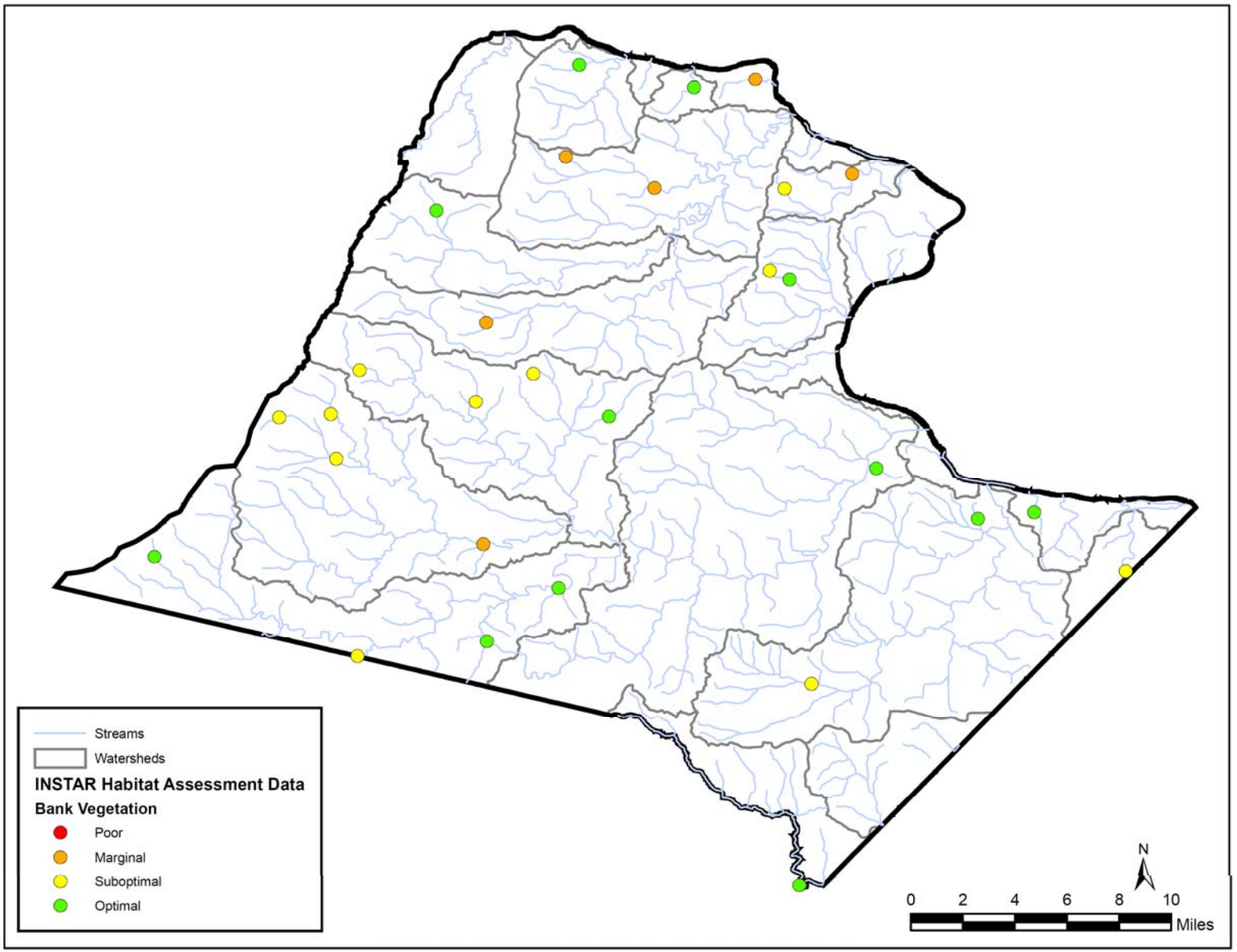


Figure 3-9. Bank vegetation scores for stream sampling locations from Virginia Commonwealth University's (VCU) Interactive Stream Assessment Resource (INSTAR; Data compiled by Versar, 2009)

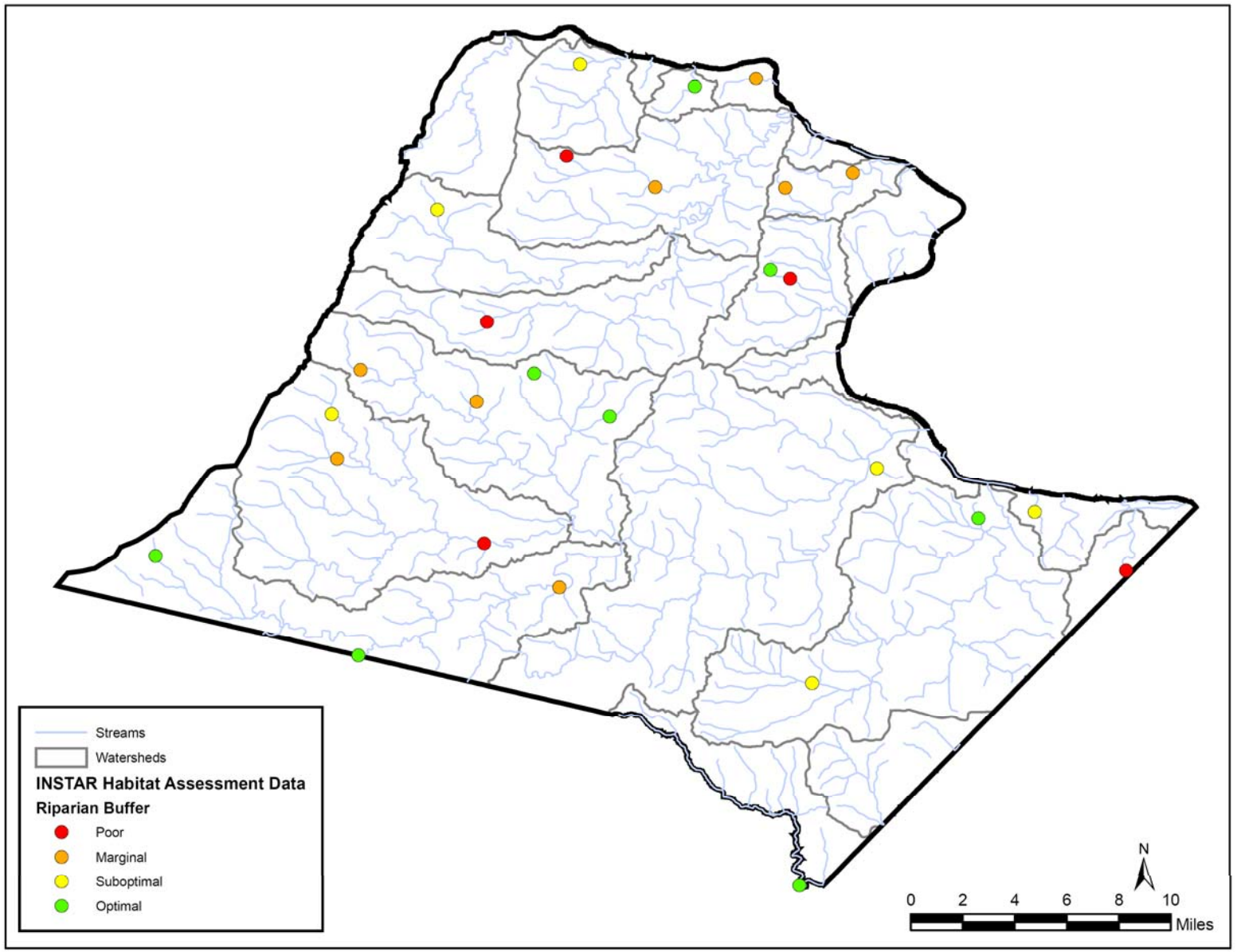


Figure 3-10. Riparian buffer scores for stream sampling locations from Virginia Commonwealth University's (VCU) Interactive Stream Assessment Resource (INSTAR; Data compiled by Versar, 2009)

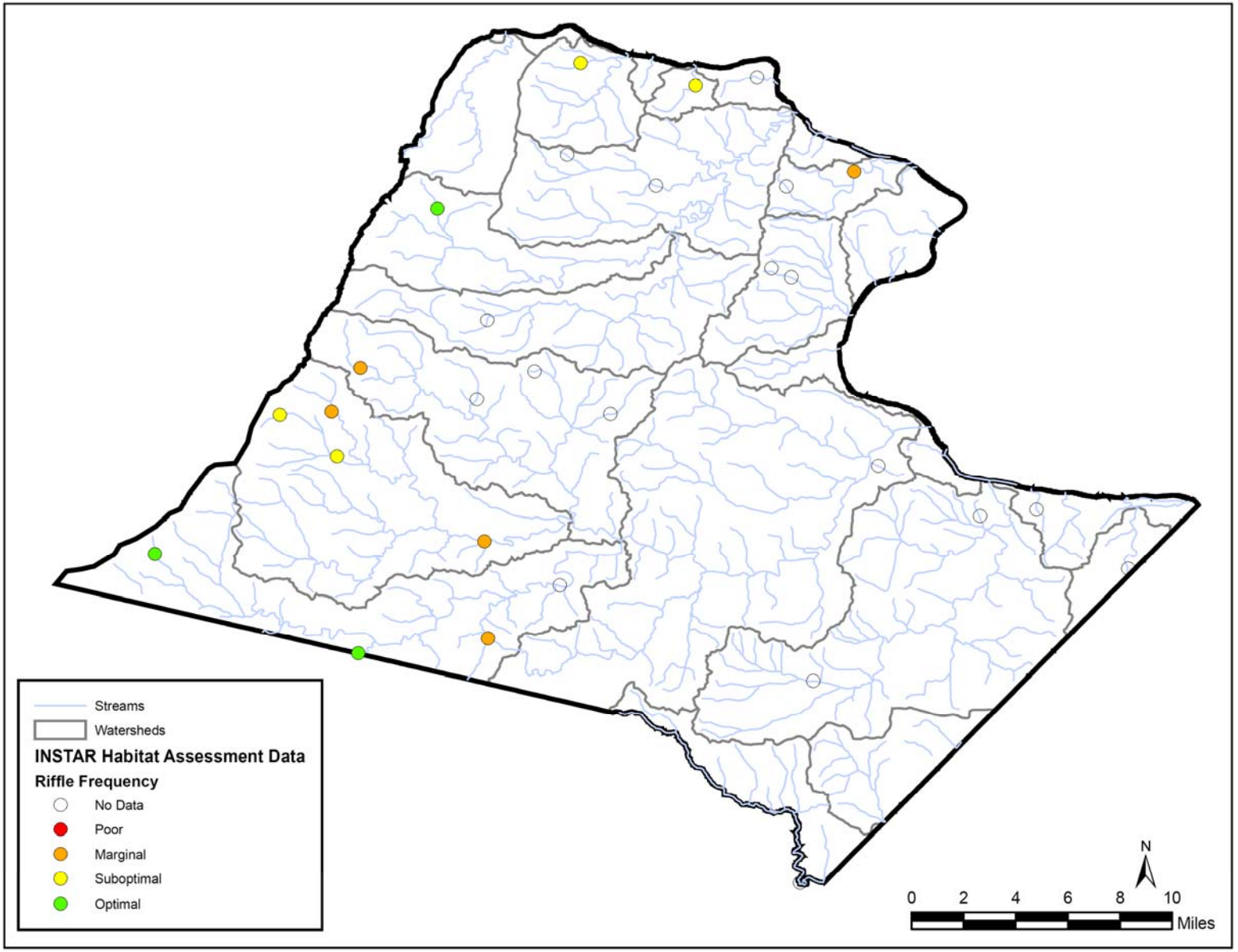


Figure 3-11. Riffle frequency scores for stream sampling locations from Virginia Commonwealth University's (VCU) Interactive Stream Assessment Resource (INSTAR; Data compiled by Versar, 2009)

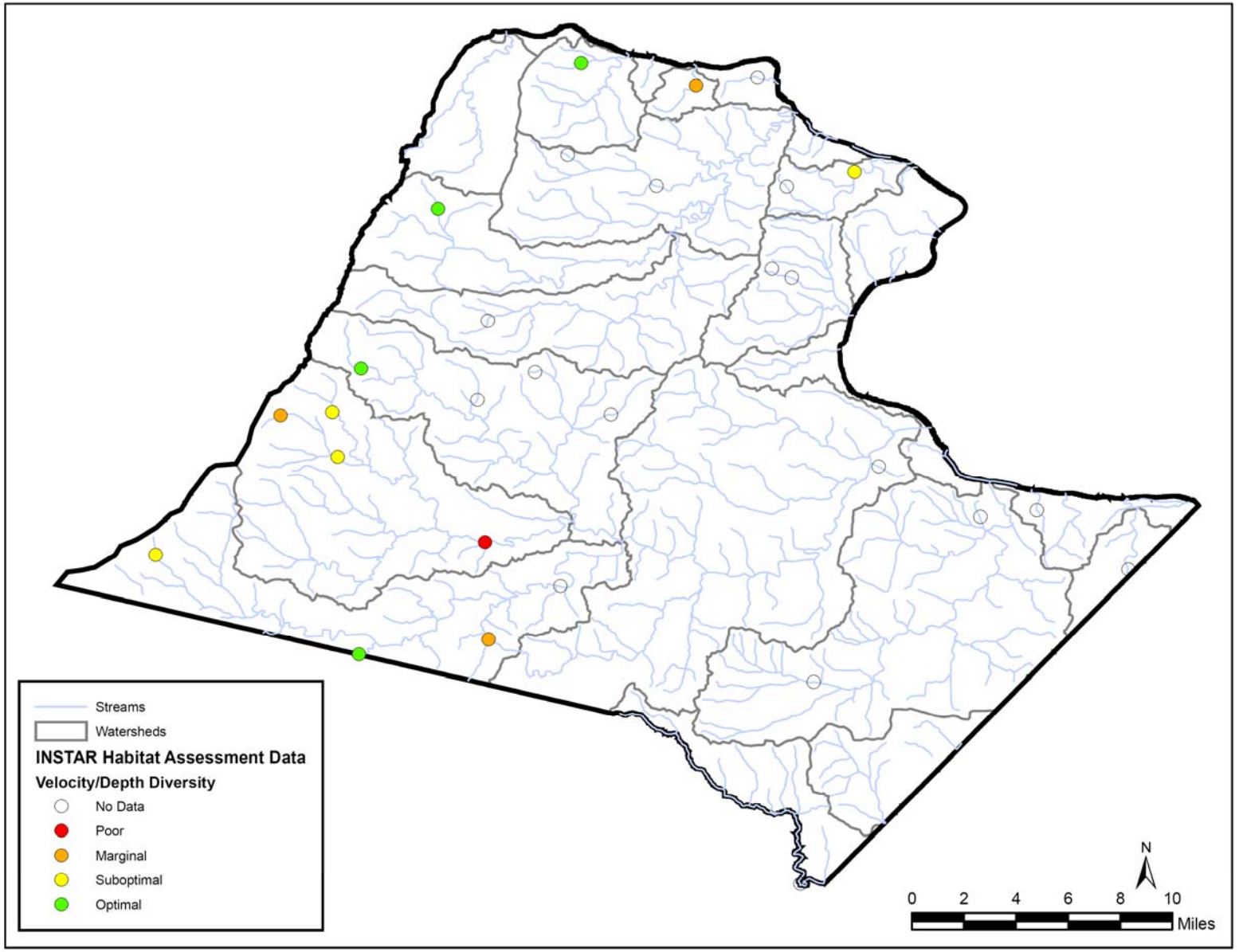


Figure 3-12. Velocity/depth diversity scores for stream sampling locations from Virginia Commonwealth University's (VCU) Interactive Stream Assessment Resource (INSTAR; Data compiled by Versar, 2009)

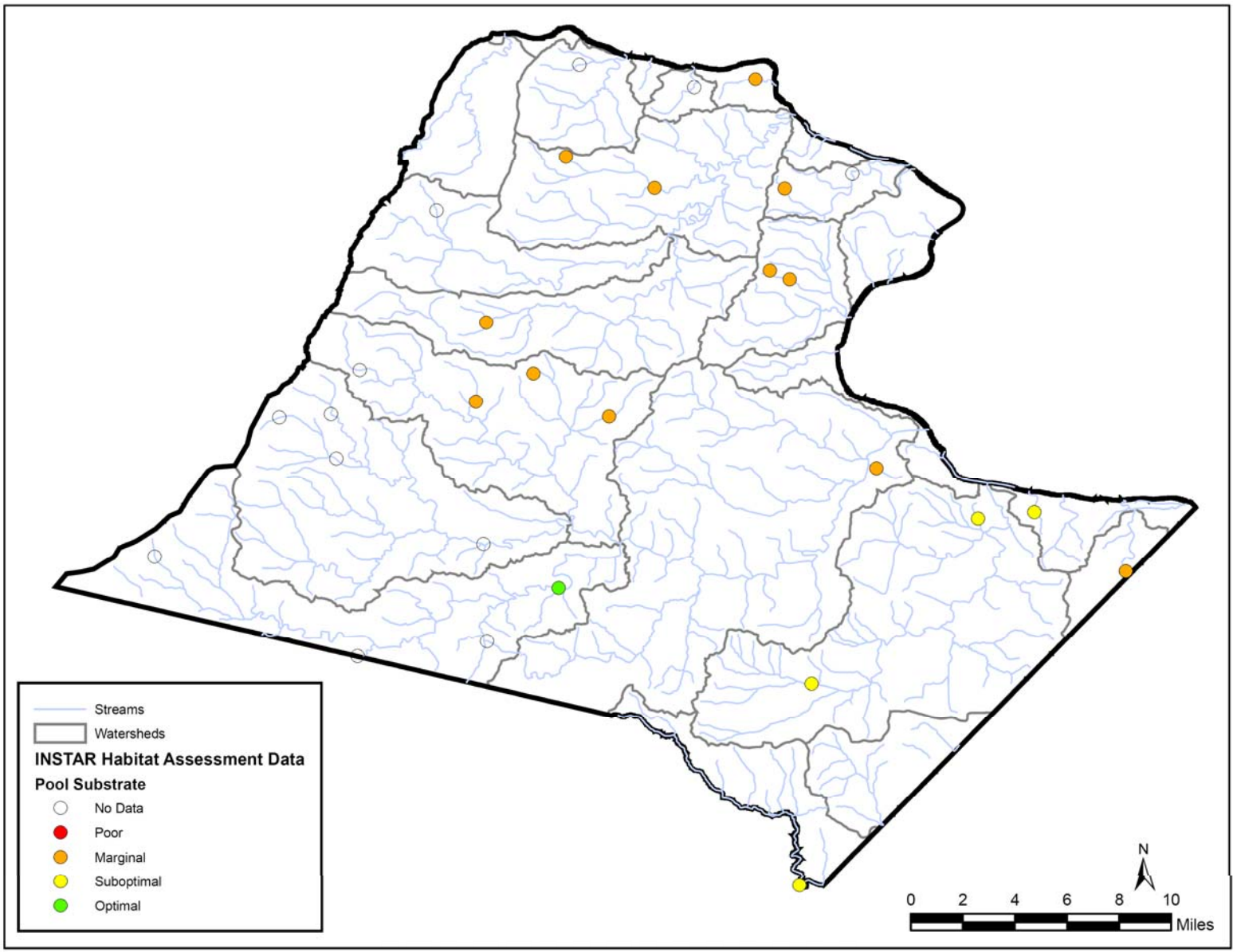


Figure 3-13. Pool substrate scores for stream sampling locations from Virginia Commonwealth University's (VCU) Interactive Stream Assessment Resource (INSTAR; Data compiled by Versar, 2009)

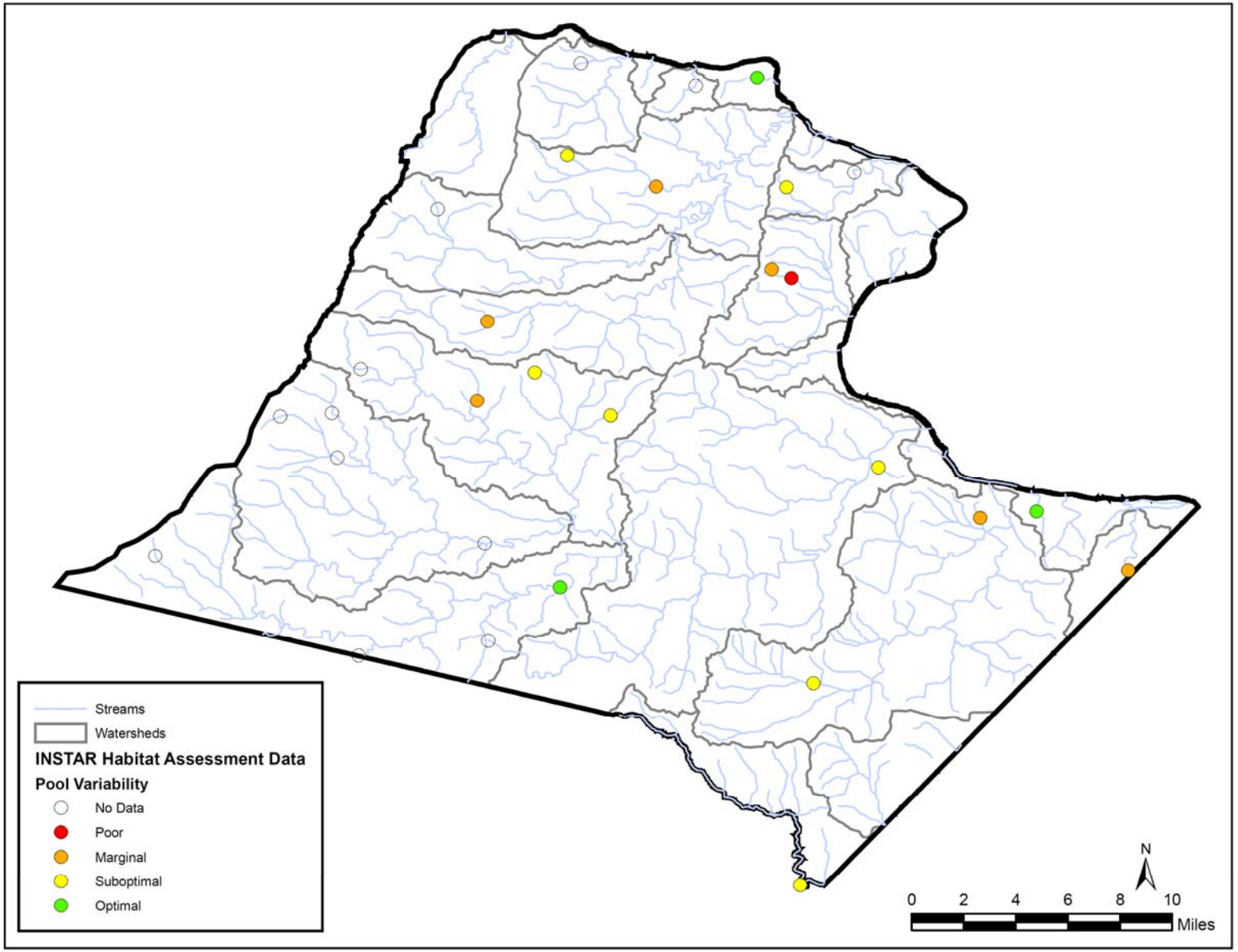


Figure 3-14. Pool variability scores for stream sampling locations from Virginia Commonwealth University's (VCU) Interactive Stream Assessment Resource (INSTAR; Data compiled by Versar, 2009)

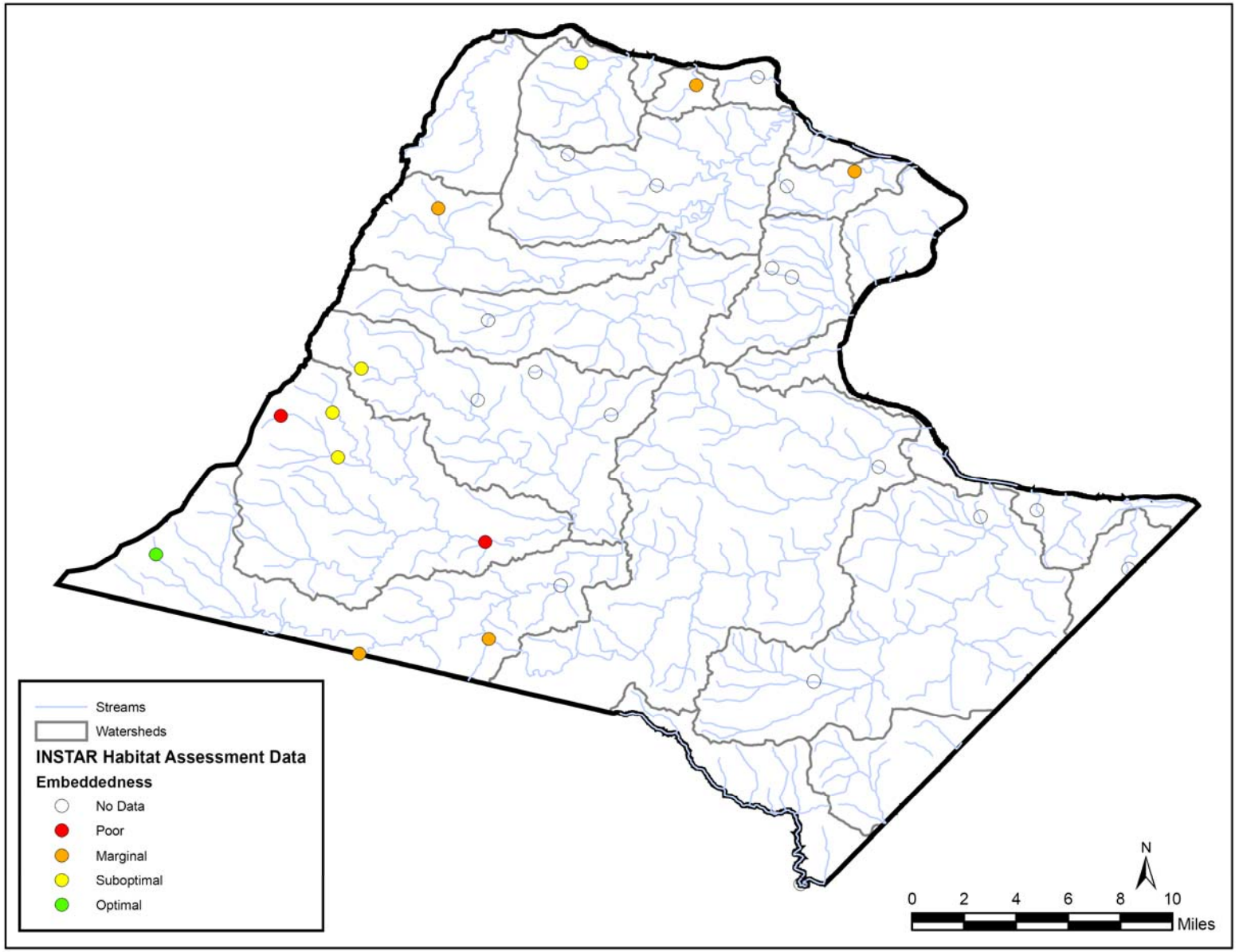


Figure 3-15. Embeddedness scores for stream sampling locations from Virginia Commonwealth University's (VCU) Interactive Stream Assessment Resource (INSTAR; Data compiled by Versar, 2009)

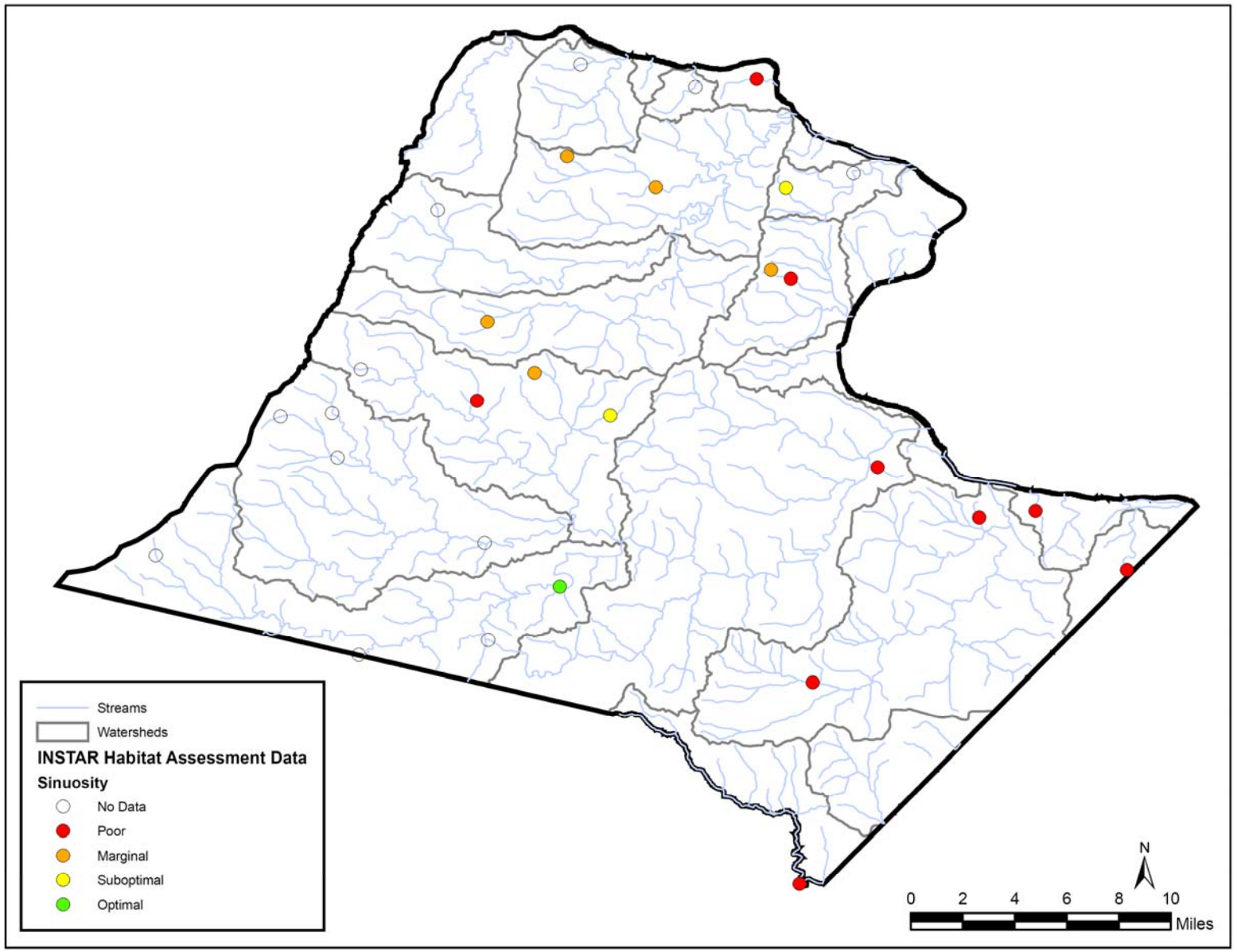


Figure 3-16. Sinuosity scores for stream sampling locations from Virginia Commonwealth University's (VCU) Interactive Stream Assessment Resource (INSTAR; Data compiled by Versar, 2009)

## 3.4 STREAM MITIGATION AND MITIGATION BANKING SCORES

We reviewed two site-specific applications of the Unified Stream Methodology (USM, USACE, and DEQ 2007) to summarize the use of this scoring tool for stream mitigation and mitigation banking. Development of the USM was a joint effort between the U.S. Army Corps of Engineers (USACE), Norfolk District and Virginia DEQ. This manual provides a method to rapidly assess what the stream compensation requirements would be for permitted stream impacts and the amount of credits that could be obtained by implementing various stream compensation practices. The USM incorporates assessments of channel, riparian, and instream conditions at a stream site. It can be used throughout the Commonwealth of Virginia in wade-able intermittent or perennial streams.

Through this method, a Reach Condition Index (RCI) score is assigned to the stream to be impacted. RCI values range from 0.5 to 1.5 and result from a weighted average of Condition Indices (CIs) determined for four parameters assessed at the reach, including channel condition, riparian buffer, in-stream habitat, and channel alteration. Channel condition assesses the cross-section of the stream and the prevailing condition (erosion, aggradation) and is assessed on a 1 to 3 score with 1 being "Severe" and 3 being "Optimal" condition. The riparian buffer parameter assesses both banks' 100 foot riparian area, and ranks it on a 0.5 to 1.5 scale, with 0.5 being "Poor" and 1.5 being "Optimal." In-stream habitat is assessed including variation in substrate size, water velocity, and depths; presence of woody and leafy debris; substrate stability; amount of embeddedness; amount of shade; presence of undercut banks, rootmats, and submerged aquatic vegetation (SAV); presence of riffle-pool complexes; and stability of features. In-stream habitat is scored on a 0.5 to 1.5 scale, with 0.5 representing "Poor" in-stream habitat and 1.5 representing "Optimal" in-stream habitat. Finally, channel alteration is assessed, including channelization, dredging, hardening, or altering, and rated on a 0.5 to 1.5 scale, with 0.5 representing "Severe" alteration and 1.5 representing "Negligible" alteration. After determining the RCI score, the severity or type of impact is assessed based on four Impact Classification categories, each with a corresponding Impact Factor (IF). An activity considered to have a Severe impact has the highest IF of 1.0, representing an activity that is presumed to have acomplete or near-complete loss of all beneficial stream functions. Conversely, an activity considered to have Negligible impacts has an IF of 0. Multiplied together, the IF, the RCI, and the length of reach impacted give the Total Compensation Requirement. The type and amount of the various applicable compensation practices that could fulfill the compensation requirement is then determined. This method is appropriate for use in projects requiring stream compensation under USACE's regulatory program and DEQ's Virginia Water Protection Permit Program (VWPP). This method can be applied to stream compensation projects performed on-site, off-site, for a stream mitigation bank, or for an in-lieu fee fund project, thereby, ensuring a standard

application for evaluating and crediting all stream compensation projects. The following two examples illustrate the use of USM:

**Seven Hills Water Quality Monitoring** (Virginia Waters and Wetlands 2008a)

Stream monitoring was conducted along Piney Branch and Foley Branch in Loudoun County at the proposed Seven Hills site. Physical, chemical, and biological assessments were performed. The only existing disruption to the sites was the installation of sewer lines, including changes to the upland buffer conditions near the sites. Geomorphic analysis was conducted using the USM set forth by USACE and Virginia DEQ. Two Piney Branch sites and three Foley Branch sites were assessed in August 2007 as a baseline and again in April 2008. One site in Piney Branch was assessed only in April 2008. The average RCI for Piney Branch was 1.19 and for Foley Branch was 1.18. Variation in USM scores was most likely due to slight differences by observers and the actual site conditions at the time of assessment relative to the stage of construction of adjacent sewer lines. The Impact Factor at each of these sites was zero, thus the Compensation Requirement was also zero.

**Dawsons Corner Water Quality Monitoring** (Virginia Waters and Wetlands 2008b)

Stream monitoring was conducted along two unnamed tributaries to Bull Run in Loudoun County at the proposed Dawsons Corner site. Physical, chemical, and biological assessments were performed. Construction disturbance had yet to begin at these sites, with the majority of open space remaining in hay/pasture. Geomorphic analysis was conducted using the USM. Five sites along the two tributaries were assessed in August 2007 for a baseline and again in April 2008. The average RCI for the smaller tributary 1.19 and for the larger tributary was 1.25. Variation in USM scores was most likely due to slight differences by observers. The Impact Factor at each of these sites was zero, thus the Compensation Requirement was also zero.

The USM is intended as a tool for quantifying the amount of restoration to be required as mitigation for impacts incurred at a particular site. However, it is not a tool that lends itself to providing stream assessment, particularly over large areas, i.e., the watershed or county scale.

## 3.5 FISH SURVEYS AND IBI DEVELOPMENT

In the late 1990s, NRCS developed a fish Index of Biotic Integrity (IBI, Teels and Danielson 2001) based on fish surveys conducted in three Northern Virginia watersheds, including Goose Creek. During 2000-2003, NRCS applied this fish IBI by conducting fish surveys in these same watersheds, including Goose Creek in Loudoun County, to evaluate the benefit of riparian buffer restoration (Teels et al. 2005). Both of these surveys are summarized in Chapter 2 of this report. These surveys provided fish assessment data for selected sites in Loudoun County. Sites were targeted to stream locations where buffer restoration was

implemented. Baseline data were collected beginning in 2000 and data collection continued through 2003 as restoration was implemented.

The fish IBI was developed and rigorously tested by NRCS and is available as an assessment tool, should Loudoun County government or other groups be interested in future assessments based on fish assemblage characteristics. Reference sites for development of the NRCS fish IBI were located throughout the three watersheds assessed (Goose Creek, Occoquan, and Rappahannock). With this broad regional reference, the fish IBI would likely be applicable to other watersheds in Loudoun County, provided that the same field and data analysis protocols were employed.

## 3.6 LEESBURG USA AND USSR DATA SUMMARY

Information has been previously collected in the Leesburg area during field reconnaissance studies conducted to characterize environmental problems in streams. These "stream-walk" surveys were conducted using the Unified Stream Assessment (USA) and Unified Subwatershed and Site Reconnaissance (USSR) methods developed by the Center for Watershed Protection (CWP; Kitchell and Schueler 2004, Wright et al. 2004).

As recommended by the *Goose Creek Vulnerability Analysis* (CWP 2002; see summary in Chapter 2), a study was undertaken in 2006 to conduct watershed planning and assessments in the two primary subwatersheds contained within the Town of Leesburg limits. The final report, entitled *Summary of Findings from Tuscarora Creek Field Work and Baseline Assessment* (CWP 2007; see summary in Chapter 2), provides an overview of problems at specific locations, as well as recommendations for a variety of watershed improvements.

The area covered by the Tuscarora field work, separated into the Upper Tuscarora Direct Drainage (Upper DD) and Lower Tuscarora Direct Drainage (Lower DD), encompassed 10 square miles and 8 linear stream miles known as Tuscarora Creek, which empties into Goose Creek not far from its confluence with the Potomac River. Eighty-three percent of land in these subwatersheds lies within the Town of Leesburg's jurisdiction. Note that the Tuscarora headwaters were located outside of the study area.

### Unified Stream Assessment (USA)

CWP, The Piedmont Environmental Council (PEC), the Town of Leesburg and other project partners conducted a physical stream corridor assessment along 11 stream miles, 27 reaches, within the Tuscarora Upper DD and Lower DD subwatersheds during the week of August 7-9, 2006 using CWP's USA methodology. The USA is used to identify restoration and maintenance opportunities and impacts within the stream corridor. Findings were as follows:

> *An overall quantitative score for each reach was assigned based on average physical condition as measured by various in-stream and riparian parameters*

*(diversity of in-stream habitat, floodplain connectivity, vegetative buffer width, etc). These scores were used to classify stream reaches into condition categories ranging from excellent to very poor. The resulting reach scores for Tuscarora Creek ranged from good to very poor due to its suburban character. Reach categories are defined based on a reference condition, which is considered to be the least impaired, best attainable condition for a stream in a given region. For this assessment, the reference condition was limited to the least disturbed stream reach observed in the Tuscarora DD subwatersheds.* (CWP 2007)

Fourteen stream reaches were found to be in good to fair condition and the remaining 13 were found to be in poor to very poor condition. "Good reaches often had better quality riparian buffer and floodplain connectivity than streams scoring in the fair or poor range." The authors noted that these classifications were based on the limited sampling of impacted conditions in the Upper and Lower DD portions of Tuscarora Creek and were likely not comparable to conditions in other parts of the Goose Creek watershed. Recommendations at 100 sites surveyed included approaches such as infrastructure repair, discharge investigations, stream restoration, trash clean up, and buffer reforestation.

**Unified Subwatershed and Site Reconnaissance (USSR)**

The USSR provides a quick but thorough characterization ("windshield tour") of upland areas to identify major sources of pollutants and restoration opportunities for source controls, pervious area management, and improved municipal maintenance (i.e., education, retrofits, and referral for immediate enforcement). watershed groups, local government staff, and consultants

The Tuscarora Creek USSR focused on two assessment components. The Neighborhood Source Assessment (NSA) is an assessment of the age, lot size, tree cover, drainage, lawn size, general upkeep, evidence of resident stewardship and potential for restoration, while the Hotspot Site Investigation (HSI) assesses the potential for stormwater pollution from source areas.

Neighborhood Source Assessments yielded the following results:

*None of the neighborhoods in the study area met the definition of a high pollution generator; one was considered to have little to no pollution severity, and the rest were classified as moderate pollution generators. All but one site were identified as having moderate restoration potential. The top priorities for all of the neighborhoods include tree planting, landscaping with native vegetation, and downspout disconnection.* (CWP 2007)

Hotspot investigations at 20 locations yielded no confirmed hotspots, but six sites were cited as potential hotspots and two others had practices that represented a possible pollution source.

# 4 REVIEW OF BENTHIC PROTOCOLS, METRICS, AND INDICATORS

Various protocols, metrics, and biological indicators are used to assess biological condition based on benthic macroinvertebrate monitoring. In this section, we review and compare several different protocols and scoring approaches that are commonly used by monitoring groups in Loudoun County and nearby areas.

## EPA Rapid Bioassessment Protocols (RBP)

U.S. EPA's Rapid Bioassessment Protocols (RBP, Barbour et al. 1999) provide general guidance for all stages of stream bioassessment, from selection of field methods to data analysis and interpretation. Field methods include multihabitat sampling using 20 jabs (or kicks) with a D-frame dip net, applicable in a variety of stream types, along with other options such as kick seine for riffle/run cobble substrate. Using the RBP, a subsample (usually 100, 200, 300, or 500 organisms) is sorted in the laboratory and then identified to a specified taxonomic level. The RBP does not require a certain taxonomic level, but notes that genus/species level identification "provides more accurate information on ecological/ environmental relationships and sensitivity to impairment. Family level provides a higher degree of precision among samples and taxonomists, requires less expertise to perform, and accelerates assessment results."

The RBP offers guidance for benthic data analysis, including the multimetric approach implemented by most water resource agencies in the United States. The multimetric approach to analysis is based on a system developed originally by Karr (1981, 1991) for analysis of freshwater fish data, resulting in an index that rates biological condition. Karr's approach is known as the Index of Biotic Integrity (IBI) method. Using this approach, biological metrics that quantify attributes of the biological assemblage at a site are computed and compared with values that would be expected at a regional "reference" condition, representing streams that are only minimally impaired (degraded) by human activities. The RBP lists typical metrics used in benthic bioassessments, including the examples in Table 4-1.

Scores for individual metrics are combined into an overall indicator of biological conditions at a site. Indicator scores are used to assess biological condition, assign narrative ratings (good, fair, poor, etc.), and determine whether a site is considered biologically impaired. With EPA's RBP as guidance, specific details of metric scoring, index calculation, and rating scales are left to be determined by individual programs at the state or local level.

## Virginia Stream Condition Index (VSCI)

For non-coastal streams, Virginia DEQ uses the Virginia Stream Condition Index (VSCI), developed by Tetra Tech (2003) and further tested and validated by DEQ (2006). This approach represents a state-level application of EPA's RBP (Barbour et al. 1999). The VSCI is a multimetric indicator of biotic integrity that compares benthic communities to a reference

Table 4-1. Examples of metrics commonly employed in stream benthic macroinvertebrate assessments and their expected responses to degradation (adapted from Barbour et al. 1999).

| Category | Metric | Definition | Predicted Response to Increasing Degradation |
|---|---|---|---|
| **Richness measures** | Total No. taxa | Measures the overall variety of the macroinvertebrate assemblage | Decrease |
| | No. EPT taxa | Number of taxa in the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) | Decrease |
| | No. Ephemeroptera Taxa | Number of mayfly taxa (usually genus or species level) | Decrease |
| | No. Plecoptera Taxa | Number of stonefly taxa (usually genus or species level) | Decrease |
| | No. Trichoptera Taxa | Number of caddisfly taxa (usually genus or species level) | Decrease |
| **Composition measures** | % EPT | Percent of the composite of mayfly, stonefly, and caddisfly larvae | Decrease |
| | % Ephemeroptera | Percent of mayfly nymphs | Decrease |
| | % Chironomidae | Percent of midge larvae | Increase |
| **Tolerance/Intolerance measures** | No. of Intolerant Taxa | Taxa richness of those organisms considered to be sensitive to perturbation | Decrease |
| | Hilsenhoff Biotic Index | Uses tolerance values to weight abundance in an estimate of overall pollution. Originally designed to evaluate organic pollution | Increase |
| | % Tolerant Organisms | Percent of macrobenthos considered to be tolerant of various types of perturbation | Increase |
| | % Dominant Taxon | Measures the dominance of the single most abundant taxon. Can be calculated as dominant 2, 3, 4, or 5 taxa. | Increase |
| **Feeding measures** | % Filterers | Percent of the macrobenthos that filter fine particulate organic matter (FPOM) from either the water column or sediment | Variable |
| | Shredders | Percent of the macrobenthos that "shreds" leaf litter | Decrease |
| | % Grazers and Scrapers | Percent of the macrobenthos that scrape or graze upon periphyton | Decrease |
| **Habit measures** | Number of Clinger Taxa | Number of taxa of insects | Decrease |
| | % Clingers | Percent of insects having fixed retreats or adaptations for attachment to surfaces in flowing water. | Decrease |

condition for the non-coastal streams of Virginia. The VSCI was developed using historical data collected in Virginia at reference and stressed streams in 1994-1998, and was tested against additional data collected in 1999-2002, and validated with probability-based data. The VSCI sample index period for spring sampling is March 1 through May 31.

Samples are collected in the field using a D-net and making 20 jabs or kicks in productive habitat. Samples are taken to the lab for subsampling (approximately 100-organism subsamples) and identification to the family taxonomic level. Calculation of the VSCI score is based on eight standard metrics:

- Total Taxa
- EPT Taxa
- % Ephemeroptera
- % Plecoptera + Trichoptera less Hydropsychidae
- % Scrapers
- % Chironomidae
- % Top 2 Dominant Taxa
- HBI (family)

Scores for each metric are calculated by comparing a site score to the range of scores from all sites. Metric scores are combined to calculate the multimetric VSCI, with a maximum possible score of 100. The VSCI score is compared with that expected under reference condition, which is used to set thresholds. Scores are used to rate a monitored site in one of four categories (DEQ 2008):

| Assessment Category | Score Range |
|---|---|
| Excellent | $\geq 73$ |
| Good | 60-72 |
| Stress | 59-43 |
| Severe Stress | $\leq 42$ |

**Virginia Save-Our-Streams (VA SOS)**

The Virginia Save-Our-Streams (SOS) program, administered by the Izaak Walton League of America, developed a method for assessing the health of streams by monitoring macroinvertebrates. This method was developed to involve citizen volunteers in water quality monitoring and to supplement monitoring data collected by Virginia DEQ. The SOS method is similar in its general design to methods used by professionals, but is tailored to the capabilities of non-professionals. The program provides training and certification for volunteers. Methods are documented on the VA SOS web site (http://www.vasos.org), including standard operating procedures, macroinvertebrate identification sheets, and field data sheets.

In Loudoun County, the VA SOS Modified, Rocky Bottom Method is used (http://www.vasos.org/pages/method.htm). Kick-net samples are taken in one square meter of riffle substrate, and macroinvertebrates from each individual sample are removed from the sampling net and sorted by taxa into separate containers. At least 200 organisms from each riffle sampled are identified in the field to the taxonomic level of order or in a few cases to family, and the number of organisms in each taxonomic group is recorded. The SOS water quality rating score, a simple biotic index based on the percentage of organisms in various groups, is calculated using data from each macroinvertebrate sample. The following metrics are used for

- % Mayflies + Stoneflies + Most Caddisflies
- % Common Netspinners
- % Lunged Snails
- % Beetles
- % Tolerant
- % Non-Insects

Each metric is assigned a score of 2, 1, or 0, depending upon its range. The total number of 2, 1, and 0 scores are used to compute an overall Virginia Save Our Streams Multimetric Index score. Scores are assigned the following ratings:

| Rating | Score Range |
|---|---|
| Acceptable ecological condition | 9 - 12 |
| Ecological conditions cannot be determined at this time (Gray Zone) | 8 |
| Unacceptable ecological condition | 0 - 7 |

**INSTAR modified Index of Biotic Integrity (mIBI) and Virtual Stream Assessment (VSA)**

VCU's INSTAR program also uses EPA RBP methods. Macroinvertebrates are collected using D-frame dip nets (20 jabs). Samples are processed in the laboratory where 200-organism subsamples are identified to the lowest possible taxon (typically genus) and enumerated. Over 50 separate ecological metrics including benthic, fish, habitat, geomorphic and landscape indicators are computed and have been used to develop the modified Index of Biotic Integrity (mIBI) and regional Virtual Stream Assessment (VSA) models. Benthic macroinvertebrate metrics include those typically generated for RBP assessments. INSTAR evaluates ecological condition by comparing stream data to an appropriate reference model by river basin and stream order. Field and analytical methods are described on the INSTAR web site (http://instar.vcu.edu/).

**EPA Wadeable Stream Assessment (WSA)**

Developed by EPA's Environmental Monitoring and Assessment Program (EMAP), the Wadeable Streams Assessment (WSA) was the first statistically valid, probability-based national survey of the biological condition of small streams (http://www.epa.gov/owow/streamsurvey/index.html). EPA coordinated the program through two offices, its Office of Water and Office of

Research and Development, and worked with state agencies to conduct the assessment in 2004-2005.

WSA employed EPA RBP field and laboratory methods. Macroinvertebrates were collected using D-frame dip nets, taking 11 jabs at designated transects (USEPA 2004a). Samples were processed in the laboratory where 500-organism subsamples were identified to the lowest possible taxon (usually genus, but some groups to family) and enumerated (USEPA 2004b).

The specific metrics chosen for benthic assessment varied among the nine ecoregions used in the analysis (USEPA 2006). The Piedmont area of the mid-Atlantic, including Loudoun County, fell within the Southern Appalachian region. A reference condition, based on the "least-disturbed" sites available, was established for each region. Metrics were scored in comparison with the reference condition and then combined to create an overall Macroinvertebrate Index for each region, with values ranging from 0 to 100.

**Loudoun Watershed Watch (LWW) / Audubon Naturalist Society (ANS) RBP**

Loudoun Watershed Watch (LWW) members (including LWC, LSWCD, North Fork Goose Creek Committee (NFGC), and others) have employed the stream sampling method of the Audubon Naturalist Society (ANS) which is based on EPA's RBP. The program provides training and certification for volunteers. LWW methods are documented in its sampling manual (Loudoun Watershed Watch and Audubon Naturalist Society 2005), which includes protocols and field data sheets (http://www.loudounwatershedwatch.org/pdf/Stream_Monitoring_Operations_Manual.pdf)

Macroinvertebrates are monitored using a D-net sampling to collect 200-organism samples. Organisms are identified in the field and the number of organisms in each taxonomic group is recorded. Insects are identified to family and the non-insects to order. Metrics include several of the EPA RBP metrics:

- Number of Taxa
- Number of EPT Taxa
- % Dominant Taxon
- Modified Hilsenhoff Index

| Rating | Score Range |
|---|---|
| Good | > 16 |
| Fair | 8-16 |
| Poor | < 8 |

LWW also calculates the VA SOS Multimetric Index, using the six metrics listed under SOS above. In 2008, LWC switched to using VA SOS sampling methods for all of its volunteer monitoring.

**Rapid Stream Assessment Technique (RSAT)**

The Rapid Stream Assessment Technique (RSAT) sampling protocol for benthic macroinvertebrates (Galli 1996) involves turning over 10 cobble-size stones and taking at least three dip net or D-net samples. Macroinvertebrates are identified in the field to order. The presence of each of the various taxa is recorded. Notes are taken on the relative abundance of groups according to the following categories: absent/not found, scarce, scarce/common, common/abundant, and abundant. A biological indicator score is given based on observations of the diversity and abundance of various taxa, with scoring corresponding to narrative descriptions of the macroinvertebrate community in four categories, as follows: 7-8 Excellent, 5-6 Good, 3-4 Fair, and 0-2 Poor. This biological indicator score is combined with other recorded observations of channel stability, scouring and sediment deposition, instream habitat, water quality, and riparian condition to yield a total RSAT Score:

| Rating | Score Range |
|---|---|
| Excellent | 42-50 |
| Good | 30-41 |
| Fair | 16-30 |
| Poor | < 16 |

**Comparison of Methods and Indicators**

All of the benthic assessment approaches outlined above were developed for the purpose of assessing stream biological conditions. In fact, the EPA RBP serves as a common foundation upon which many of the other assessment protocols were built. Each has been implemented effectively by individual programs to provide valuable information about the range of stream conditions observed and the degree of suspected degradation.

These approaches vary in their ease of application. The VA SOS, RSAT, and ANS RBP protocols all provide for rapid, field-based assessment that can be readily conducted by trained volunteers. Teams carry out field identification of organisms to family or order level, as well as a straightforward calculation of scores that rate stream condition. In contrast, VSCI, INSTAR, and EPA WSA use similar field methods, but are conducted by professional biologists and rely on laboratory identification of macroinvertebrates to genus level. Indicators and models used in these programs are typically more complex, require more time for data management, and are conducted within a broader regional context for analysis.

The methods also vary in specific differences regarding field and laboratory methods. Differences in sampling gear, sample size (number of organisms), taxonomic level of

identification, and other methodological differences mean that data collected using one method cannot be readily interpreted using an indicator developed by a different monitoring program.

Use of reference-based standards is one substantial difference among the protocols reviewed. VSCI, INSTAR, and EPA WSA have each developed a regional reference that serves to set expectations. The individual metrics describe attributes of the benthic community that would be expected under reference condition, i.e., in streams minimally impaired or least disturbed by human activities. This reference standard is quantified in the specific thresholds used for scoring the metrics and the overall indicator. No comparison has been done among the reference conditions established by these different groups. Therefore it is not possible to make a direct translation between scores derived by these different programs.

With the other biomonitoring protocols commonly used for rapid stream assessment (VA SOS, RSAT, and ANS RBP), benthic community data are not scored in comparison with a regional reference. However, these indicators still provide a good relative rating of biological condition that can be tracked over time and compared among locations surveyed. For example, volunteer data indicating that a particular tributary is consistently in Poor condition, or has changed from Acceptable to Unacceptable ecological condition over time, are strong evidence for stream degradation.

A recent study (Southerland et al. 2005) evaluating the potential for integrating stream assessment results from three states—Virginia, West Virginia, and Maryland—derived the following conclusions related to integrated assessments:

- Consistency of survey design, sample frame and map scales used by different programs are important;
- Results from different biological sampling procedures can be integrated if reference-based indicators are used to summarize the results; and
- Ratings of stream condition will depend on how indicators are linked to reference condition, so a common reference condition ("yardstick") must be used to set thresholds of degradation.

Southerland et al. (2005) found VSCI scores fairly comparable with West Virginia's benthic stream ratings, even though the two state programs used slightly different approaches to define reference condition, similar (although not identical) metrics, and slightly different field methods.

In a study comparing EPA's WSA with several state indicators, including the VSCI, Southerland et al. (2006) found that the regression relationship of WSA benthic condition indicators on state biological indicators all had relatively poor fits. The adjusted R2 value for the relationship between WSA's indicator and VSCI was 0.33. These data indicate that raw indicator scores were not comparable among programs. This is not unexpected because the programs sample the benthic macroinvertebrate community differently and have developed their indicators differently. In addition, the VSCI and other state indicators were developed on a finer

scale (i.e., based on more regions) than were the WSA indicators. Also, agreement between WSA and State assessments was relatively poor at the level of three condition classes (Poor, Fair, and Good). However, overall comparability between WSA and state assessments was good at the level of two condition classes (i.e., "passing" or "failing" the threshold of degradation). This suggests that results from WSA and state surveys would yield comparable results for characterizing the extent of stream miles designated as impaired. Results also imply that VSCI provides a more appropriate tool for local assessments within Virginia than the WSA indicator, which was developed over the larger Southern Appalachian ecoregion and could be less accurate in characterizing local conditions.

Two recent studies have compared volunteer and professional assessment methods. In a comparison study conducted by Virginia Tech (Engel 2001), sites were sampled using professional methods concurrently with volunteers who utilized the SOS protocol. The data were statistically analyzed to determine whether the results of volunteers and professional aquatic biologists were correlated and if they arrived at the same conclusions about ecological condition. It was determined that the Virginia SOS method consistently overrated ecological condition. In a study conducted by Cacapon Institute (Navis and Gillies 2001), stream assessment results using SOS protocols were compared to results of RBP stream assessment as used by West Virginia's Department of Environmental Protection. This study found that SOS results did not provide stream assessment data comparable to professional RBP results because they lack abundance data and thereby omit critical information. In addition, the Cacapon Institute study found that the SOS method of field-picking live organisms tends to disproportionately miss some small organisms in specific groups, like midges and blackflies, when compared to picking preserved samples in the lab. As in the Virginia Tech study, SOS scores tended to overrate sites that the RBP stream score found to be impaired.

Loudoun County's Comprehensive Watershed Management Plan (CH2MHill 2008) made recommendations concerning the future use of benthic macroinvertebrate assessments of stream condition. In particular, the CWMP promoted the use of reference conditions and multiple metrics to evaluate macroinvertebrate data. Virginia DEQ's VSCI appears to be the most appropriate, reference-based, regionally valid benthic indicator for use in the Loudoun County Stream Assessment. Use of the VSCI will be consistent with DEQ's ongoing monitoring of stream conditions in Loudoun County.

# 5 INTEGRATED ASSESSMENT

The available biological, habitat, and reconnaissance data for Loudoun County streams do not provide a sufficient basis for conducting a comprehensive, integrated assessment. Each of the individual studies summarized in this report (Chapters 2 and 3) contributes valuable information for its intended purpose. However, differences in study design, stream monitoring and assessment methods, and geographic and temporal coverage of the data all preclude a simple, straightforward integration of these diverse data sets. Below, we discuss these differences, as well as present some general patterns in stream conditions that are evident in available data collected by the various stream monitoring groups.

**Study design.** Study design and site selection approaches used by the various monitoring groups have differed greatly. Many of the sites were targeted to particular locations of interest, fulfilling local interest and providing important information about suspected problem areas or about high quality streams. Targeted sampling is very efficient in sampling sites with a desired characteristic (e.g., pollution or degradation "hotspots") because prior knowledge of the study area is applied when selecting sites. However, because site locations are specifically targeted, it is not possible to make unbiased inferences about overall watershed conditions from these assessments.

The alternative is a probability-based study design, which involves random sampling. In probability-based sampling, each member of the population from which the sample is to be selected has a known probability of selection. When a probability-based design is used, statistical inferences may be made about the entire population from the data obtained from the sampling units. For example, by using a probabilistic design, inferences can be drawn about the entire population of streams in a county or within a particular watershed, even though not every single "piece" of the stream network is sampled. The ability to calculate uncertainty associated with estimates (to quantify the precision of results) is another advantage. Virginia DEQ selects some sites for its statewide survey through a probability-based approach, as does VCU's INSTAR.

**Stream Monitoring and Assessment Methods.** The use of different methods and biological indicators preclude simply combining data collected by different organizations into a single, integrated picture of conditions. Field, laboratory, and data analysis protocols vary substantially among the different monitoring programs in Loudoun County, as discussed in Chapter 4.

**Geographic and Temporal Coverage.** As might be expected, past studies in Loudoun County offer a great deal of information available for certain areas, but their coverage is not consistent across the county. Nor have data been collected over a consistent timeframe. Noteworthy patterns include the following:

- Data from various programs tend to cluster in areas of interest, in line with the interest of the participants. For example, Loudoun Watershed Watch sites are found

in the northern and central part of the county. Goose Creek Association has a few sites in Loudoun County, but an even greater number in Fauquier County.

- In particular, there have been a number of data collection efforts in Goose Creek and its tributaries, with results reflecting a broad range of conditions. Goose Creek has been noted both for the presence of rare taxa (noted by Palmer in the 1990s) and for benthic impairments (as listed by Virginia DEQ).
- Fish data are available only for Goose Creek and its tributaries, through studies conducted by the NRCS.
- Broad Run shows signs of degradation that are likely associated with urban land uses.
- VCU's INSTAR provides good distribution of sites throughout the county.
- Virginia DEQ has sampled a variety of sites across the county, but the number and locations of sites has varied from year to year.
- In general, there has been variable coverage from year to year, with sampling efforts that are not consistent over time. This has been true both for DEQ sampling and for monitoring by volunteer groups.
- In addition, some studies such as the Goose Creek Source Water Assessment and RSAT studies were conducted as one-time efforts in particular watersheds.
- At sites where data have been collected over multiple years, the only general trends observed have been of similar or declining condition, not improvement.

# 6 CONCLUSIONS AND RECOMMENDATIONS

Although there have been a number of previous stream monitoring efforts in Loudoun County, they do not yet provide a consistent, countywide assessment of stream benthic and habitat conditions. The individual studies conducted by state, university, local, and citizen groups are each valuable for their own purposes, particularly when targeted to particular areas. However, they do not yield a consistent picture that can be used to assess conditions countywide or within all county watersheds.

Through two recent efforts, Loudoun County has identified a need for stream assessment data to support its watershed management efforts. In 2006, Loudoun County convened the Strategy for Watershed Management Solutions (SWMS) project, a collaboration consisting of 69 representatives from 41 different development, agriculture, conservation, county, state, federal, and citizen groups. The SWMS Team recommended probability-based sampling to provide a statistically valid characterization of watershed conditions, as well as targeted monitoring to evaluate trends. The community-based Loudoun Watershed Management Stakeholder Steering Committee was formed as a result of the SWMS.

The Strategy was followed by development of the Comprehensive Watershed Management Plan (CWMP, CH2MHill 2008), prepared for the Department of Building and Development and funded in part by an EPA grant. The CWMP, completed in September 2008, reviewed water quality data but did not provide an analysis of biological assessment data. One recommendation of the CWMP was to conduct stream assessments countywide, including benthic macroinvertebrate monitoring to characterize watershed conditions. Also recommended was a need for additional habitat assessment data to support habitat restoration efforts. The CWMP noted that stream assessment data would help to identify problems of stream degradation and potential solutions.

Based on our review of past studies and an evaluation of the county's goals for its planned stream assessment, we have made the following recommendations, which served as the basis for development of the Strategic Plan and Protocols for the Loudoun County Stream Assessment (Roth et al. 2009).

For the Loudoun County Stream Assessment, we recommend use of a benthic and habitat assessment method that is consistent with that employed by Virginia DEQ. The VSCI approach to benthic macroinvertebrate sampling and data analysis provide a validated, reference-based indicator developed using EPA's RBP guidance. VSCI is already scaled to a regional reference condition, developed from statewide data for streams in the same geographic setting, which provides an appropriate assessment context for data interpretation. VSCI data collected by Loudoun County will be directly comparable to those of DEQ, an important consideration particularly for streams currently listed as impaired or which may be listed based on future results.

Loudoun County is implementing a probability-based sampling design in its 2009 Stream Assessment, to provide an unbiased, consistent characterization of benthic macroinvertebrate and habitat conditions in streams throughout the county. Stratification of sites by watershed will also allow for assessment and comparison of results on a watershed basis. The probability-based study design enables calculation of unbiased estimates such as mean values, or percentage of stream miles exceeding particular threshold values, with quantifiable confidence. Sampling is to be conducted with sufficient number of sites to characterize all watersheds adequately. Within the total number of sites available for the survey, distribution of sites among watersheds will provide information about each watershed. Additional or backup sites are provided to ensure that a minimum number of sites are sampled, even if landowner permission or other constraints do not allow sampling of some selected sites.

Loudoun County is also targeting a set of sites to locations previously sampled by Virginia DEQ, to provide additional trend data for these sites. Because some of the sites are also being sampled by DEQ in 2009, these sites will also provide a cross-check between the County and state monitoring programs.

The stream assessment will also implement a strategy of systematic sampling to assess physical habitat condition. Sites will be placed along each stream reach, along mainstems between confluences and on tributary streams, in order to provide broad coverage for the stream habitat assessment data collected. Along with the habitat assessments completed at benthic monitoring sites, this approach will provide good coverage countywide, filling in gaps that might otherwise not be sampled by probability-based sampling alone.

For both benthic and habitat assessment, the stream network provided by the National Hydrography Dataset (NHD) is an appropriate sampling frame. The county's survey will be based on the NHD Medium Resolution data, sampling NHD-designated perennial streams for benthic monitoring and perennial plus intermittent streams for additional habitat assessment.

Completion of the Loudoun County Stream Assessment in 2009 will provide for a comprehensive evaluation of streams throughout the county. Employing the same benthic assessment methods used by Virginia DEQ will allow Loudoun County to make use of the reference-based VSCI and will provide comparability with state data. Use of a probability based survey design for stream benthic and habitat monitoring will offer a powerful, unbiased analytical tool for assessing stream conditions. Additional data are to be collected at targeted sites, the same locations assessed by DEQ. Finally, an extensive, systematic sampling of stream habitat will help fill in the gaps and "complete the picture" of stream conditions throughout the stream network. Countywide and watershed-specific results will be useful to the county's watershed management efforts.

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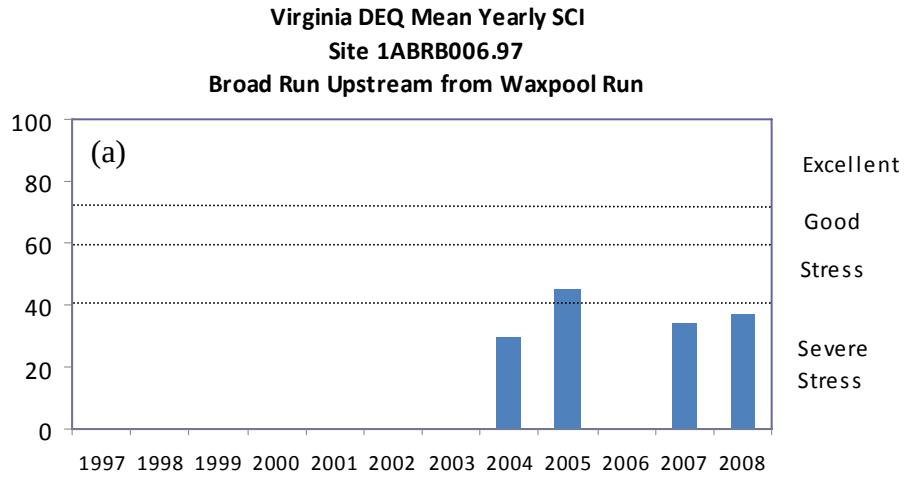
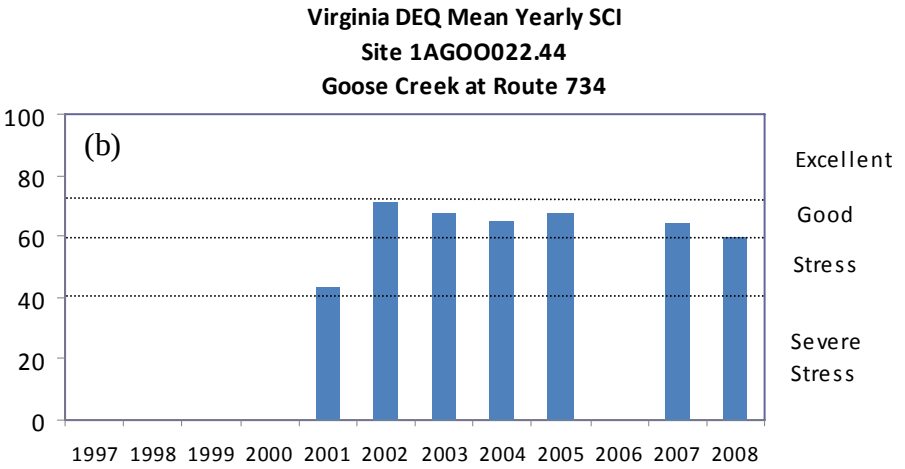
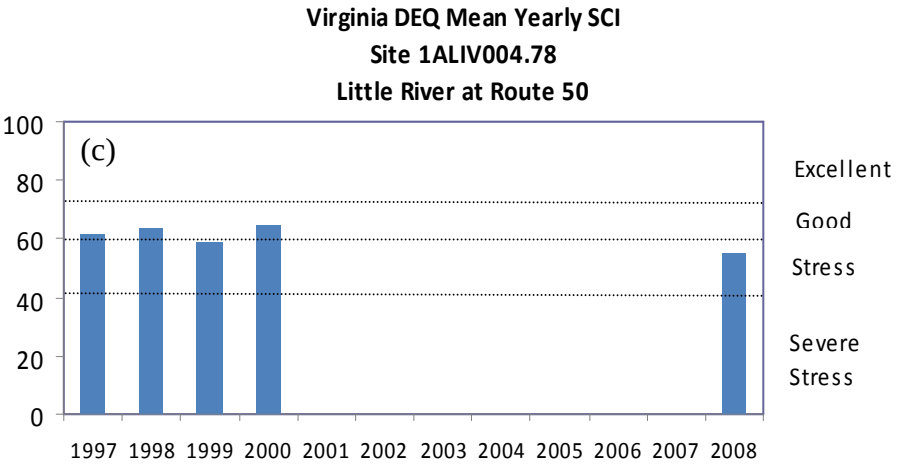
# APPENDIX

# YEAR TO YEAR COMPARISON GRAPHS

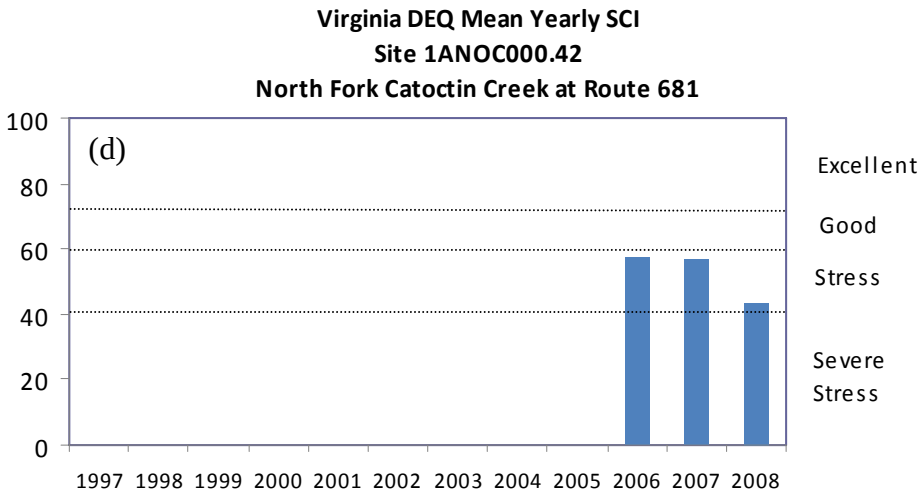

Appendix 2

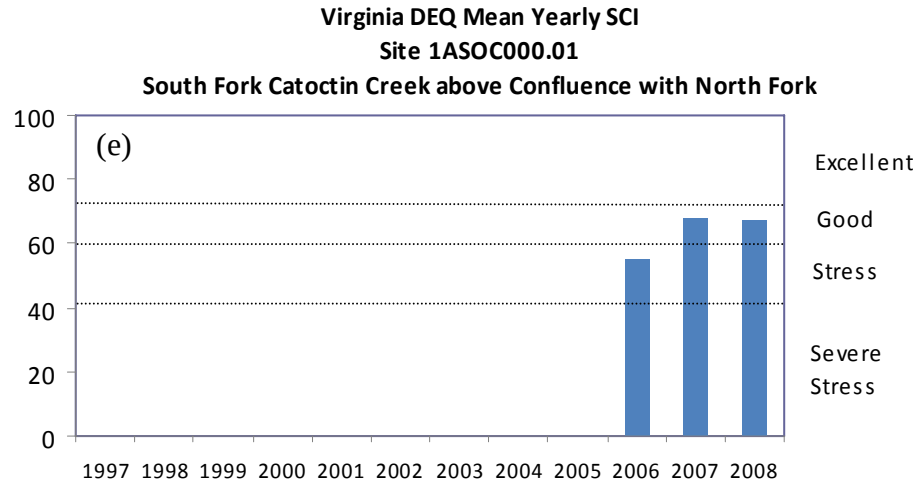


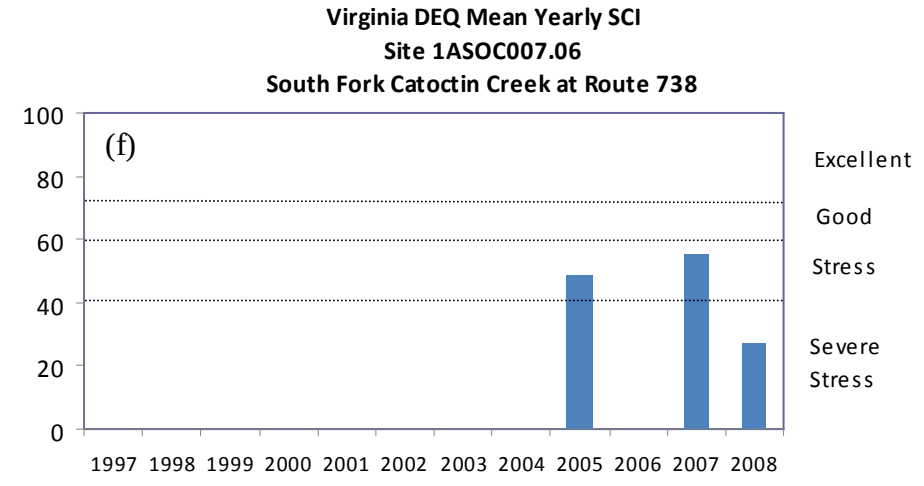




Appendix Figure 1 (a-h). Virginia DEQ benthic SCI scores, by yearly average, for selected sites

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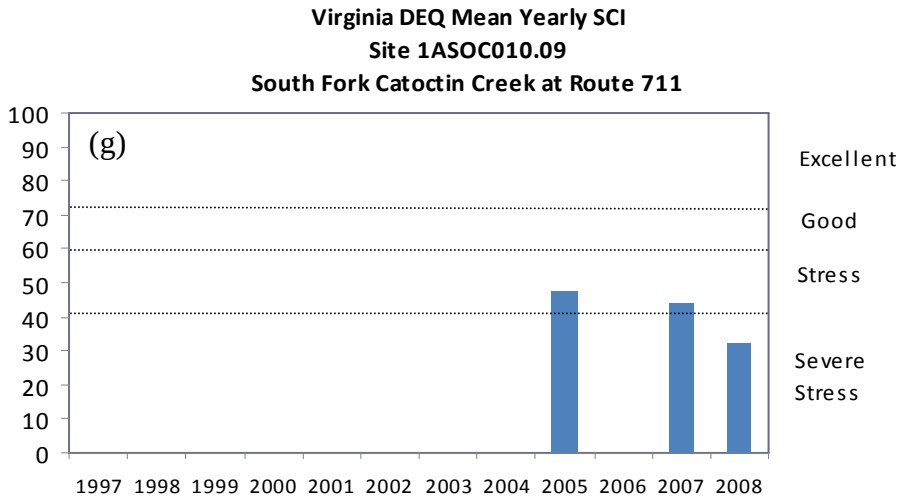


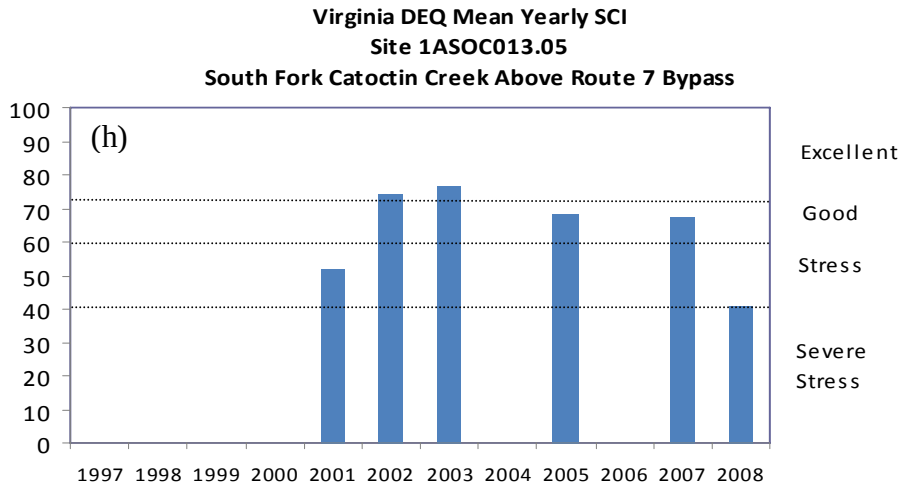


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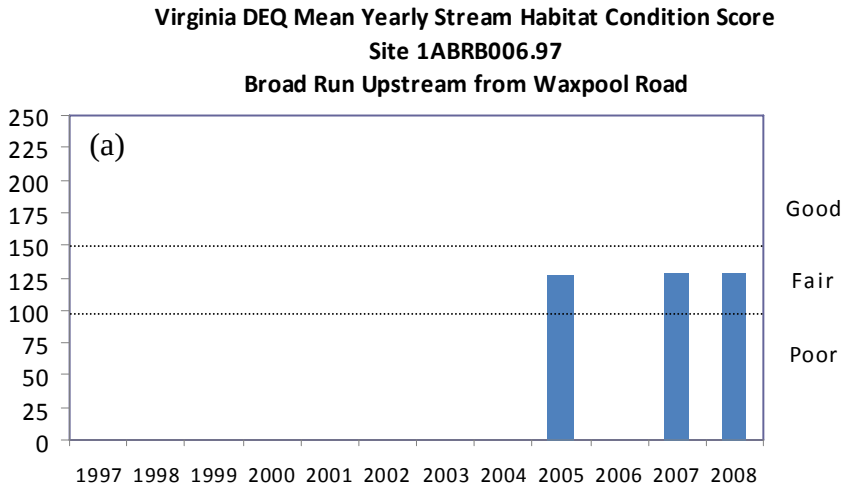
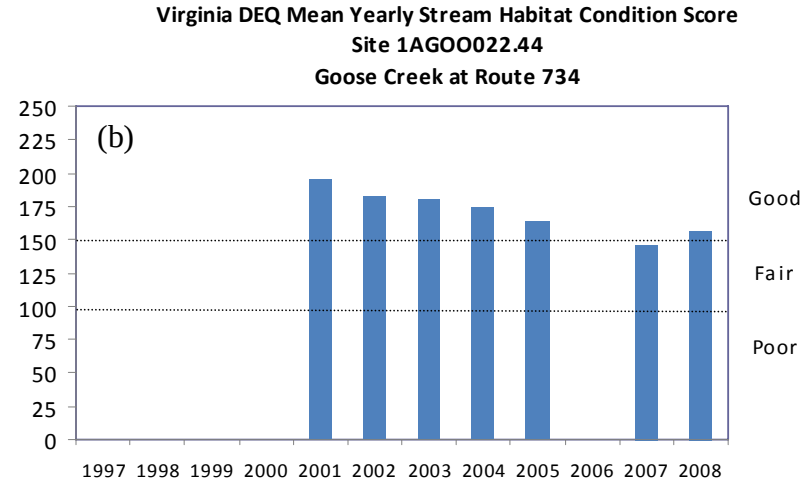
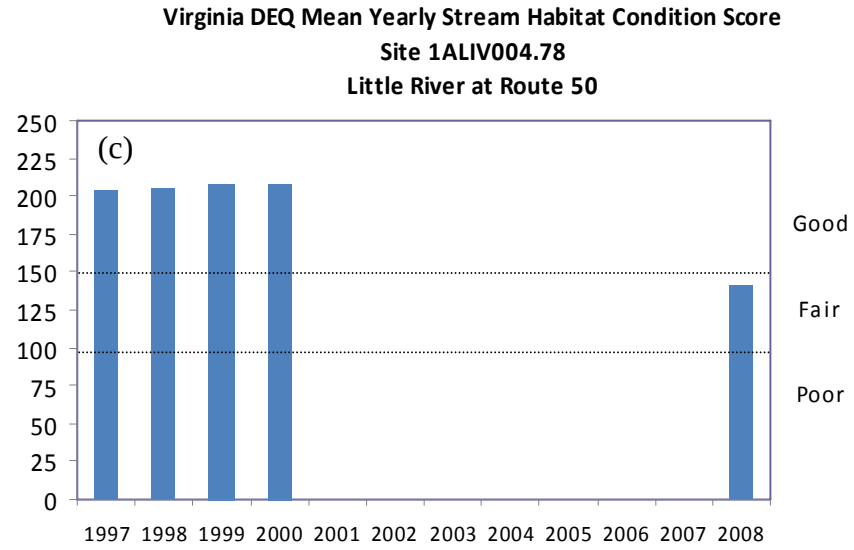
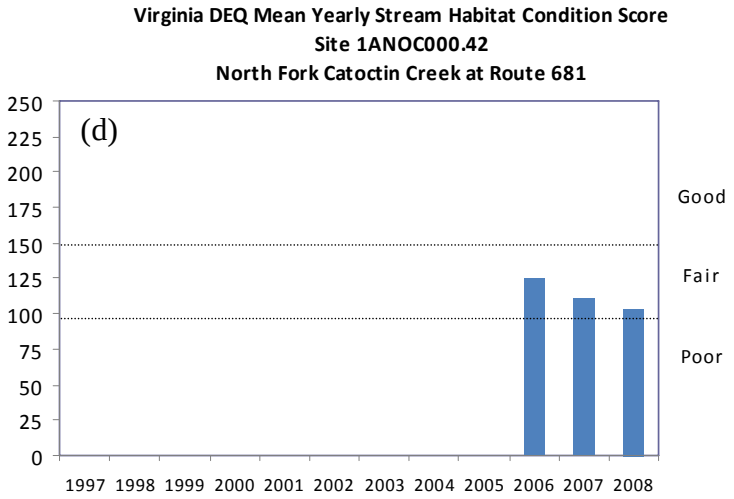
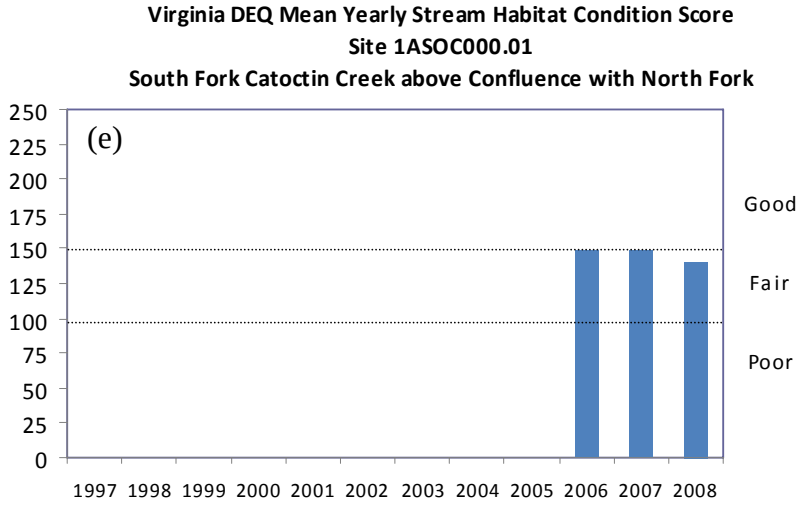


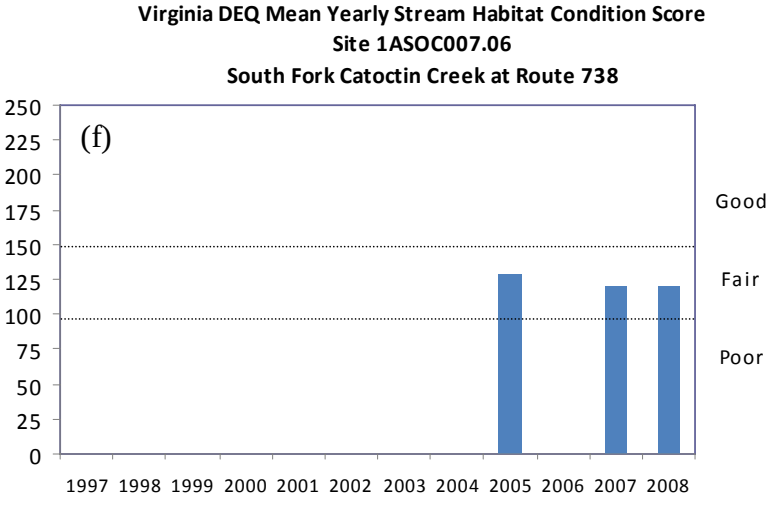




Appendix Figure 2 (a-k). Virginia habitat scores by yearly average, for selected sites.

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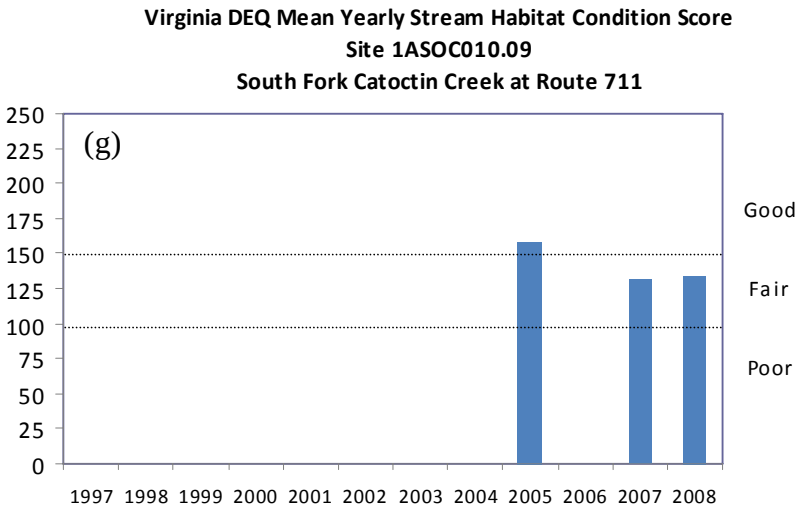


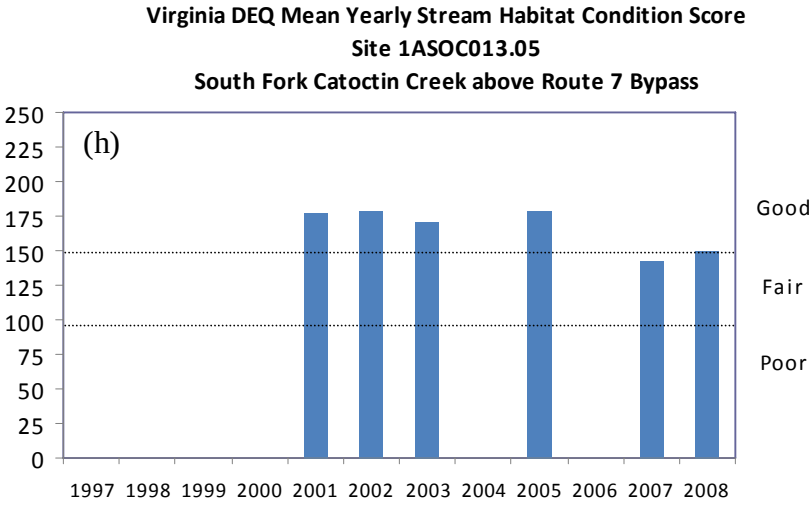


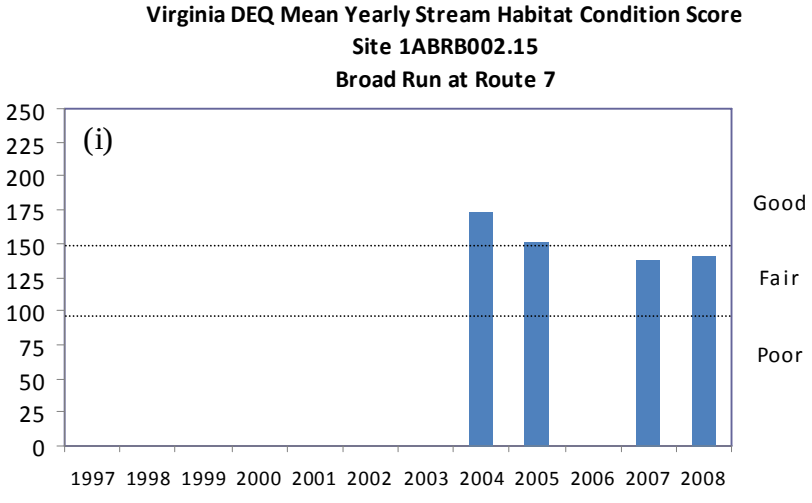


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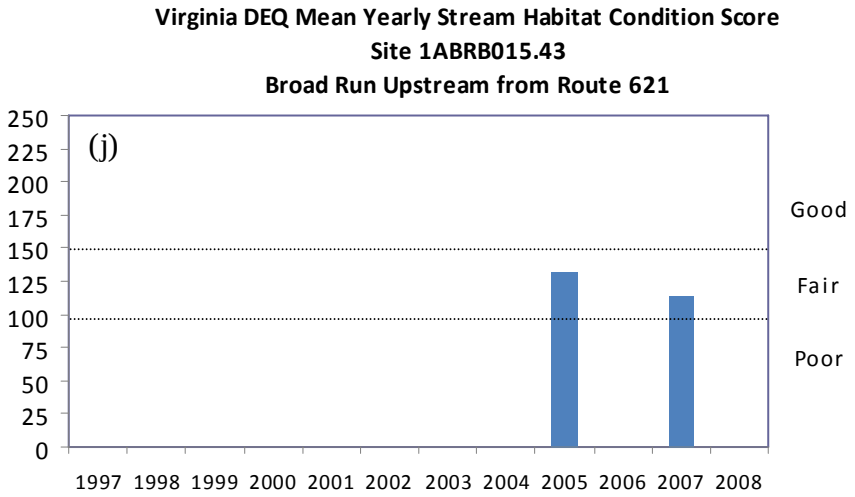


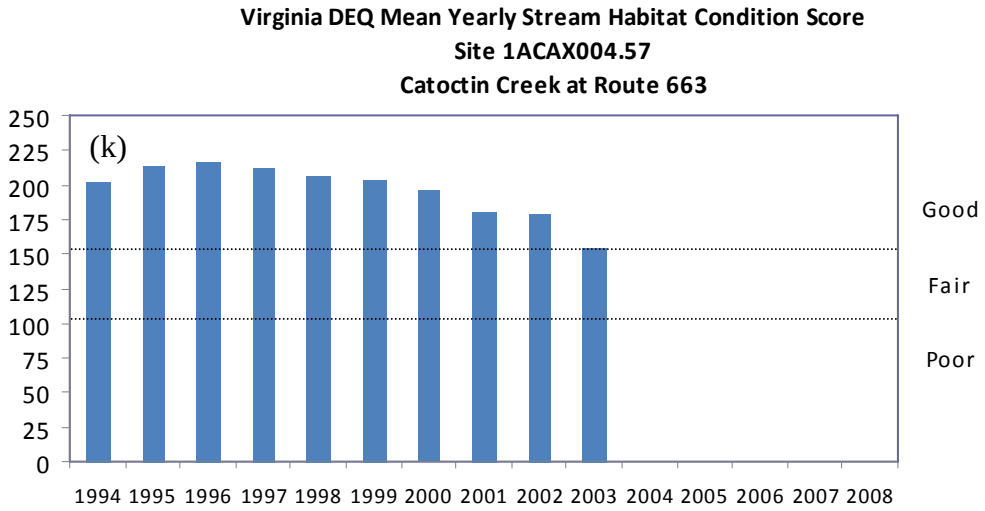


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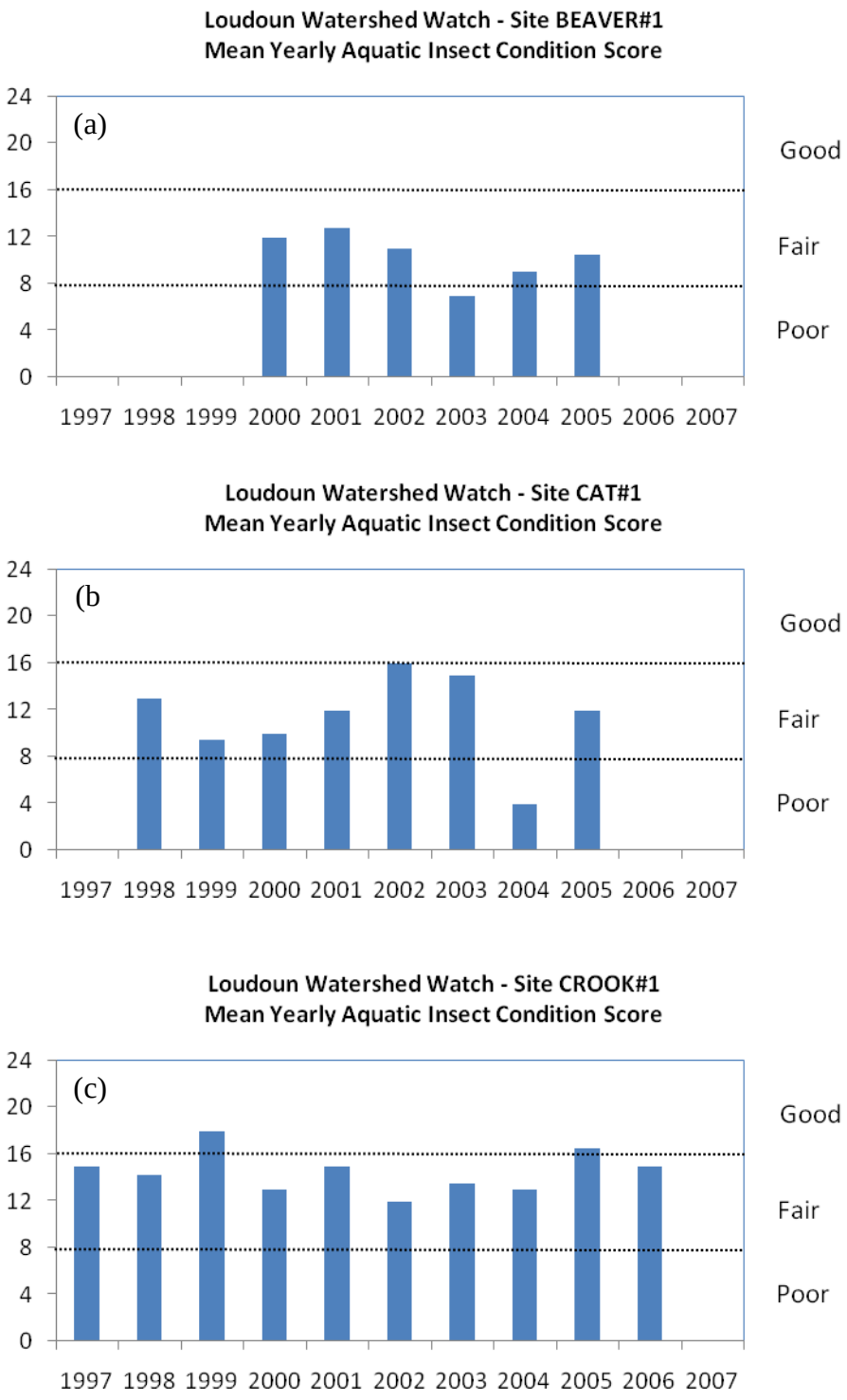
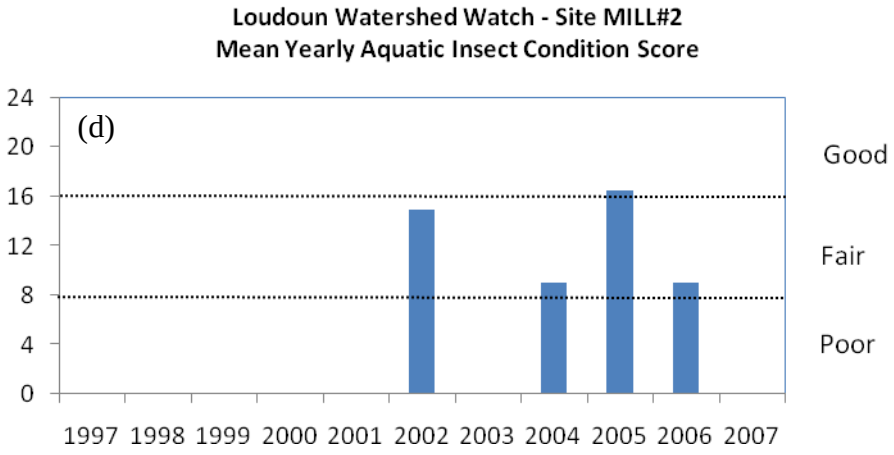
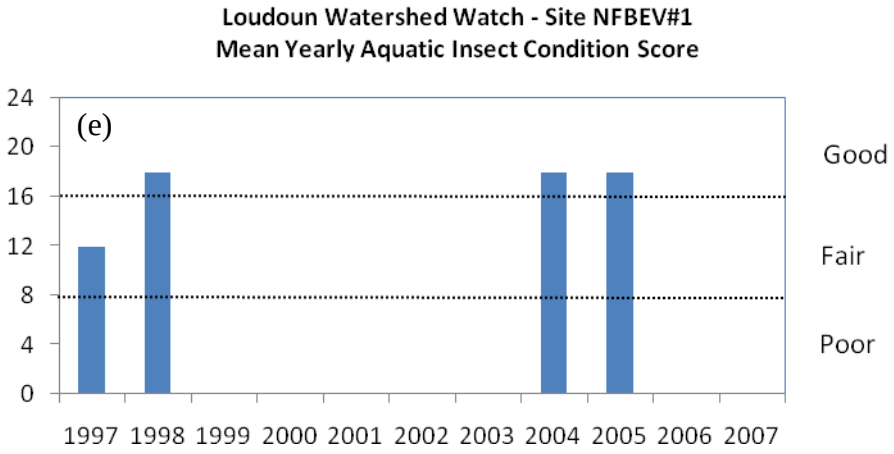
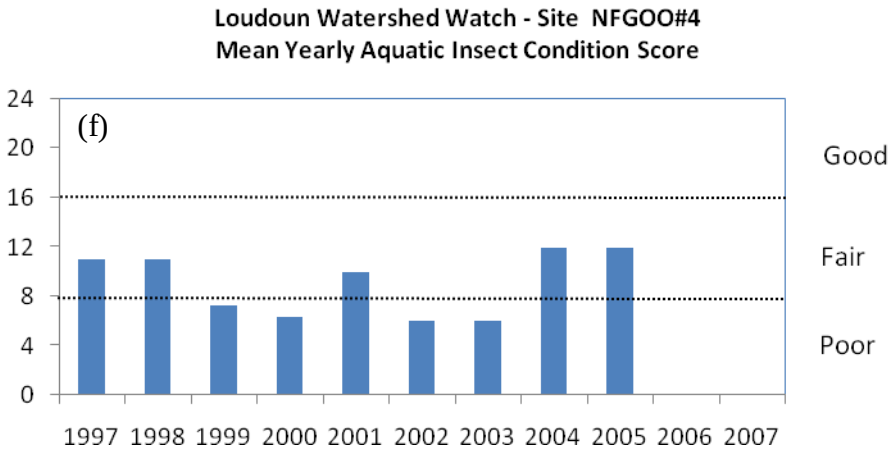



Appendix Figure 3 (a-m). Loudoun Watershed Watch aquatic insect condition scores, by yearly average, for selected sites

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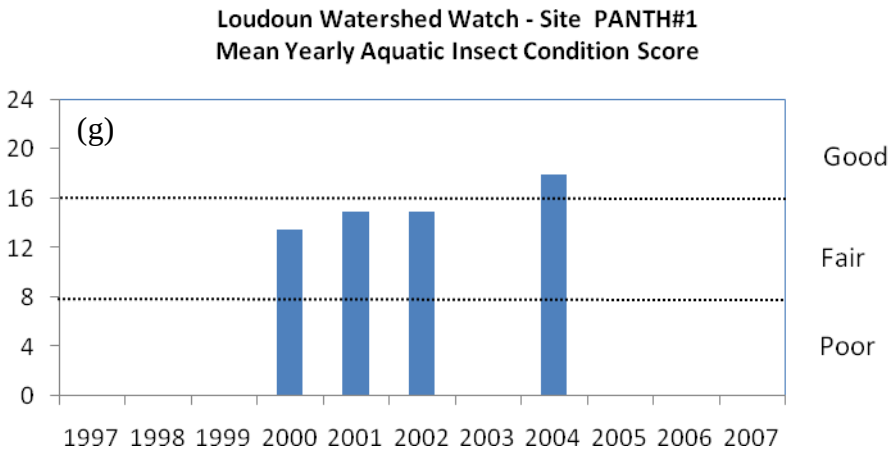


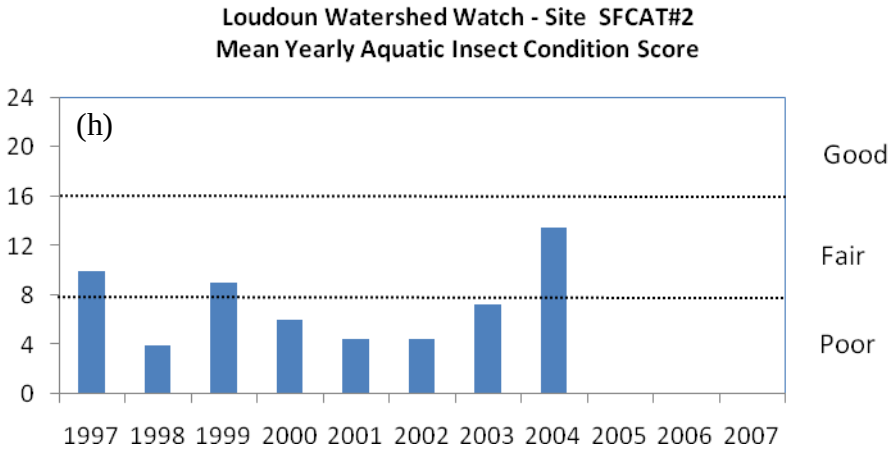


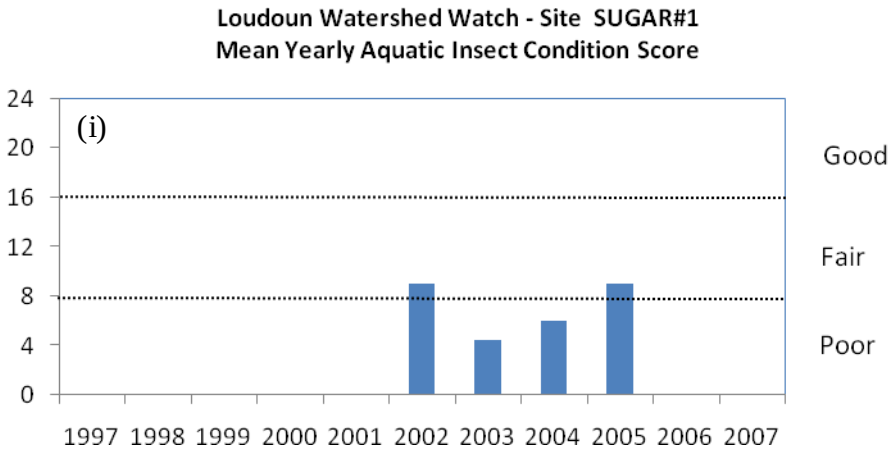


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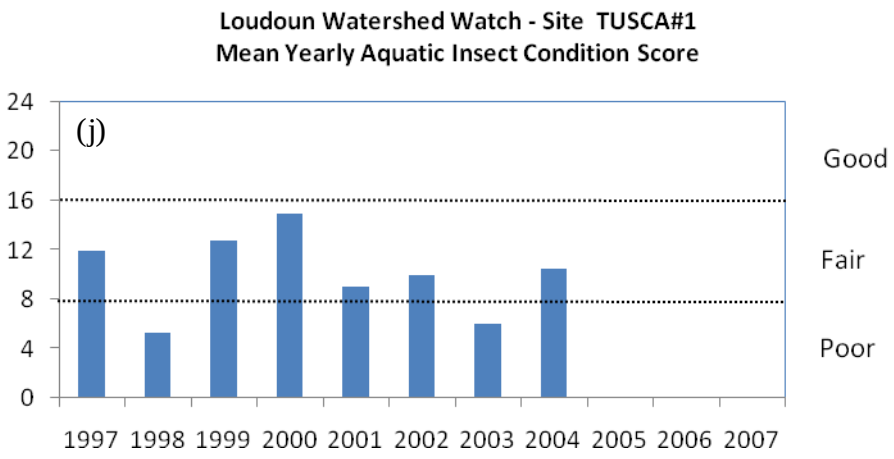


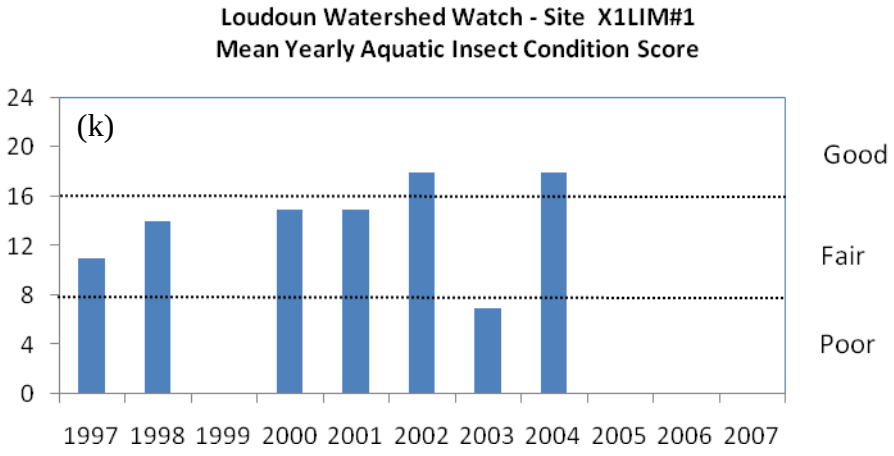


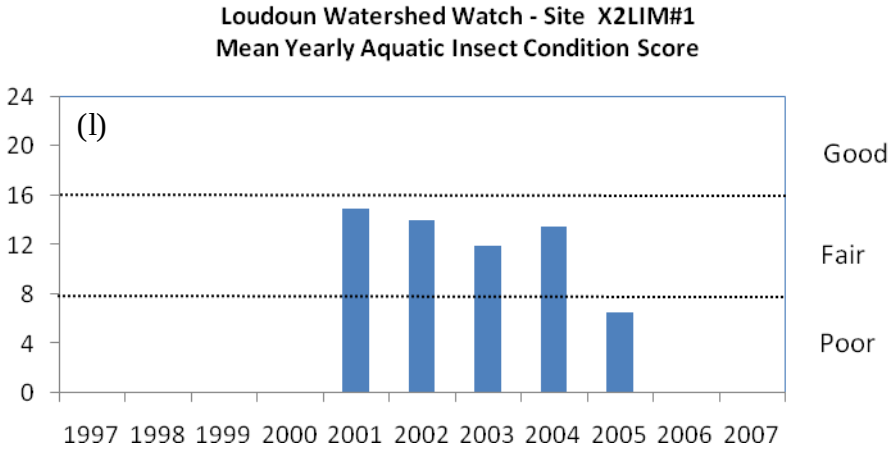


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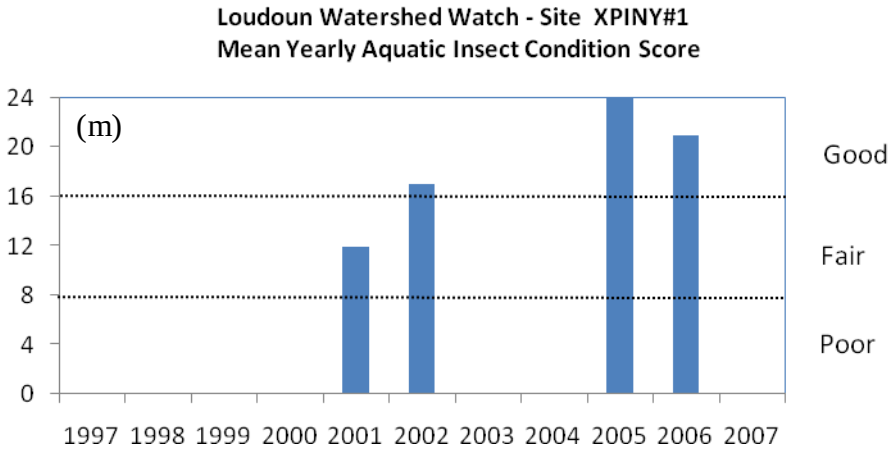


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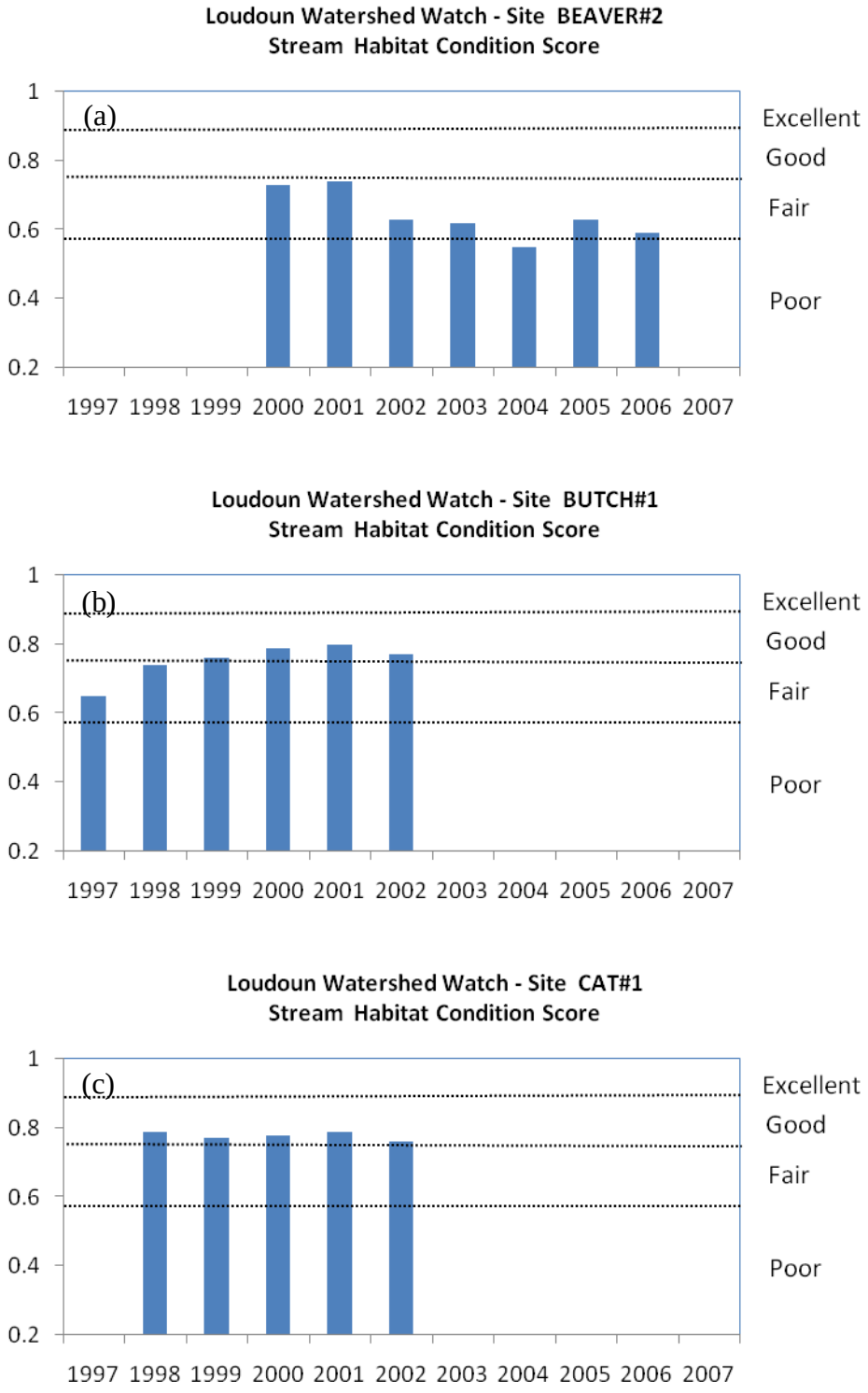
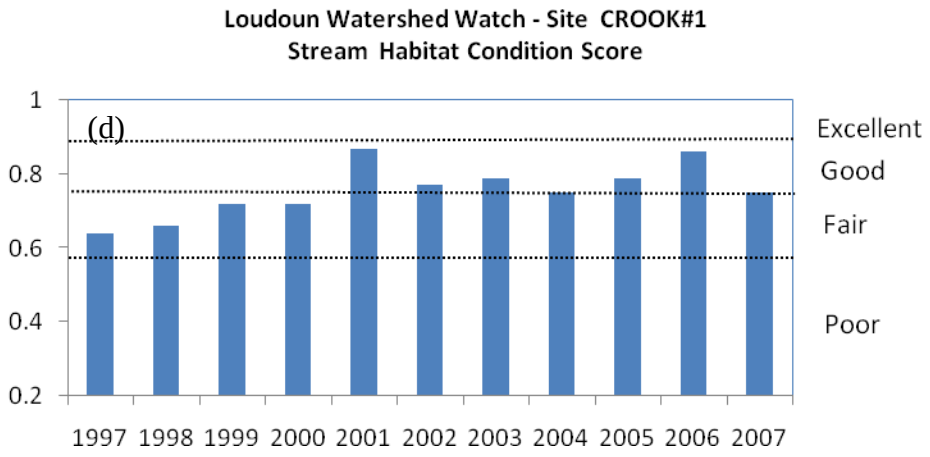
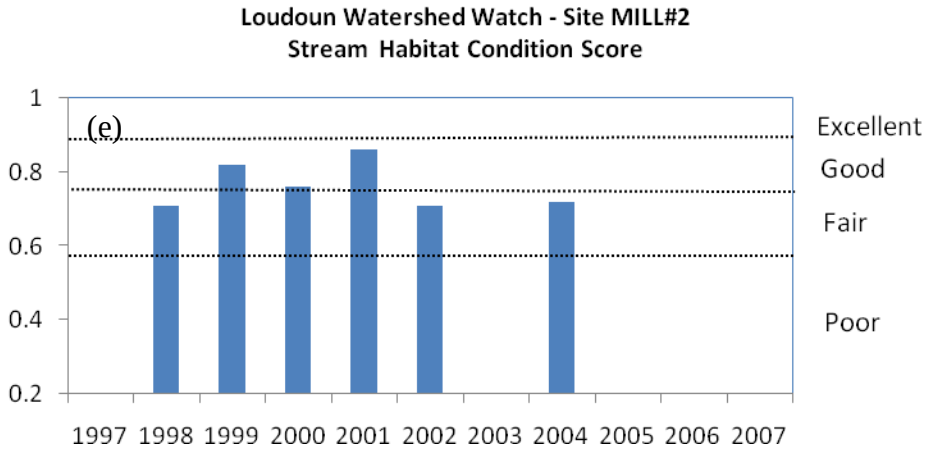
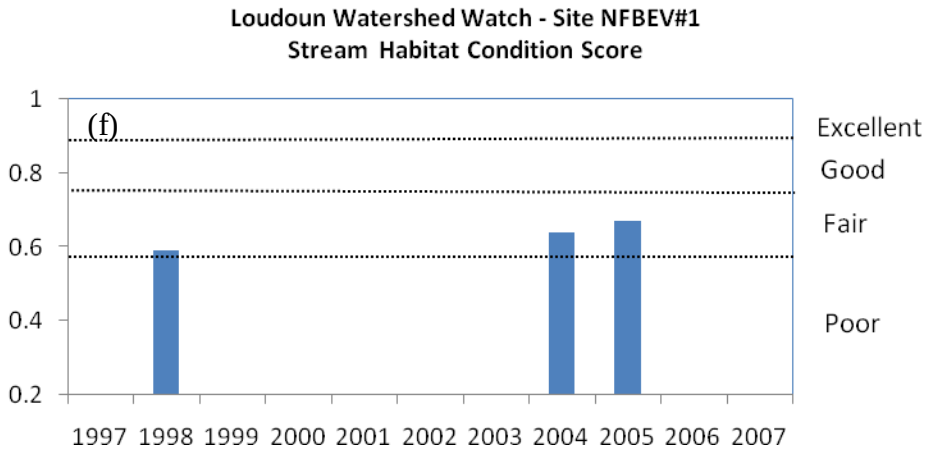



Appendix Figure 4. Loudoun Watershed Watch habitat scores, by yearly average, for selected sites

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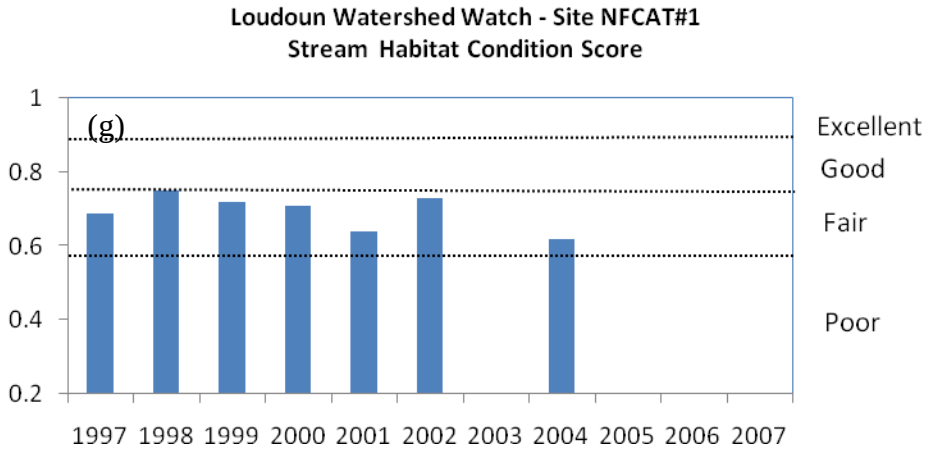


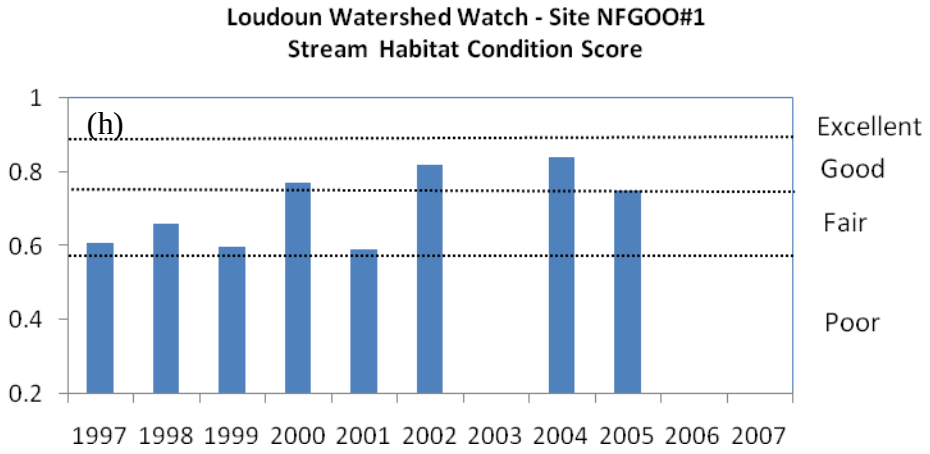


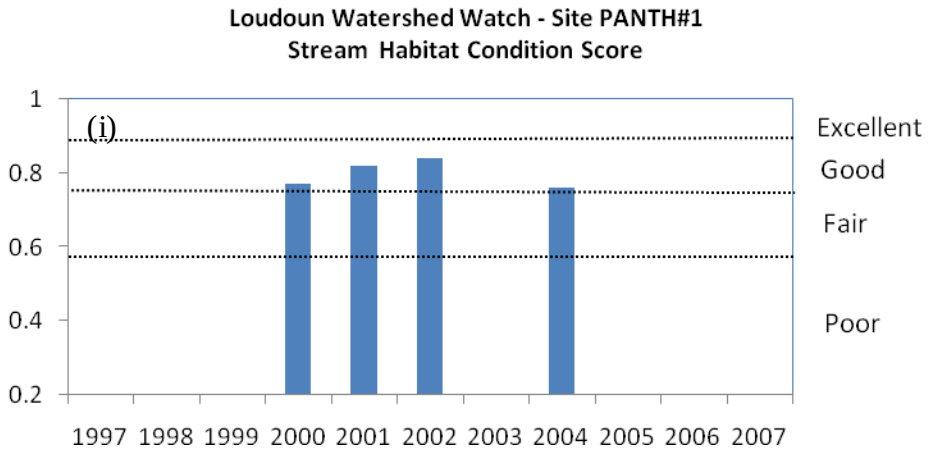


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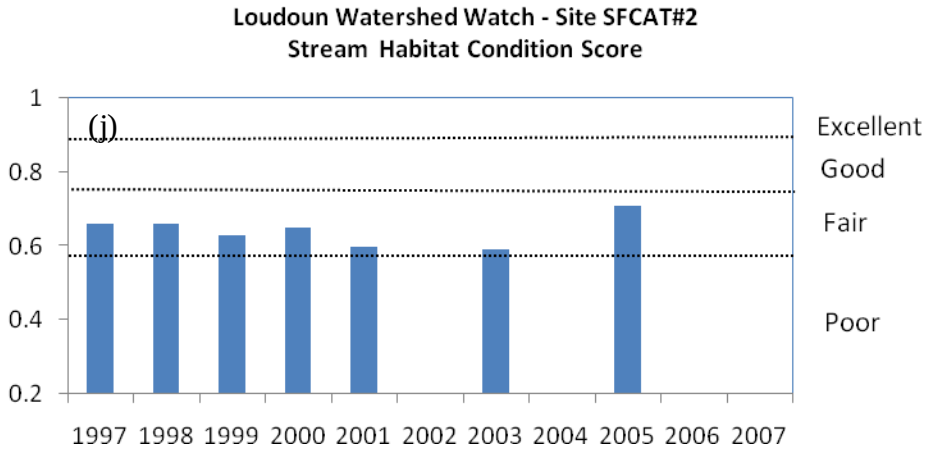


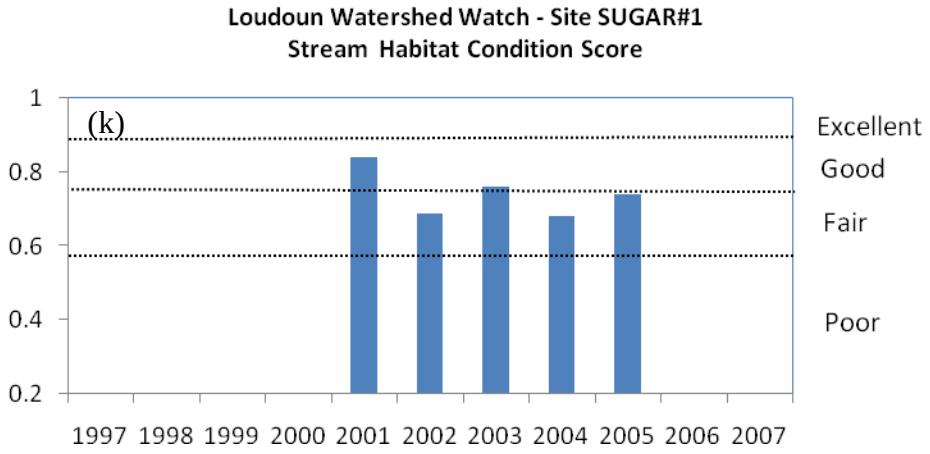


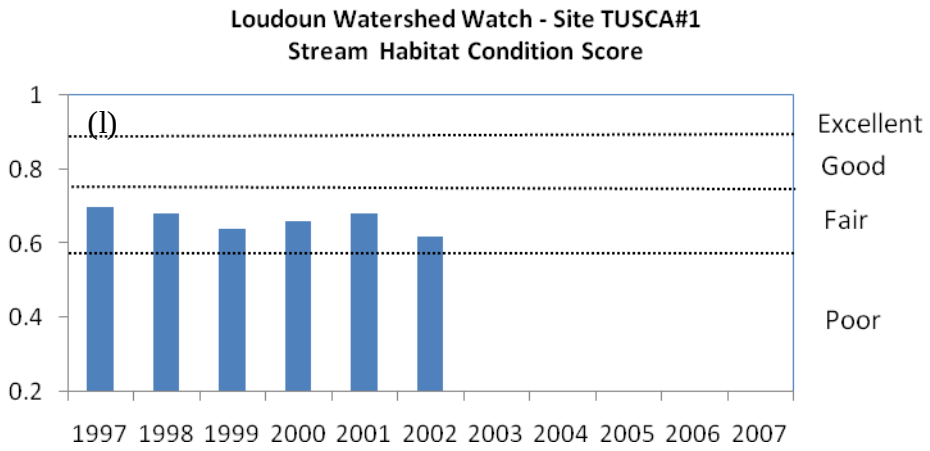


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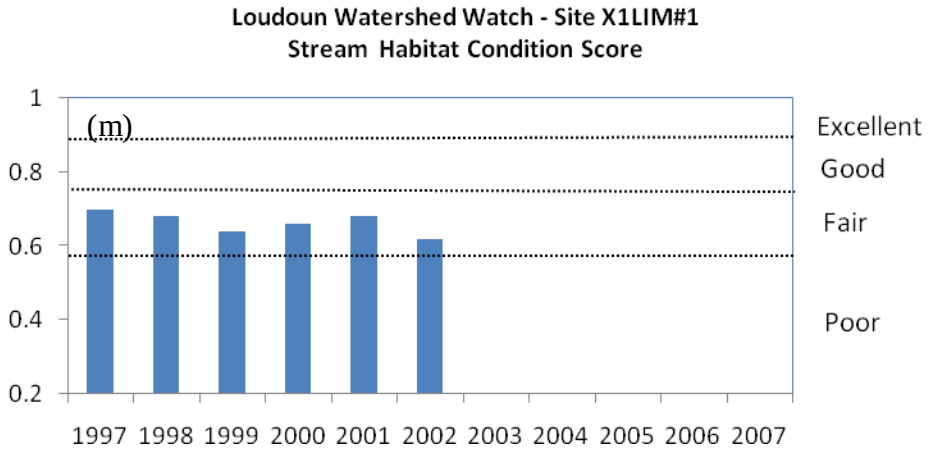


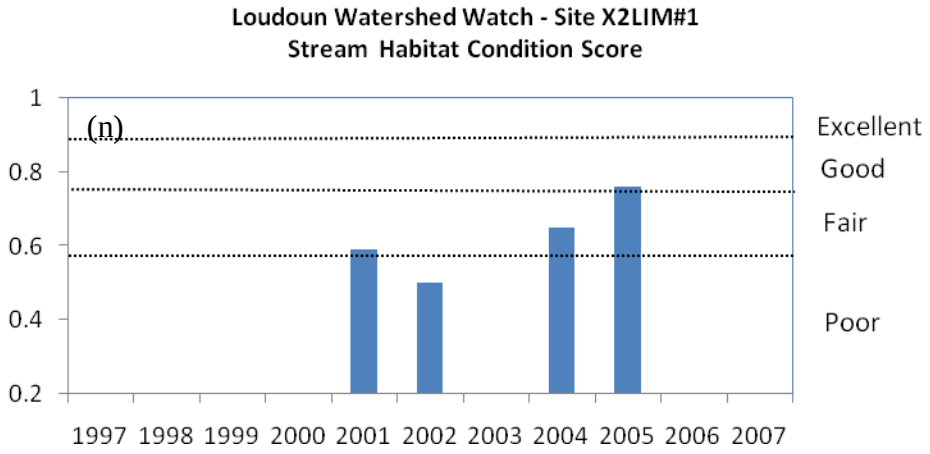


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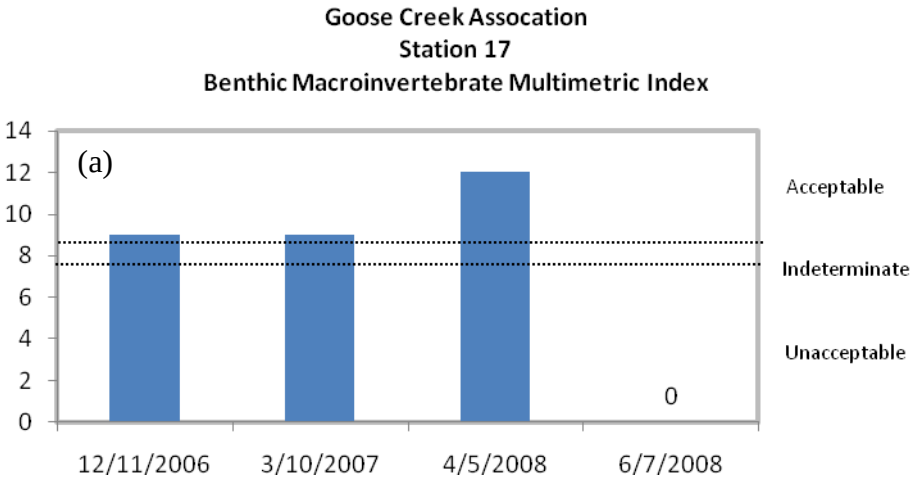
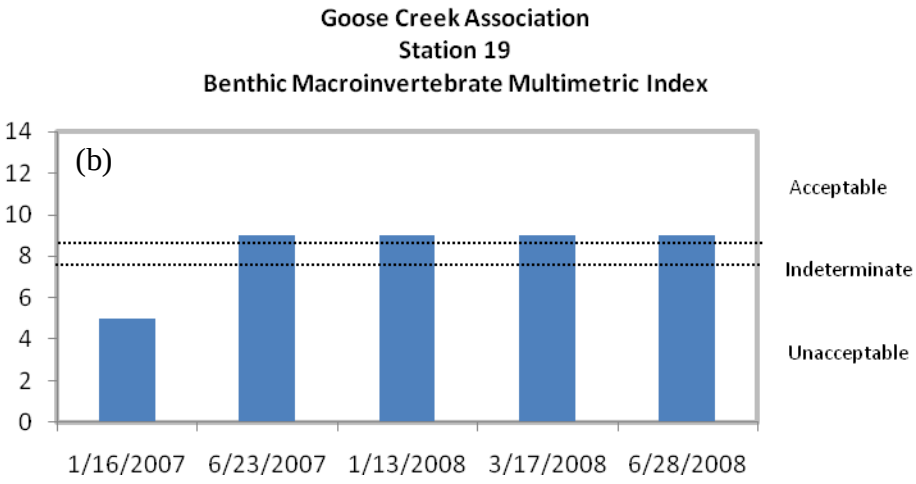
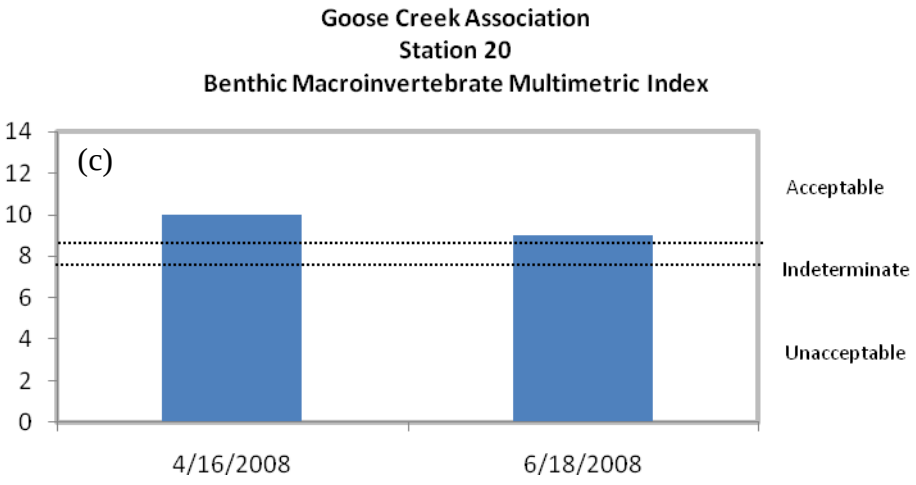
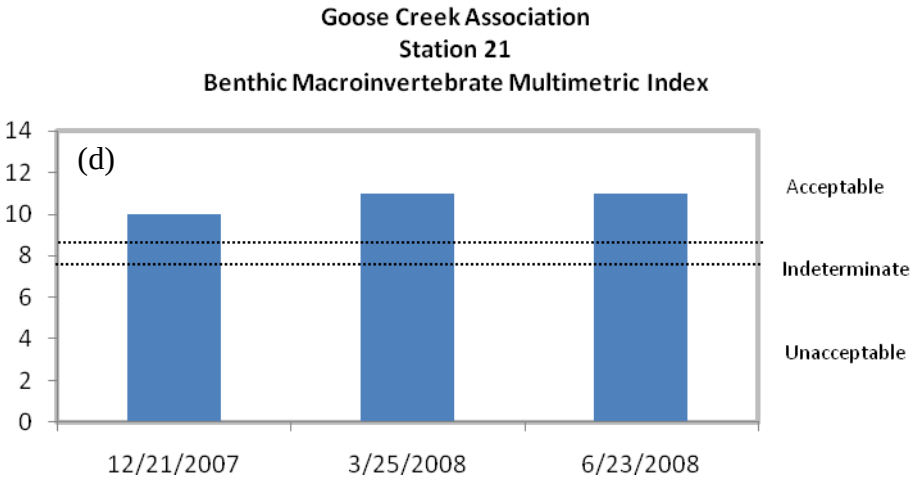
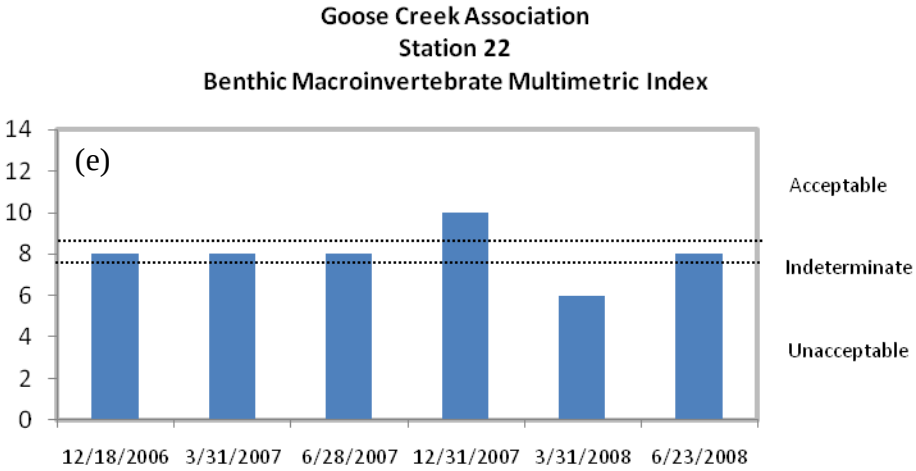



Appendix Figure 5 (a-e). Goose Creek Association benthic macroinvertebrate multimetric index scores, by sample date, for selected sites




Appendix Figure 5. (Continued)

Appendix 22