Comparison Watershed Selection When Applying the AllForX Approach for Sediment TMDL Development

Kristine N. Bronnenkant

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Brian L. Benham, Chair
Zachary M. Easton
Jason R. Hill
Eugene R. Yagow

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ABSTRACT

This study compared physical characteristics used when selecting comparison (healthy) watersheds for the All-Forested Load Multiplier (AllForX) Approach, and examined a quantitative watershed characteristic as a selection criterion. The AllForX Approach uses a regression relationship between Virginia Stream Condition Index (VSCI) scores and AllForX values (a unit-less multiplier that is the ratio of a modeled existing sediment load divided by a modeled all-forested load condition) for an impaired watershed and several comparison watersheds to develop sediment TMDL target loads. The Generalized Watershed Loading Function (GWLF) model was used to simulate sediment loads for twenty watersheds (four impaired and 16 comparison) in the Upper James and New River basins in Virginia's Ridge and Valley physiographic region. Results suggest that within Virginia's Ridge and Valley physiographic region it may be possible to select comparison watersheds that are of a different stream order (watershed size) and lie in different river basins from the impaired watershed. Results further indicated that the topographic index (TI) distributions were not different across the modeled watersheds, indicating the watersheds are hydrologically similar. These results support selecting comparison watersheds regardless of river basin or stream order within Virginia's Ridge and Valley physiographic region. Finally, there was no statistical difference between the AllForX regressions when using the entire period of record or the two most recent VSCI data points. Therefore, for the watersheds modeled for this study, either all of the VSCI samples or the two most recent may be used in the AllForX Approach.

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CHAPTER 1: INTRODUCTION

Under the Clean Water Act (CWA), states are required to list water bodies, which do not support their designated uses, as "impaired." Virginia's water quality standards specify that surface waters are designated for the following uses: "recreational use" (e.g., swimming, fishing, and boating) and "aquatic life use" (e.g., viable fish and benthic populations). Water quality criteria protect these uses. In Virginia, the Department of Environmental Quality (VADEQ) is responsible for water quality monitoring and for developing the list of impaired waters. As a first step in removing water bodies from the impaired list, a Total Maximum Daily Load (TMDL) is developed. A TMDL is a watershed-specific study that determines the allowable pollutant load a waterbody can assimilate and still meet its designated uses. Each TMDL is pollutant specific. As a result, a single waterbody may have multiple TMDLs.

Benthic macroinvertebrates are strong indicators of the health of a stream or river. In Virginia, biological monitoring is performed by VADEQ using multiple metrics to distinguish between healthy and impaired streams. Waters in which the benthic community is degraded violate the general aquatic life use standard and are considered to have a "benthic impairment." Metrics are used to evaluate the in-stream biological community e.g., total taxa, the percent of the 2 most dominant taxa, and % scrapers. These metrics are scored and summed to obtain a single score called the Virginia Stream Condition Index (VSCI) (VADEQ, 2006). Metrics that evaluate benthic habitat suitability are also assessed. A water body's VSCI score can range from 0 to 100, with a VSCI below 60 indicating an impairment. When a benthic impairment exists, the benthic community is being stressed by one or more pollutants. When developing a TMDL to address a benthic impairment, a stressor analysis is performed to determine the pollutant most likely to be stressing the stream. Once the stressor (or stressors) is identified, a TMDL(s) is then developed to address that pollutant. In Virginia, excess sediment is the leading cause of benthic impairments (VADEQ, 2012).

Sediment TMDLs are developed to address benthic impairments caused by excessive in-stream sediment loads generated from agricultural, forestry, mining, transportation, and residential land use activities (Yagow et. al, 2011). For Virginia's non-coastal watersheds, sediment TMDLs have historically been developed using the Reference Watershed Approach

(RWA) (VADEQ, 2008; Yagow et. al, 2011). The RWA compares sediment loads from the impaired watershed to a single reference watershed that has similar characteristics, but is non-impaired. The sediment load in the comparable, reference watershed is used to set the TMDL target sediment load in the impaired watershed. Sediment loads in both watersheds are estimated using modeling; typically, the Generalized Watershed Loading Function (GWLF) model has been applied when using the RWA (Yagow et. al, 2011; Yagow et. al, 2014).

There are a couple of concerns with using the RWA for determining target sediment loads. Finding a reference watershed that is comparable with the impaired watershed can be difficult. Also, because there is no sediment standard, determining the sediment load that is appropriate for restoring the biological community to healthy limits is difficult to validate. Therefore, when using the RWA, the TMDL target load determined for the impaired watershed could be more (or less) conservative than the load actually needed to address the benthic impairment (Yagow et. al, 2014).

The All-Forested Load Multiplier Approach (AllForX) has been developed as an alternative to the RWA for developing sediment TMDLs in non-coastal watersheds in Virginia (Yagow et al., 2013). The relatively new Virginia AllForX is similar to a method used in Maryland (MDE, 2006). In the AllForX Approach, an impaired watershed and several comparison watersheds are modeled under “existing” conditions and then under “all-forested” conditions. The ratio of the existing load to the all-forested load defines the unit-less all-forested load multiplier (AllForX) for each watershed (Eqn.1-1). The AllForX values are then plotted against the average Virginia Stream Condition Index (VSCI) scores for the corresponding watersheds.

$$AllForX = \frac{existing\ load}{all\ forested\ load} \qquad \text{Eqn. 1-1}$$

In the AllForX Approach, a plot is developed using both the impaired and comparison watersheds. The plot uses VSCI scores on the Y-axis and the AllForX value on the X-axis. A regression line is fit to the data. Using this regression, the AllForX value that corresponds to a VSCI of 60 is determined. The “target” AllForX threshold value is then multiplied by the impaired watershed all-forested load to determine the TMDL target sediment load. Since multiple comparison watersheds are used for the regression, a confidence interval can be calculated around the AllForX threshold value. The lower limit of an 80^{th} percentile confidence interval is used to quantify the TMDL margin of safety (MOS). The AllForX Approach provides a direct relationship between the biological community and the sediment load through the plot of VSCI scores versus the AllForX values. To date, comparison watersheds used in the AllForX Approach have been chosen based on similarity in stream order to that of the impaired watershed, the fact that the impaired watershed and the reference watersheds lie in the same river basin, proximity to the impaired watershed, and best professional judgment.

The objectives of this study were threefold (1) to determine if the watershed characteristics used to select comparison (healthy) watersheds when applying the AllForX Approach (i.e., stream order or watershed size and the proximity of the comparison and impaired watersheds, as defined by them lying within the same river basin) are significant, (2) to evaluate the utility of the topographic index (TI) as a potential quantitative criteria for use when selecting comparison watersheds for the AllForX Approach, and (3) to compare how the TMDL AllForX threshold value ($AllForX_{TV}$) differs when using the entire period of record of VSCI scores versus the 2 most recent VSCI scores. To address these objectives, the Generalized Watershed Loading Function (GWLF) model was used to simulate sediment loads for 20 watersheds (four impaired and 16 comparison) in the Upper James and New River basins in the Ridge and Valley physiographic province of Virginia.

Hypotheses

1. Within the Ridge and Valley physiographic region of Virginia, for the watersheds modeled for this study, stream order (i.e., watershed size) or proximity of the impaired and comparison watershed (i.e., within the same river basin) are not significant variables that must be considered when selecting comparison watersheds for use in the AllForX Approach.
2. Within the Ridge and Valley physiographic region of Virginia, for the watersheds selected for this study, there is no difference between the distributions of topographic index (TI) values of the impaired and comparison watersheds.
3. Within the Ridge and Valley physiographic region of Virginia, for the watersheds modeled for this study, when using the AllForX Approach, there is not a significant difference between AllForX threshold values when using either the entire period of record of VSCI scores or the two most recent VSCI scores.

CHAPTER 2: LITERATURE REVIEW

The Clean Water Act

The Federal Water Pollution Control Act (FWPCA) of 1948 was developed to reduce pollution in the nation's waters and preserve the nation's waters for their intended uses, such as public water supplies, fish and aquatic life, recreational purposes, and agricultural and industrial uses. After extensive amendments, the FWPCA became known as the Clean Water Act (CWA) in 1972 (USEPA, 2014). The purpose of the CWA is to restore and maintain the chemical, physical and biological integrity of the Nation's waters (USEPA, 2002). Specifically, section 303(d) of the CWA requires states to identify water bodies that do not meet state water quality standards and to develop a Total Maximum Daily Load (TMDL) for those water bodies (USEPA, 2002). A TMDL quantifies the amount of a particular pollutant a water body can assimilate and still meet applicable water quality standards. Pollutants entering the Nation's waters originate from both point and nonpoint sources. Point source pollution originates from a readily identifiable source, such as industrial wastewater or sewage treatment effluent. Point source pollution is managed through the CWA's National Pollutant Discharge Elimination System (NPDES) permit process. Under this process, businesses are required to keep their effluent within permit limits. Nonpoint source pollution originates from diffuse sources, is harder to measure and, therefore, is more difficult to reduce or eliminate. Nonpoint source pollution (NPS) is typically not regulated. Control of NPS pollution is most often achieved by incentivizing polluters to implement pollution control measures, like best management practices (BMPs). In Virginia, the Department of Conservation and Recreation (DCR) has been tasked with overseeing Virginia's Nonpoint Source Pollution Management Program (VADCR, 2009). The program is a voluntary, non-regulated, incentive-based program designed to reduce NPS pollution in Virginia's water bodies.

From its enactment until the mid-1980s, the CWA mainly focused on reducing point source pollution through the creation of the National Pollutant Discharge Elimination System (NPDES) (USEPA, 2014). While the NPDES permit process has been effective in reducing pollution, NPS pollution has not seen a similar significant improvement/reduction (USEPA, 1992). The continual poor quality of the nation's waters led to a series of lawsuits alleging that the Environmental Protection Agency (EPA) was not following Section 303(d) of the CWA, which requires the EPA to create TMDLs when an individual state did not follow the regulations. These lawsuits were typically settled using a consent decree process whereby EPA, in coordination with the affected states, developed a schedule and timeline over a ten-year period, in order to ensure progress towards improved water quality through TMDL development (USEPA, 2009).

A TMDL is defined as:

$$TMDL = WLA + LA + MOS \qquad \text{Eqn. 2.1}$$

Where TMDL = Total Maximum Daily Load

WLA = waste load allocation (permitted sources)

LA = load allocation (nonpoint sources)

MOS = margin of safety (buffer to account for uncertainty)

Water Quality Standards

To meet the CWA's requirements, states have developed water quality standards. Under Section 62.1-44.15(3a) of the State Water Control Law, Virginia's regulations state that:

All state waters, including wetlands, are designated for the following uses: recreational uses, e.g., swimming and boating; the propagation and growth of a balanced, indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them; wildlife; and the production of edible and marketable natural resources, e.g., fish and shellfish (Section 9-VAC-25-260-20).

In Virginia, both numeric and narrative water quality criteria have been developed to meet water quality standards. Examples of numeric criteria include some measure of various water quality parameters or contaminants, i.e., dissolved oxygen, pH, temperature, and coliform bacteria. Narrative or qualitative water quality criteria have been established for those indicators of water quality that are not as readily quantifiable. These criteria are often based on a narrative description of the biological integrity of the water body. Virginia's code states:

State waters, including wetlands, shall be free from substances attributable to sewage, industrial waste, or other waste in concentrations, amounts, or combinations which contravene established standards or interfere directly or indirectly with designated uses of such water or which are inimical or harmful to human, animal, plant, or aquatic life (Section 9-VAC-25-260-20).

To evaluate the biological integrity of the water bodies, Virginia's Department of Environmental Quality (VADEQ), monitors the benthic macroinvertebrate community (i.e., organisms that are bottom-dwelling and large enough to see with the naked eye) twice a year (fall/spring) at locations across the state. If over time, the sampling shows the benthic community to be unhealthy; the water body is designated as "impaired" and the stream segment is added to the Virginia's 303(d) list. Addition to the 303(d) list means that a TMDL is required to address the identified impairment. For benthic impairments, the pollutant of interest is not typically specified, and must be determined through a weight of evidence-based stressor analysis. Once the offending pollutant or pollutants are identified, existing and target pollutant loads are estimated during a modeling process and load reductions needed to improve the biological integrity of the waterbody are determined.

Biological Monitoring

Biological monitoring to assess the health of streams began in Virginia in the early 1970s (VADEQ, 2012). Assessments of the number, diversity, and pollution tolerance of the benthic macroinvertebrates at the monitoring location aid in determining if the stream is meeting the aquatic life designated use (Yagow et. al, 2011). While chemical and physical monitoring provides data on water quality at a point in time, biological monitoring provides a long-term assessment of water quality. Benthic macroinvertebrates typically found in healthy streams include stoneflies, mayflies and caddisflies. Higher percentages of these organisms in a given sample are more indicative of healthy streams, while aquatic worms, black flies, and midge flies are more pollution tolerant and are found in greater abundance in impaired streams (Taccogna and Munro 1995).

Biological monitoring methods have evolved with time. In the early 1990s, the EPA developed the Rapid Bioassessment Protocol (RBP) II (Tetra Tech, 2003). The RBP II created an easily repeatable monitoring framework that compared the benthic macroinvertebrate community evaluated in a given stream to a "reference" healthy stream site. The RBP II method also included a habitat assessment component that assessed how stream/river bank conditions and in-stream characteristics (i.e., embeddedness) impacted the benthic macroinvertebrate community. The RBP II method yielded ratings of "non-impaired", slightly impaired," moderately impaired," or "severely impaired."

Since 2006, the VADEQ has used a new benthic community assessment measure, the Virginia Stream Condition Index (VSCI) (VADEQ, 2006). Applied to non-coastal streams only, the VSCI assessment method produces a score that is relevant to a set of reference conditions, rather than a specific reference station. The Virginia bioassessment procedure uses the VSCI method, which includes a series of 8 metrics that are used to evaluate the benthic macroinvertebrate community in stream. The combination of the VSCI metrics results in a score between 0 and 100. VSCI scores below 60 are considered impaired, requiring a TMDL to be developed to address the benthic impairment. VSCI scores at or above 60 are representative of healthy biological communities.

Stressor Analysis

While the VSCI assessment is used to identify whether a stream is impaired or not, it does not identify the cause of the impairment. A stressor analysis process must be undertaken to identify the most probable stressor (pollutant) that is causing the impairment. During a stressor analysis, a candidate list of possible stressors is created and each candidate is evaluated. When more than one stressor is present, the stressor with the greatest impact is considered the most probable stressor (USEPA, 2000). Potential stressors may include ammonia, hydrologic modifications, metals, pH, TDS/conductivity/sulfates, temperature, toxics, nutrients, organic matter, and sediment (Yagow et. al, 2011).

To identify the most probable stressor, the candidate list is evaluated using all available evidence, including chemical and physical monitoring data, biological metrics and habitat evaluations, aerial photography of the watershed, and a visual assessment of the conditions throughout the watershed. The evidence provides information that can be used to assess potential stressors. In Virginia, the most probable stressor is often found to be sediment (VADEQ, 2012). Excessive sedimentation causes pores in the stream bottom to be filled (embeddedness), effectively removing the natural habitat for benthic communities. Excess sediment may come from residential runoff, forestry operations, construction sites, agriculture, and in-stream disturbances from livestock farming (Yagow et. al, 2011). Once the most probable stressors are identified, TMDLs are developed to address the cause(s).

Sediment TMDL Case Studies from Other States

Approaches for evaluating sediment loads in watersheds vary across the USA based on available measured data, time, and desired outcomes. For instance, a TMDL was developed for

Deep Creek Watershed in Montana using extensive resources to measure flows, temperature, suspended sediment, and chemical water quality during a six year period. Fish counts and benthic macroinvertebrate monitoring were also conducted. The source of the Deep Creek impairment was determined to be excessive sediment entering the stream. Links between suspended sediment loads and sediment sources were developed using regression, best professional judgment, and a reference reach approach. (USEPA, 1999). As a result of developing the TMDL, steps have been taken to reduce the sediment load reaching Deep Creek.

While benthic macroinvertebrate sampling was a small portion of the Deep Creek TMDL, other states rely heavily on benthic macroinvertebrate as an indicator of sediment impairments. The relationship between the biological communities in impaired streams to healthy biological communities in similar 'reference' watersheds is often used to determine sediment loads and sediment reductions necessary for completing a TMDL. Some TMDLs that have been developed using benthic macroinvertebrate as the primary indicator are the Lower Arkansas River, KS (USEPA, 2002b) and the Conodoguinet Creek watershed, PA (Tetra Tech, 2000).

Reference Watershed Approach

When developing sediment TMDLs in Virginia, the Reference Watershed Approach (RWA) has often been used to determine the TMDL target sediment load for the impaired watershed (VADEQ, 2008; Yagow et. al, 2011). In the RWA, a single reference watershed is selected that is non-impaired, but similar to the impaired watershed across a range of characteristics (e.g., land use, soils, slope, and elevation). An area adjustment is performed on the reference watershed to allow sediment load comparisons between equal area watersheds. The total average annual sediment load (i.e., ton/yr) is simulated for both the impaired and area adjusted reference watershed. The simulated, area adjusted load for the non-impaired reference watershed is used to set the TMDL target sediment load for the impaired watershed. Based on the modeling and the level of detailed sediment source characterization, the allocation scenario in the TMDL study specifies what reductions are needed from the various sediment sources in the watershed to achieve the TMDL target sediment load.

The RWA has limitations. With only one reference watershed for comparison, it can be difficult to find a watershed that closely matches the characteristics of the impaired watershed. Another issue may develop when trying to determine the appropriate sediment reductions needed to return the biological community to healthy conditions. In some cases, the target sediment load developed from the reference watershed may be too conservative (Yagow et. al, 2014). One study based on the RWA found that the selection of different reference watersheds produced significantly different results in recommended sediment reductions (Wagner, 2004). An approach that has been developed in Maryland addresses some of the issues with the RWA.

Maryland Approach

In 2006, the Maryland Department of the Environment (MDE) established a methodology that directly links the health of the biological community with the sediment loads in a watershed (MDE, 2006). A sediment load threshold was established for estimating sediment loads in the non-tidal region of the state. This method is an adaptation of the RWA. In the Maryland Approach, a regression of normalized sediment loads vs. Index of Biological Integrity (IBI) scores was established for watersheds in non-coastal Maryland. The normalized sediment load was calculated as the load at existing conditions divided by the all-forested or natural conditions (MDE, 2006). Maryland has two primary indicators of biological health, the Fish Index of Biological Integrity (F-IBI) and Benthic Macroinvertebrate Index of Biological Integrity (B-IBI). These indices are similar to the VSCI in that they are both indices of the biological integrity in a water body.

When developing the Maryland Approach, sediment loads for existing conditions and all-forested conditions were modeled using the Chesapeake Bay Program Phase 5 (CBP P5) watershed model (USEPA, 2010). Logistic regression of the health of the biological community to the normalized sediment loads was performed to find the sediment load threshold for the non-tidal region of Maryland. This threshold provides a state-wide numeric standard for non-tidal waters and may be multiplied by the existing sediment load of an impaired watershed to find the target sediment load, or what the load would need to be to return the health of the stream to natural conditions. Further comparisons of embeddedness and epifaunal substrate validated the methodology developed in this approach. The threshold was established for the non-tidal region because of similarities in the benthic macroinvertebrate communities and fish structure within the non-tidal region of the state.

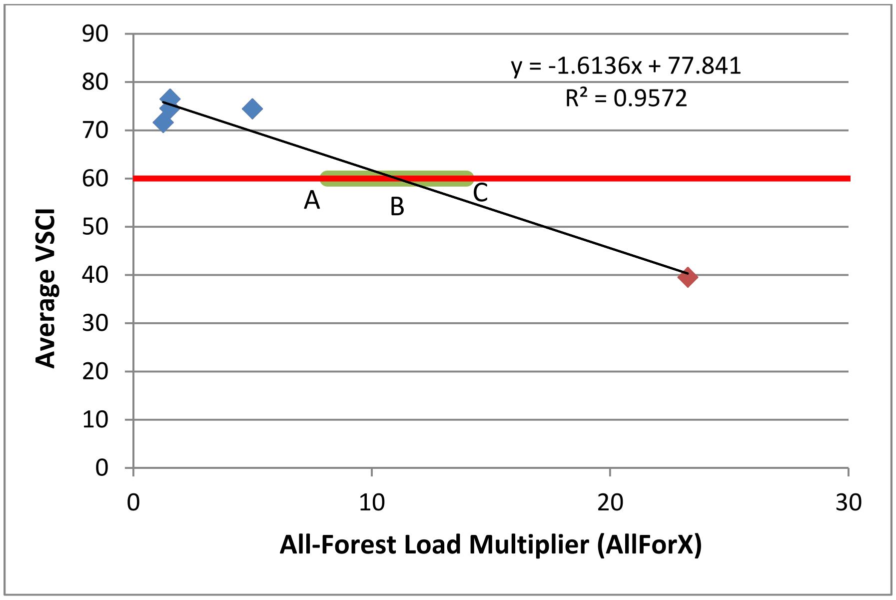
All-Forested Multiplier (AllForX) Approach

A modified version of the Maryland Approach was developed for use in Virginia's non-tidal regions to provide a more reasonable sediment target load than the RWA (Yagow et. al, 2013). The All-Forested Load Multiplier (AllForX) Approach uses VSCI scores to represent the in-stream biological conditions and an "AllForX" value to represent existing sediment loads normalized by an all-forested condition. The "AllForX" value for a given watershed is the ratio of the simulated sediment load under existing conditions to the all-forested condition. As a result, a link is created between in-stream biological health and sediment loads.

In the AllForX Approach, the sediment load exiting a watershed is estimated for two land use configurations – the existing condition, which uses the most current land use data available, and an all-forested condition, which changes the existing land uses to an all-forested (background) condition. Sediment loads are estimated using a continuous watershed scale simulation model. To date, the Generalized Watershed Loading Function model (GWLF) has been used for all AllForX applications (Yagow et. al, 2014). To simulate all-forested loads, forested conditions are applied to all existing land use types. The original area for each land use is maintained to keep certain watershed characteristics the same (e.g. soils data, slope). When using GWLF, the SCS curve number (CN) and cover factor (C) are changed to represent an all-forested condition. Unlike the RWA, the AllForX Approach uses multiple comparison (healthy) watersheds to determine the TMDL target load. In the AllForX Approach, sediment loads under existing and all-forested conditions are simulated for a single impaired and multiple comparison watersheds.

To use the AllForX Approach, one must plot the average VSCI score for a given watershed vs. the AllForX value for that watershed. Both the impaired and any/all comparison watershed data are plotted, Figure 2-1.Typically, the arithmetic average VSCI score using all available sampling data is plotted. A linear regression is then fit to the impaired and comparison watershed data. Using the regression, the AllForX value that corresponds to a VSCI score of 60 (the impairment threshold) is determined. The AllForX threshold value is multiplied by the all-forested sediment load of the impaired watershed to determine the TMDL target sediment load. An 80% confidence interval is applied at the location of the AllForX threshold value. The lower bound point on the 80% confidence interval establishes the margin of safety (MOS), which is factored into the TMDL target load to account for uncertainty within the modeling process. The difference between the AllForX threshold value and the MOS AllForX value is multiplied by the all-forested sediment load of the impaired watershed to obtain the MOS sediment load. The TMDL target allocation load is found by subtracting the MOS load from the TMDL target load.

The TMDL allocation load is the maximum allowable sediment that the impaired water body can handle and remain healthy. The use of regression in the AllForX Approach provides a direct link between the biological community and the TMDL sediment load. The AllForX Approach has been created for localized applications within Virginia. At this time, it is not meant to provide a numeric standard for the entire non-tidal region of Virginia (Yagow et. al, 2013).



B = AllForX threshold value used for the TMDL; A to C = the 80% Confidence Interval (green line);
B – A = AllForX value used for the MOS; A = AllForX value used for the target allocation load.

Figure 2-1. Hypothetical plot of regression fit and AllForX threshold value created for illustration purposes (Yagow et. al, 2014)

Generalized Watershed Loading Functions Model (GWLF)

Mathematical computer models are often used to simulate the fate and transport of pollutants to and in water bodies. The Generalized Watershed Loading Function model (GWLF) has often been applied to develop sediment TMDLs (Yagow et. al, 2011; Yagow et. al, 2014). GWLF is a lumped parameter model capable of simulating sediment loads within a watershed (Haith, 1985). Lumped parameter models, lump or gather homogenous data into similar groups. For example, similar land uses across a watershed are lumped together. Groups that possess a combination of unique, but similar characteristics (e.g., land use and soils, or land use and slope, or land use and sub-watershed) are termed hydrologic response units (HRU). A suite of HRUs represents a watershed. The sediment load from the HRUs is simulated using empirical equations

[(Soil Conservation Service-Curve Number (SCS-CN) (USDA, 1986) and Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978)]. The SCS-CN method is used to estimate runoff while the Universal Soil Loss Equation is used to estimate erosion for each HRU. GWLF simulates surface and subsurface flows, sediment yield and sediment delivery as well as dissolved and attached nitrogen and phosphorous loads from rural, urban, and mixed land use watersheds (Evans et al., 2003). GWLF assumes that all the sediment generated within a given year flows out of the watershed during the same year (no net sediment deposition). The GWLF model year runs from April to March (Borah et al., 2006).The GWLF model is sometimes termed a "mid-range" model as its capabilities and complexity falls into a category between simple, spreadsheet type models, and more complex process-based models like the Hydrological Simulation Program Fortran (Haith et. al, 1992).

Hydrology and Sediment Simulation in GWLF

A daily water balance is used to simulate hydrology; this procedure accounts for various types of storages within the watershed. Precipitation is the driving force behind the pollutant fate and transport processes included within the GWLF model, Figure 2-2.

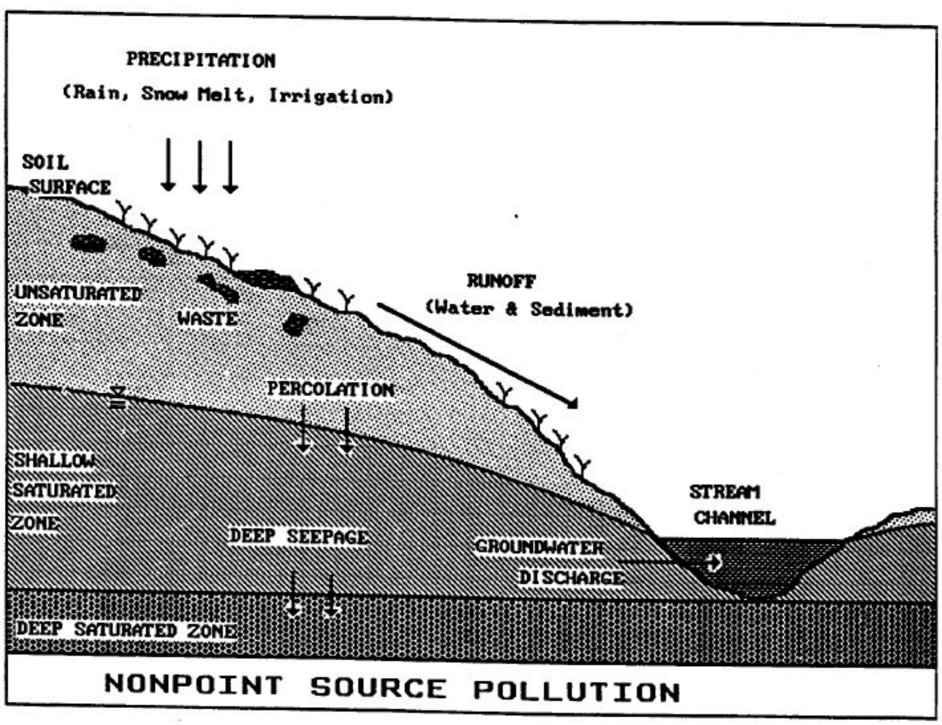


Figure 2-2. Hydrologic process in GWLF

GWLF uses the Soil Conservation Service (presently NRCS) CN method (USDA, 1986) to simulate runoff generated from each of the different pervious land uses. The SCS (CN) method is an empirical equation developed from thousands of plot years of rainfall runoff data to predict runoff generation from a HRU. The SCS CN equation is:

$$Q = \frac{(P-0.2S)^2}{(P+0.8S)} \qquad \text{Eqn. 2.2}$$

Where:

Q = accumulated runoff depth (cm)

P = rainfall and snowmelt depth (cm)

S = average available moisture storage when runoff begins (cm)

$$S = 25.4\left(\frac{1000}{CN}\right) - 10 \qquad \text{Eqn. 2.3}$$

Where:

CN = curve number

To calculate available storage (S) values in metric units, a conversion factor (25.4) is used in Equation 2.3. A unique curve number (CN) is assigned to each land use. Curve number values range from 6-92. The CN is a function of hydrologic soil group, antecedent moisture conditions and land use. For application in GWLF, CNs are calculated for each pervious land use, based on the hydrologic soil group and antecedent moisture conditions. Any precipitation that does not generate runoff infiltrates into the unsaturated zone, Figure 2-2. As the soil in the unsaturated zone reaches its water holding capacity, excess water percolates into the saturated zone. Water can also be lost to evapotranspiration. Potential evapotranspiration is a function of land cover and available soil moisture. Groundwater discharge from the saturated zone reservoir is discharged into streams based on a base flow recession coefficient. Water may leave the system via a deep saturated zone by way of a seepage zone (based on a seepage coefficient).

The GWLF model is capable of modeling seventeen (17) land use types. Of these 14 are rural and 3 are urban (impervious). Using the USLE, GWLF simulates average annual soil loss from pervious surfaces which is then converted to an average daily soil loss, Eqn. 2-4.

$$S_{day} = 0.132 * RE * KLSCP * A \qquad \text{Eqn. 2.4}$$

Where:

S_{day} = sediment available for transport (tons/day)

RE = Rainfall erosivity factor (function of daily rainfall)

K = Soil erodibility factor (dimensionless)

LS = Topographic factor (dimensionless)

C = Cover and management factor (dimensionless)

P = Supporting practice factor (dimensionless)

A = Source area (hectares)

A conversion factor, 0.132, associated with the SI units of rainfall erosivity is applied to the USLE equation. Monthly sediment loss transported to the stream from the land surface within the watershed is estimated using the USLE equation and a sediment delivery ratio (SDR). The SDR is the ratio of erosion generated on the landscape to sediment delivered to the watershed outlet. The SDR is a function of watershed size, Eqn. 2.5 is used for watersheds < 50 km^2, while Eqn. 2.6 is used for watersheds > 50 km^2.

$$SDR = 5 * 10^{-6} * area^2 - 1.4 * 10^{-3} * area + 0.198 \qquad \text{Eqn. 2.5}$$

$$SDR = 0.4518(area^{-0.298}) \qquad \text{Eqn. 2.6}$$

Where:

SDR = sediment delivery ratio

Area = watershed area (km^2)

For impervious land uses, GWLF uses an exponential buildup and wash-off equation (Sartor and Boyd, 1972).

Channel stream erosion was not originally included in GWLF (Haith, 1985); however, an equation was later added to account for stream bank and channel erosion in AVGWLF (Evans et al., 2003). The lateral erosion rate (LER) of a stream bank is calculated by incorporating mean monthly stream flow, percent urban land, animal density, CN, soil erodibility, and slope, Eqn 2.7 and Eqn. 2.8.

$$LER = a * q^{0.6} \qquad \text{Eqn 2.7}$$

Where:

LER = an estimated lateral erosion rate (meters/month)

a = an empirically-derived constant related to the mass of soil eroded from the stream bank depending on various watershed conditions

q = monthly stream flow (m^3/s)

$$a = (0.00467 * PD) + (0.000863 * AD) + (0.000001 * CN) + (0.000425 * K) + (0.000001 * MS) - 0.000036 \quad \text{Eqn 2.8}$$

Where:

PD = percent developed land in the watershed

AD = Animal density of the watershed in animal equivalent units (AEUs)

CN = Average curve number value of the watershed

K = Average soil k factor for the watershed

MS = mean topographic slope (%) of the watershed

Stream bank derived erosion loads are calculated by multiplying the lateral erosion rate by the stream length with livestock access, the average channel depth, and an average soil bulk density (Wagner, 2004). The model uses a daily time step to estimate sediment yield, which is then aggregated into a monthly yield.

Topographic Index

Criteria currently used to select comparison watersheds when using the AllForX Approach include proximity of the impaired and comparison watersheds, stream order (watershed size) and best professional judgment. The second objective of this research seeks to explore the use of an alternative watershed characteristic measure as a quantitative criterion for selecting comparison watersheds for the AllForX Approach. Topography strongly influences hydrologic processes in watersheds. Topographic indices are a popular method for describing spatial soil moisture patterns and have been used in runoff models (e.g., TOPMODEL, SWAT, GWLF) to account for spatial variability in runoff (Grabs et. al, 2009). The topographic wetness index (TI) was established by Bevin and Kirby (1979) and relates contributing upslope catchment area and slope steepness, and is often used as a predictor of runoff generating areas, soil moisture distributions and shallow lateral subsurface flows,

$$TI_i = ln\frac{\alpha_i}{tan\beta_i} \qquad \text{Eqn. 2.9}$$

Where

TI_i = topographic index of grid cell i

α_i = the upslope contributing area per unit length of contour

β_i = topographic slope of the cell

Higher TI values are indicative of soils with high moisture content, with a large upslope contributing area and/or flat slopes. Soils in these areas are prone to higher runoff volumes and soil loss. Comparatively, lower TI values are typically seen in areas with small upslope contributing area and/or steep slopes. The TI was evaluated as a potential metric for selecting hydrologically similar comparison (healthy) watersheds when using the AllForX Approach.

CHAPTER 3: METHODS

The first objective of this research project was to determine if the criteria used to select comparison (reference) watersheds when applying the AllForX Approach to develop sediment TMDLs are equally important. The second objective was to compare the topographic index (TI) distributions for all watersheds (impaired and comparison) to evaluate whether TI could be used as a quantitative criteria for comparison watershed selection. The third and final objective was to compare how the TMDL AllForX threshold value varies when using an entire period of record of VSCI scores for the comparison and impaired watersheds versus the two most recent VSCI scores.

Watershed selection

This research is restricted to watersheds that lie within the Ridge and Valley physiographic region in Virginia. Impaired and comparison watersheds used in this research were selected based on river basin, drainage area, and the number of biological monitoring samples. Four groups of five watersheds each were assembled. Each group included an impaired watershed and four comparison watersheds. The 20 selected watersheds lie within the New and Upper James River Basins (Figure 3-1). Two groups in each basin were classified as "small-sized", 2.6 km^2 to 26 km^2 (1 and 10 square miles), and "medium-sized", 26 km^2 to 518 km^2 (10 and 200 square miles), streams (Table 3-1), in accordance with criteria developed by Ohio EPA (1987). This sizing criterion is analogous to classification by stream order.

Table 3-1. Breakdown of groups by drainage area and river basin

	Drainage Area	
River Basin	2.6-26 km^2	26-518 km^2
James River	JR1	JR2
New River	NR1	NR2

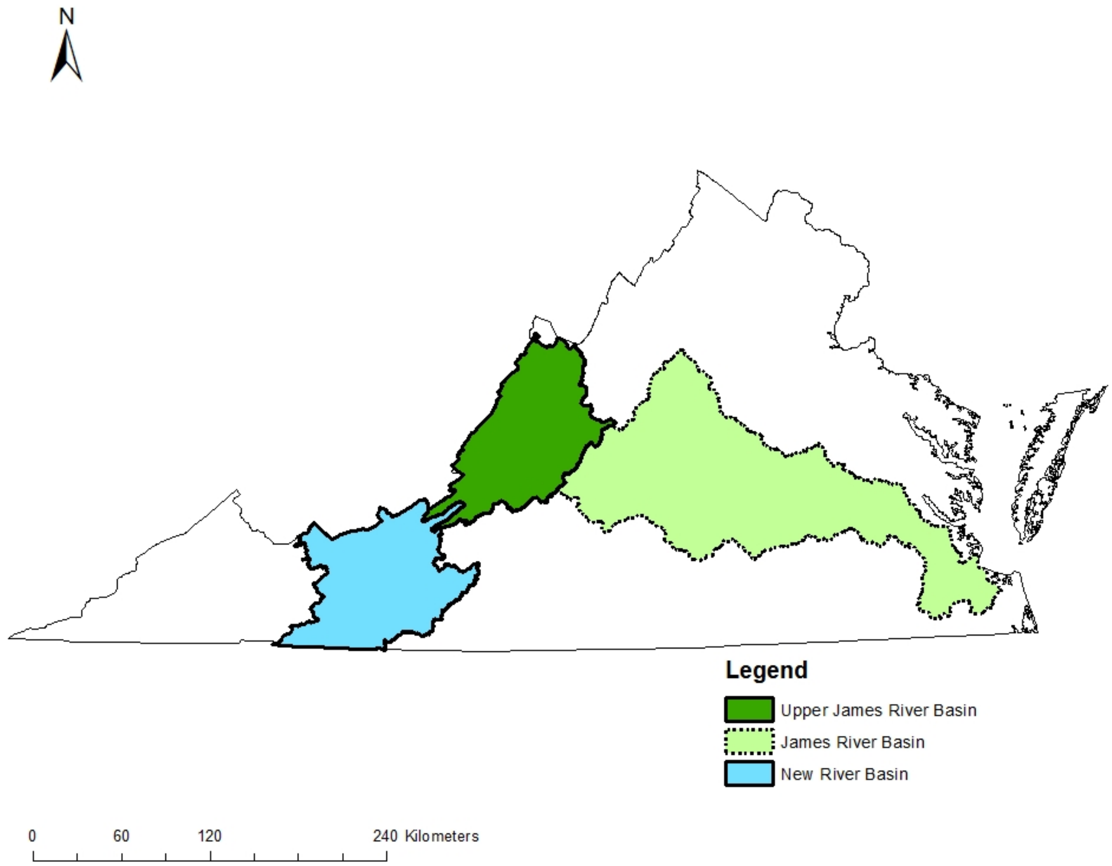


Figure 3-1. Location of Upper James River basin and New River basin within the state of Virginia

Streams identified with benthic impairments on Virginia's 2012 "303(d) list" that met the criteria outlined above (i.e., river basin and drainage area) formed the initial pool of impaired watersheds. Biological monitoring stations for each of the impaired watersheds were identified from the 303(d) list. Using the monitoring station locations and 10 x10 meter Digital Elevation Model (DEM; USGS, 2014) data, watersheds were delineated using ArcSWAT (Neitsch et al, 2002). Within the Upper James River basin, five impaired watersheds met the drainage area constraints (> 2.6 km^2 and < 518 km^2). In the New River basin, the current 303(d) list of impaired watersheds were all < 26 km^2. Therefore, to find an impaired watershed >26km^2, watersheds with an existing, EPA approved sediment TMDL were also considered.

For comparison healthy watersheds, the Virginia Department of Environmental Quality's (VADEQ) established list of reference biological monitoring stations in the New and Upper James River basin was used as a starting point (VADEQ, 2014) and the biological integrity

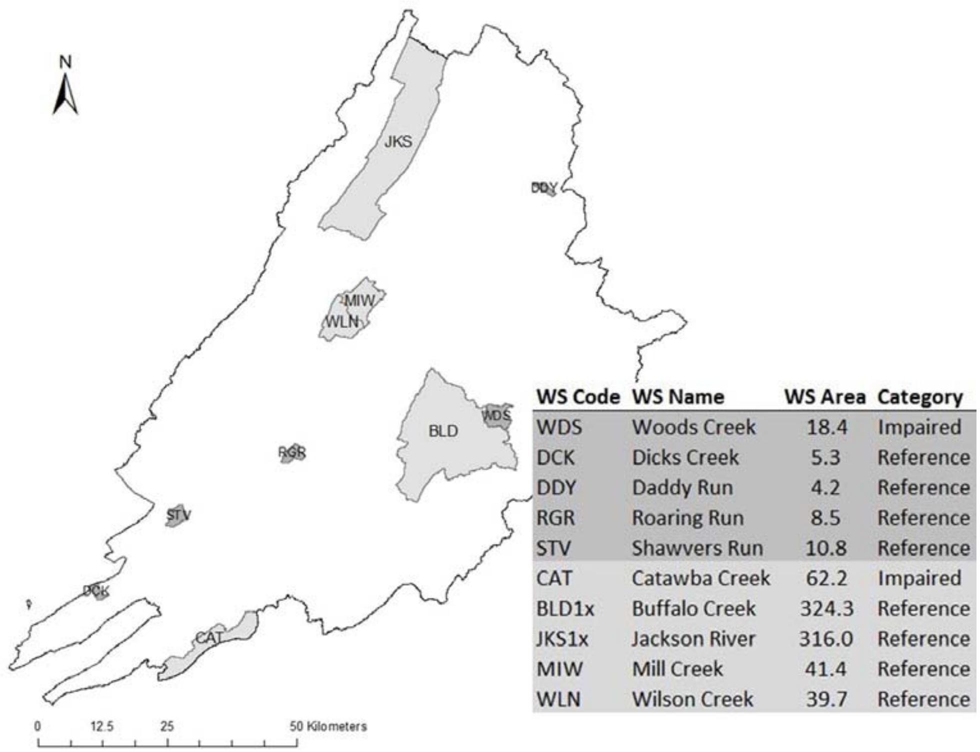
(VSCI scores) of each station were considered. Those stations with data showing no benthic impairment constituted the pool of comparison watersheds. The candidate comparison watersheds were delineated using the same procedures as the impaired watersheds. Watersheds with drainage areas of < 2.6 km^2 and > 518 km^2 were eliminated from the pool of candidate comparison watersheds.

The New River basin small watershed group (NR1) had only four potential candidate comparison watersheds. As a result, the other three watershed groups (NR2 and JR1 and JR2) were limited to four comparison watersheds. To ensure a consistent VSCI observation period between the four watershed groups, only those comparison watersheds with two or more VSCI score observations between 2003 and the present (Fall 2013) were considered.

If two biological monitoring stations were present on a candidate stream, only the most downstream station was considered. Once the pool of impaired and comparison watersheds was established, if more than one impaired watershed and/or more than four comparison watersheds met the selection criteria for each group, then the final groups of five watersheds were randomly selected, with the impaired and comparison watersheds treated as independent samples. Table 3-2 contains the list of candidate watersheds. The impaired watersheds are shaded grey. The watersheds used for this study are in **bold**. Figure 3-2 and 3-3 show the locations of the 20 selected watersheds by river basin and group.

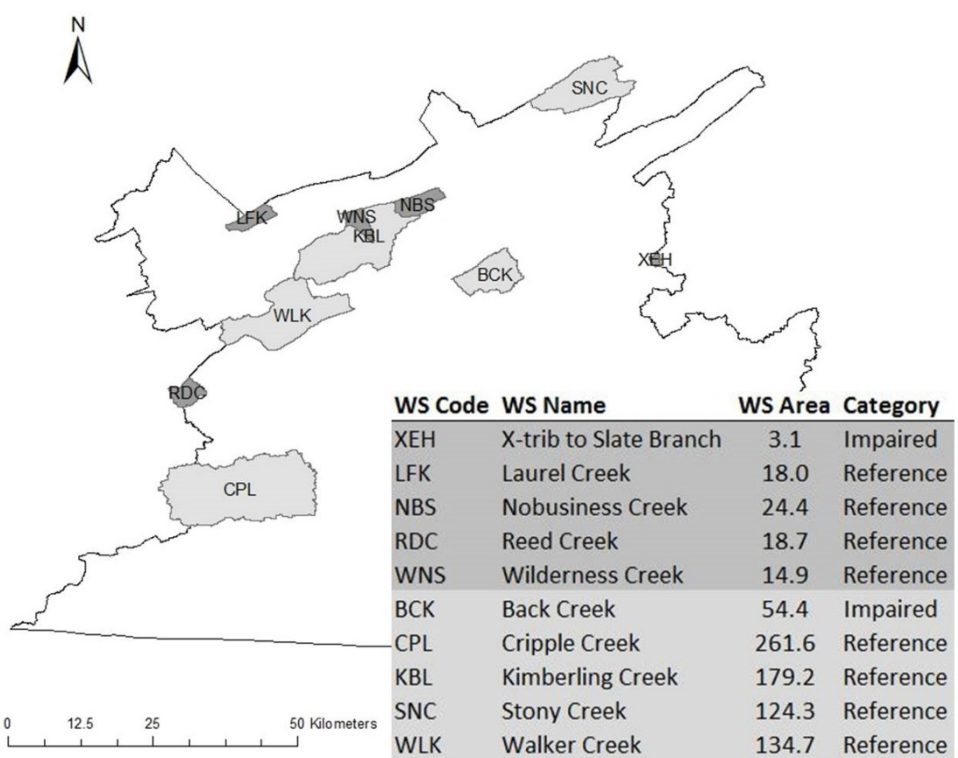
Table 3-2. Pool of candidate watersheds. Bolded watersheds were modeled for this study.

DEQ Station ID	Stream Name	Modeling Watershed Name	Watershed Area (km^2)	No. of Biological Samples	Average VSCI	Average of two most recent VSCI
James River basin, 2.6-26 km^2 (JR1)						
2-MRC002.14	Moore's Creek	MRC	6.9	7	45.1	57.9
2-WDS000.12	**Woods Creek**	**WDS**	**18.4**	**3**	**39.5**	**48.4**
2-XUL001.67	Mill Creek, UT (XUL)	XUL	4.6	2	42.4	42.4
2-CSR003.94	Cast Steel Run	CSR	10.1	2	75.6	75.6
2-DCK003.94	**Dicks Creek**	**DCK**	**5.3**	**4**	**71.6**	**71.4**
2-DDY000.75	**Daddy Run**	**DDY**	**4.2**	**4**	**76.5**	**81.4**
2-PTR005.13	Patterson Creek	PTR	20.7	2	66.6	66.6
2-RGR001.11	**Roaring Run**	**RGR**	**8.5**	**4**	**74.5**	**75.2**
2-STV000.48	**Shawvers Run**	**STV**	**10.8**	**2**	**74.6**	**74.6**
2-XQO000.02	X Trib Poor Creek	XQO	10.9	3	74.6	74.6
2AXQS001.07	X trib to Sinking Creek	XQS	3.3	2	81.8	81.8
James River basin, 26-518 km^2 (JR2)						
2-CAT026.55	**Catawba Creek**	**CAT**	**62.2**	**2**	**46.7**	**46.7**
2-CLL003.21	Colliers Creek	CLL	57.0	6	52.4	54.3
2-BCC001.90	Back Creek	BCC	342.0	2	74.2	74.2
2-BLD000.22	**Buffalo Creek**	**BLD**	**324.3**	**4**	**66.7**	**70.2**
2-BLP000.79	Bullpasture River	BLP	284.9	3	68.0	70.0
2-JKS067.00	**Jackson River**	**JKS**	**316.0**	**3**	**75.7**	**76.9**
2-MIW003.45	**Mill Creek**	**MIW**	**41.4**	**3**	**82.0**	**81.2**
2-POT031.78	Potts Creek	POT	82.9	2	75.0	75.0
2-WLN009.07	**Wilson Creek**	**WLN**	**39.7**	**3**	**74.2**	**77.2**
New River basin, 2.6-26 km^2 (NR1)						
9-LTL001.22	Little Creek	LTL	6.7	7	50.6	59.8
9-XEH000.75	**X-Trib to Slate Branch**	**XEH**	**3.1**	**2**	**23.0**	**23.0**
9-LFK005.39	**Laurel Creek**	**LFK**	**18.0**	**6**	**70.3**	**72.9**
9-NBS006.58	**Nobusiness Creek**	**NBS**	**24.4**	**2**	**70.6**	**70.6**
9-RDC051.21	**Reed Creek**	**RDC**	**18.7**	**2**	**61.5**	**61.5**
9-WNS001.03	**Wilderness Creek**	**WNS**	**14.9**	**2**	**61.6**	**61.6**
New River basin, 26-518 km^2 (NR2)						
9-BCK009.47	**Back Creek**	**BCK**	**54.4**	**5**	**37.7**	**32.6**
9-CPL012.73	**Cripple Creek**	**CPL**	**261.6**	**2**	**74.2**	**74.2**
9-KBL007.24	**Kimberling Creek**	**KBL**	**179.2**	**2**	**69.3**	**69.3**
9-SFK002.81	Stony Fork	SFK	41.4	6	65.8	67.9
9-SNC005.04	**Stony Creek**	**SNC**	**124.3**	**2**	**73.6**	**73.6**
9-WLK052.27	**Walker Creek**	**WLK**	**134.7**	**2**	**68.0**	**68.0**



WS Code	WS Name	WS Area	Category
WDS	Woods Creek	18.4	Impaired
DCK	Dicks Creek	5.3	Reference
DDY	Daddy Run	4.2	Reference
RGR	Roaring Run	8.5	Reference
STV	Shawvers Run	10.8	Reference
CAT	Catawba Creek	62.2	Impaired
BLD1x	Buffalo Creek	324.3	Reference
JKS1x	Jackson River	316.0	Reference
MIW	Mill Creek	41.4	Reference
WLN	Wilson Creek	39.7	Reference

Figure 3-2. Map of Final Upper James River Impaired and Comparison Watershed Selection



WS Code	WS Name	WS Area	Category
XEH	X-trib to Slate Branch	3.1	Impaired
LFK	Laurel Creek	18.0	Reference
NBS	Nobusiness Creek	24.4	Reference
RDC	Reed Creek	18.7	Reference
WNS	Wilderness Creek	14.9	Reference
BCK	Back Creek	54.4	Impaired
CPL	Cripple Creek	261.6	Reference
KBL	Kimberling Creek	179.2	Reference
SNC	Stony Creek	124.3	Reference
WLK	Walker Creek	134.7	Reference

Figure 3-3. Map of Final New River Impaired and Comparison Watershed Selection

GWLF Model

The Generalized Watershed Loading Function model (GWLF) was selected for simulating sediment loads for this research. The model has commonly been used in the past to develop Sediment TMDLs in Virginia (Yagow et. al, 2011, Yagow et. al, 2014). The GWLF model requires three input files; a weather file that includes precipitation and temperature data, a transport file that includes parameters the model uses when simulating sediment loss and delivery (e.g., SCS CN), and a nutrient file that characterizes nitrogen and phosphorus fate and transport (the GWLF transport input files for the 20 simulated watersheds are included in Appendix C). The current version of the GWLF model (GWLF2010) was used for this research. The model was run in metric units using a 21-year period of record (1990-2010).

The GWLF model simulates hydrology using a daily water balance. Runoff is simulated using the SCS-CN method, Equations 2.2 and 2.3. The USLE is used within GWLF to estimate erosion for pervious land uses, Equation 2.4. Erosion from impervious land uses is generated using a buildup-washoff function. Sediment loads transported to the water body are calculated using a SDR, Equations 2.5 and 2.6, that is a function of watershed size. Stream bank and channel erosion is calculated using an algorithm developed by Evans et al (2003). GWLF generates monthly sediment loads by land use for each watershed being modeled.

Weather Input File

The weather input file provides daily average precipitation (cm) and temperature (^{o}C), organized in weather years (April-March). The Climate Forecast System Reanalysis (CFSR) was selected to generate the weather data needed to run the model. CFSR is a global meteorological dataset that interpolates hourly historical data (1979-2010) to generate local weather data using latitude and longitude (Fuka, 2013). The latitude and longitude coordinates of the centroid of each watershed were used as the location for extracting data from the CFSR. For this application, the database was queried for daily precipitation and maximum and minimum temperature. Daily maximum and minimum temperatures were averaged to develop required GWLF inputs.

Transport Input File

Hydrologic, erosion, and sediment parameters used to generate surface runoff and erosion, and stream bank and channel erosion, are included in the transport input file, Appendix C. These include parameters used to calculate the USLE and CNs that are determined by land use and soil characteristics.

Land Use Data

Land use data was derived from the USDA National Agricultural Statistics Service (NASS) digital cropland data layer for 2009 (NASS, 2009), which incorporates detailed agricultural land use data from the USDA Natural Resources Inventory dataset and non-agricultural land use data from the 2006 National Land Cover Dataset (NLCD) (Fry et. al., 2011). The specific land uses in the NASS dataset were aggregated into broader land use groups. The broader land use groups and specific land uses are shown in the first two columns in Table 3-3.

The NASS grouped land uses were then further manipulated to better represent the various major sediment sources in the watershed with GWLF. These GWLF-modeled land uses are shown in Table 3-3. Table 3-3 also shows the percent imperviousness associated with a given GWLF-modeled land use category. For GWLF modeling purposes, the NASS row crop land use group is divided into hi-till and lo-till categories based on the land use distributions developed by the Department of Conservation and Recreation (DCR) for the 2006 Virginia statewide NPS watershed assessment (Yagow and Hession, 2007) using the 6^{th} order Virginia hydrologic units (VAHU6). Using the process outlined by Yagow and Hession (2007), the NASS hay and pasture land uses were combined and redistributed into the GWLF-modeled land uses also using county-wide distributions from the 2006 NPS assessment. In instances where a watershed modeled for this study intersected multiple VAHU6 units, the area-weighted average percent distribution of the hay and pasture land uses was used to redistribute the NASS land uses.

Pasture land use was further disaggregated (Table 3-3) into three levels of pasture quality (good, fair and poor), trampled riparian pasture (trp), and animal feeding operations (afo). The pasture land use disaggregation was accomplished using the land use distributions developed for the Chesapeake Bay Watershed Model (CBWM). The CBWM uses 26 agricultural land uses, including trp and afo, to estimate pollutant loads (USEPA, 2010). These land use distributions are available by land-river segment (modeling units used in the CBWM). Using GIS, the land-river segments that intersect the 20 study watersheds used for this research were determined. The trp and afo land uses in those land-river segments were calculated as a percentage of total pasture/hay for each land-river segment. The percentage of trp and afo to pasture/hay were multiplied by the total pasture area per watershed to obtain trp and afo areas. For watersheds intersecting multiple land-river segments, area-weighted averages were calculated for the trp and afo percentages before being multiplied by the total pasture area within the watershed. Remaining pasture area not assigned to trp and afo was distributed between good (10%), fair (70%) and poor (20%) pasture (Yagow et. al, 2014). In the absence of more detailed information, this pasture land use distribution was used for all 20 study watersheds. Harvested forest was calculated as 1% of the forest land use category (USEPA, 2010). The barren land use category was calculated as 1% of the total watershed area. NASS groups "developed" land uses into three categories, low intensity (LDI), medium intensity (MDI), and high intensity (HDI). For use with GWLF, the developed land uses were divided into impervious and non-impervious components with impervious land use percentages of 20% for LDI, 50% for MDI, and 80% for HDI areas (Fry et al, 2011). To provide a way to compare the general land use distributions between the 20 watersheds used in this study, the GWLF-modeled land use categories were aggregated into three broad land use categories, agricultural, forest, and urban (last column Table 3-3). The aggregated land use comparison for the study watersheds is shown in Table 3-4, with the impaired watershed in each grouping highlighted in grey. A detailed land use distribution comparison using the GWLF-modeled land uses is provided in Appendix A.

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Table 3-3. GWLF Land Use Categories

NASS Groups	NASS Land Uses	GWLF-Modeled Land Use Categories	% Impervious	Aggregate Land Use categories
Row Crop	Corn, sorghum, soybeans, winter wheat, etc.	Hi-till cropland	0	Agriculture
		Lo-till cropland		Agriculture
Hay	Alfalfa, other hay	Hay	0	Agriculture
Pasture	Pasture/grass, shrubland, grassland herbaceous	Good pasture	0	Agriculture
		Fair pasture		Agriculture
		Poor pasture		Agriculture
		Trampled riparian pasture (trp)		Agriculture
		Animal feeding operation (afo)		Agriculture
Forest	Deciduous forest, evergreen forest, mixed forest	Forest	0	Forest
		Harvested forest		Forest
Barren	Barren	Barren	0	Urban
Open Space	Urban open space	Open space	0	Urban
LDI	Developed, low intensity	Impervious LDI	20	Urban
		Pervious LDI		Urban
MDI	Developed, medium intensity	Impervious MDI	50	Urban
		Pervious MDI		Urban
HDI	Developed, high intensity	Impervious HDI	80	Urban
		Pervious HDI		Urban

Table 3-4. Aggregated land use distribution comparison

Stream Name	Watershed Abbreviation	% Forest	% Agri.	% Urban	Watershed Area (km^2)
JR1					
Woods Creek	WDS	19.9	39.8	40.1	18.4
Dicks Creek	DCK	97.2	0.5	1.3	5.3
Daddy Run	DDY	94.4	0.0	4.7	4.2
Roaring Run	RGR	87.2	9.5	2.5	8.5
Shawvers Run	STV	96.0	0.6	2.5	10.8
JR2					
Catawba Creek	CAT	73.1	21.6	4.6	62.2
Buffalo Creek	BLD	72.2	21.2	5.8	324.3
Jackson River	JKS	76.5	19.4	3.3	316.0
Mill Creek	MIW	94.5	1.3	3.2	41.4
Wilson Creek	WLN	94.8	0.3	3.9	39.7
NR1					
X-trib to Slate Branch	XEH	1.5	18.8	79.6	3.1
Laurel Creek	LFK	88.3	6.6	4.2	18.0
Nobusiness Creek	NBS	97.8	0.1	1.1	24.4
Reed Creek	RDC	98.4	0.5	0.0	18.7
Wilderness Creek	WNS	80.9	15.2	3.2	14.9
NR2					
Back Creek	BCK	36.1	60.5	3.0	54.4
Cripple Creek	CPL	62.7	33.1	3.6	261.6
Kimberling Creek	KBL	86.7	10.3	2.1	179.2
Stony Creek	SNC	97.4	0.2	1.4	124.3
Walker Creek	WLK	58.3	35.8	4.9	134.7

Soils Data

Data from the State Soil Geographic (STATSGO) database (NRCS, 2014) was used to calculate various soil parameter inputs for GWLF. Many of the watersheds selected for this study include National Forest land. The STATSGO database is typically the most detailed soil data available for National Forest land. Therefore, to be consistent, STATSGO data was used for all watersheds. STATSGO data was downloaded on a county by county basis. Soil layers intersecting each watershed were merged and then clipped to provide full soil coverage to each watershed.

The CNs were calculated for each unique land use and hydrologic soil group combination (HRU). The erosion product, KLSCP forms the majority of the USLE and was calculated using soils data from the STATSGO database, the DEM, and the crop management lookup table, for each land use. Modifications on two Microsoft Excel spreadsheets ("Land use" and "Watershed") created by Yagow (2014) were used to compile these parameters and generate the input files for GWLF. Descriptions of all of the parameters required by GWLF can be found in Appendix B.

Two sets of GWLF transport input files were generated. The first set of transport files used the existing land use conditions for all 20 watersheds (Appendix C). Twenty additional transport files were generated for the all-forested conditions. In these latter transport files, the existing land use-related parameter values were changed to "forest" land use-related parameter values, while retaining the existing soil and topographic properties for each HRU. The CN and KLSCP values were recalculated.

Nutrient Input File

Because this research focused solely on sediment fate and transport, the only parameter of interest in the nutrient file was the sediment buildup rate, which accounts for sediment accumulation on impervious surfaces. For this research a sediment buildup rate was specified for each impervious land use category and default values were used for the other parameters in the nutrient.dat file. Nutrient files were generated using the same Microsoft Excel spreadsheets used to generate the transport files. The nutrient files were also created for the same two scenarios (existing and all-forested conditions) for all 20 watersheds.

Data Analysis

The AllForX Approach uses average annual sediment loads and VSCI scores to determine target sediment loads for impaired watersheds. GWLF generates monthly sediment loads for each land use within each watershed and does not provide sediment reductions for established BMPs. Post-processing was conducted to account for existing BMPs and summarize average annual loads for each watershed. VSCI scores were also collected for the AllForX regression.

Post-Processing

To account for established BMPs, within watersheds, Virginia DCR's developed pass-through fractions for each land use within each VAHU6 were used to represent the effectiveness of BMPs on reducing sediment loads (Yagow and Hession, 2007). These pass-through fractions were multiplied by the average annual sediment loads to account for sediment reductions from existing BMPs within each land use after GWLF modeling was run. These steps were accomplished using a Microsoft Excel spreadsheet. The spreadsheet that was used for this study automates much of the GWLF model output data summarization process (Yagow, 2014).

Modeled sediment loads by land use were summed for each watershed for both existing and all-forested conditions. The AllForX values for each watershed were calculated by dividing the existing sediment load by the all-forested sediment load. To keep sediment load comparisons consistent across the 20 watersheds, point sources were not considered in the model. MOS values were calculated, but were not used in the comparison of the AllForX target values.

VSCI Scores

The Ecological Data Application System (EDAS) is a restricted access database, which is maintained by VADEQ and is the primary repository for biological monitoring data collected by the state including semi-annual VSCI scores (Tetra Tech, 1999; VADEQ, 2014). With the assistance of VADEQ staff, VSCI score data from 2003 to the present (2013) was extracted from the EDAS database for the twenty watersheds modeled for this study. Using this data, two average VSCI scores were computed for each modeled watershed; one that used all the available data (2003 – 2013) ($VSCI_T$), and one that used only the two most recent scores ($VSCI_2$). These two averages were used in the AllForX Approach to assess the impact of using all the available data versus only the most recent VSCI data, which may be more reflective of the current conditions in the watershed.

Comparison of AllForX regressions

To address objective one, the AllForX value for each of the 20 modeled watersheds was plotted against the arithmetic average VSCI score for each watershed using the entire period of record of VSCI data ($VSCI_T$). A regression was then fit to each of the four watershed groups. The resulting regressions were compared to determine if the regressions were significantly different. For each regression, the AllForX threshold value ($AllForX_{TV}$) was determined for a VSCI score of 60 (i.e. the impairment threshold). Additional comparisons were made for regressions developed by plotting each of the four impaired watersheds ($JR1_I$, $JR2_I$, $NR1_I$, $NR2_I$) with each of the four comparison watershed groups ($JR1_C$, $JR2_C$, $NR1_C$, $NR2_C$). In other words, for a given impaired watershed (e.g., $JR1_I$), a regression line was fit to each of the comparison watershed groups and that impaired watershed, for a total of four regression lines. This was repeated for each impaired watershed. A multiple regression analysis with correlating contrast tests was performed to determine if there were significant differences in y-intercepts and slopes of these regressions. The statistics were repeated using each of the impaired watersheds as the basis for evaluating the significance of the two comparison watershed selection criteria (river basin and drainage area). This same process was done to compare the regressions and $AllForX_{TV}$ values when only the two most recent VSCI scores were averaged ($VSCI_2$), objective three. All statistical analysis was performed using R (R Core Team, 2013).

Topographic Index

To address the second objective of this study the distribution of topographic indices (TI) were compared among the 20 modeled watersheds. The TI parameter quantitatively characterizes the topography of a given watershed. The TI is a function of contributing upslope catchment area and local slope steepness. A subset of tools within the Spatial Analyst toolset in ArcGIS 10.2 was used to generate topographic indices for each watershed. A 30 x 30 meter DEM was used to calculate slope steepness ($\tan\beta$). Using the Hydrology Toolset in ArcGIS, the DEM, and the watershed boundary, flow accumulation (α) was calculated. TI values were calculated for each 30 x 30 meter raster cell within the watershed in the raster calculator tool within ArcGIS.

A distribution of the TI cell counts was generated from ArcGIS for each watershed using the zonal histogram tool within ArcGIS. The TI values were normalized and used to create a distribution that could then be compared for statistically significant differences between the distributions.

Comparison of TI Distributions

Multiple non-parametric Pairwise Wilcoxon Rank Sum tests were used to compare the differences in watershed TI distributions within each of the watershed groups and across groups. The Pairwise Wilcoxon Rank Sum test ranks each TI data point within each distribution being compared and then compares the median of the ranks. A Wilcoxon Rank Sum test was used to compare the two watersheds in each group whose distributions appeared the most different based on a visual comparison of distribution box and whisker plots. Unlike the Pairwise Wilcoxon Rank Sum test, the Wilcoxon Rank Sum test only evaluates the median of ranks of two groups of data (watersheds).

The TI distributions were large samples, including from 23,000 values to over 350,000 data points (i.e., TI values) for each watershed. To evaluate the magnitude of difference between two distributions, the effect size was calculated for each Wilcoxon Rank Sum test. A small effect size represents no practical meaning for small differences in two distributions that produce a significant difference in the Pairwise Wilcoxon Rank Sum test.

CHAPTER 4: RESULTS AND DISCUSSION

Objective 1: Determine the significance of stream order and river basin when selecting comparison watersheds

The first objective of this study was to determine if the characteristics (i.e., within the same river basin as the impaired watershed and of a similar stream order to the impaired watershed) used to select comparison (healthy) watersheds when applying the AllForX Approach to develop sediment TMDLs, are significant. To address this objective, AllForX values for each of the 20 watersheds modeled for this study were calculated by dividing the existing land use condition simulated sediment loads by the all-forested simulated sediment loads (Table 4-1). The 20 watersheds were grouped, based on river basin and drainage area (stream order), into four groups. The AllForX value for each watershed was then plotted against the corresponding arithmetic average VSCI score for that watershed, using the entire period of record to calculate the average VSCI score ($VSCI_T$). A unique linear regression was fit to each of the four watershed groups, Figure 4-1. A multiple regression analysis was performed along with linear contrasts to systematically compare the slope and y-intercepts of each group with the three other groups. The hypothesis for this analysis is that the slope and y-intercepts were not different across any of the four watershed groups.

Table 4-1. GWLF-modeled results, AllForX values and VSCI scores for the four watershed groups.

Watershed Name	Watershed Code	Avg. Annual Sediment Load Existing Conditions (Ton/yr)	Avg. Annual Sediment Load All-forested Conditions (Ton/yr)	AllForX	Avg $VSCI_T$	Avg. $VSCI_2$
JR1						
Woods Creek	WDS	2,535.2	109.0	23.3	39.5	48.4
Dicks Creek	DCK	43.6	34.8	1.3	71.6	71.4
Daddy Run	DDY	55.8	36.2	1.5	76.5	81.4
Roaring Run	RGR	330.7	66.2	5.0	74.5	75.2
Shawvers Run	STV	106.2	69.3	1.5	74.6	74.6
JR2						
Catawba Creek	CAT	3,110.6	396.2	7.9	46.7	46.7
Buffalo Creek	BLD	11,389.1	2,083.6	5.5	66.7	70.2
Jackson River	JKS	10,146.8	1,542.7	6.6	75.7	76.9
Mill Creek	MIW	373.9	219.9	1.7	82.0	81.2
Wilson Creek	WLN	322.9	230.3	1.4	74.2	77.2
NR1						
X-trib to Slate Branch	XEH	224.6	6.0	37.4	23.0	23.0
Laurel Creek	LFK	132.6	106.1	3.6	70.3	72.9
Nobusiness Creek	NBS	319	89.8	1.2	70.6	70.6
Reed Creek	RDC	200.7	164.2	1.2	61.5	61.5
Wilderness Creek	WNS	590.6	93.1	6.3	61.6	61.6
NR2						
Back Creek	BCK	4,992.1	250.0	20.0	37.7	32.6
Cripple Creek	CPL	20,393.8	2,770.9	7.4	74.2	74.2
Kimberling Creek	KBL	3,032.5	861.4	3.5	69.3	69.3
Stony Creek	SNC	554.8	441.3	1.3	73.6	73.6
Walker Creek	WLK	8,268.2	724.2	11.4	68.0	68.0

A cursory visual examination of Figure 4-1 could lead one to conclude that the regression lines for three of the four watershed groups (JR1, NR1, and NR2) are similar and that the regression for JR2 group has a different slope and intercept from the other three groups. However, the results of the statistical analysis indicate that there is no statistical significant difference between the regression lines fit to the four groups of watersheds. Recall that the $AllForX_{TV}$ is the AllForX value that corresponds to VSCI = 60 along the regression line for a given group. $AllForX_{TV}$ are shown in Figure 4-1 for each watershed group. Since the regression lines of the four watershed groups were not significantly different, the $AllForX_{TV}$ were also not significantly different.

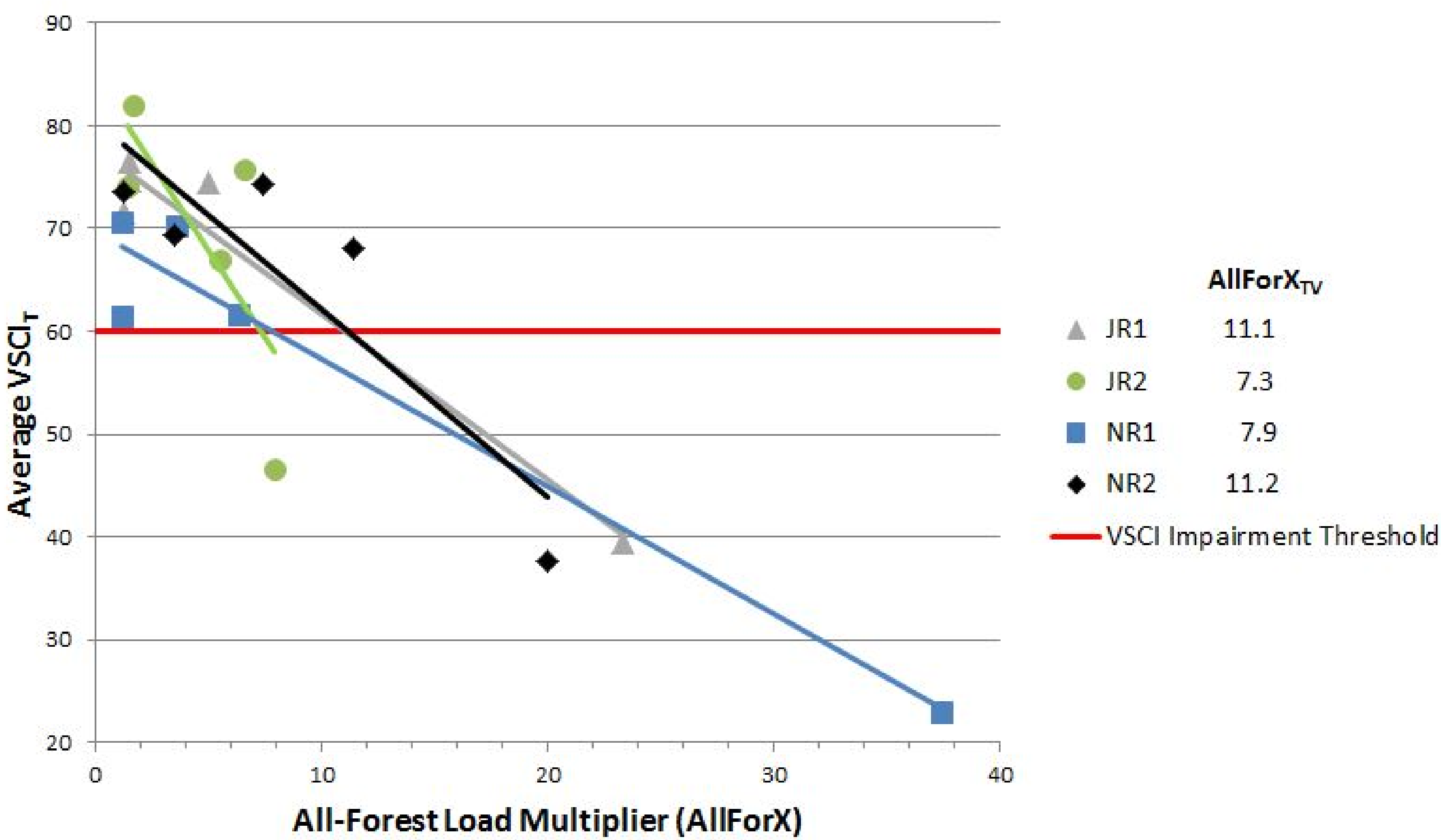

Figure 4-1.Regressions and AllForX$_{TV}$ for four watershed groups using all available VSCI$_T$ data (2003-2013).

Because there was no significant difference among the regressions for the four groups, this implies that any (or all) of the comparison watersheds could be used as comparisons for any (or all) of the impaired watersheds. Figure 4-2 shows the resulting regression when all 20 watersheds are combined to yield a single regression. The $AllForX_{TV}$ for the combined regression is 10.6. These results indicate that within the Ridge and Valley physiographic region, for the 20 watersheds modeled for this study, river basin and drainage area are not significant variables that must be considered when selecting comparison watersheds for use in the AllForX Approach.

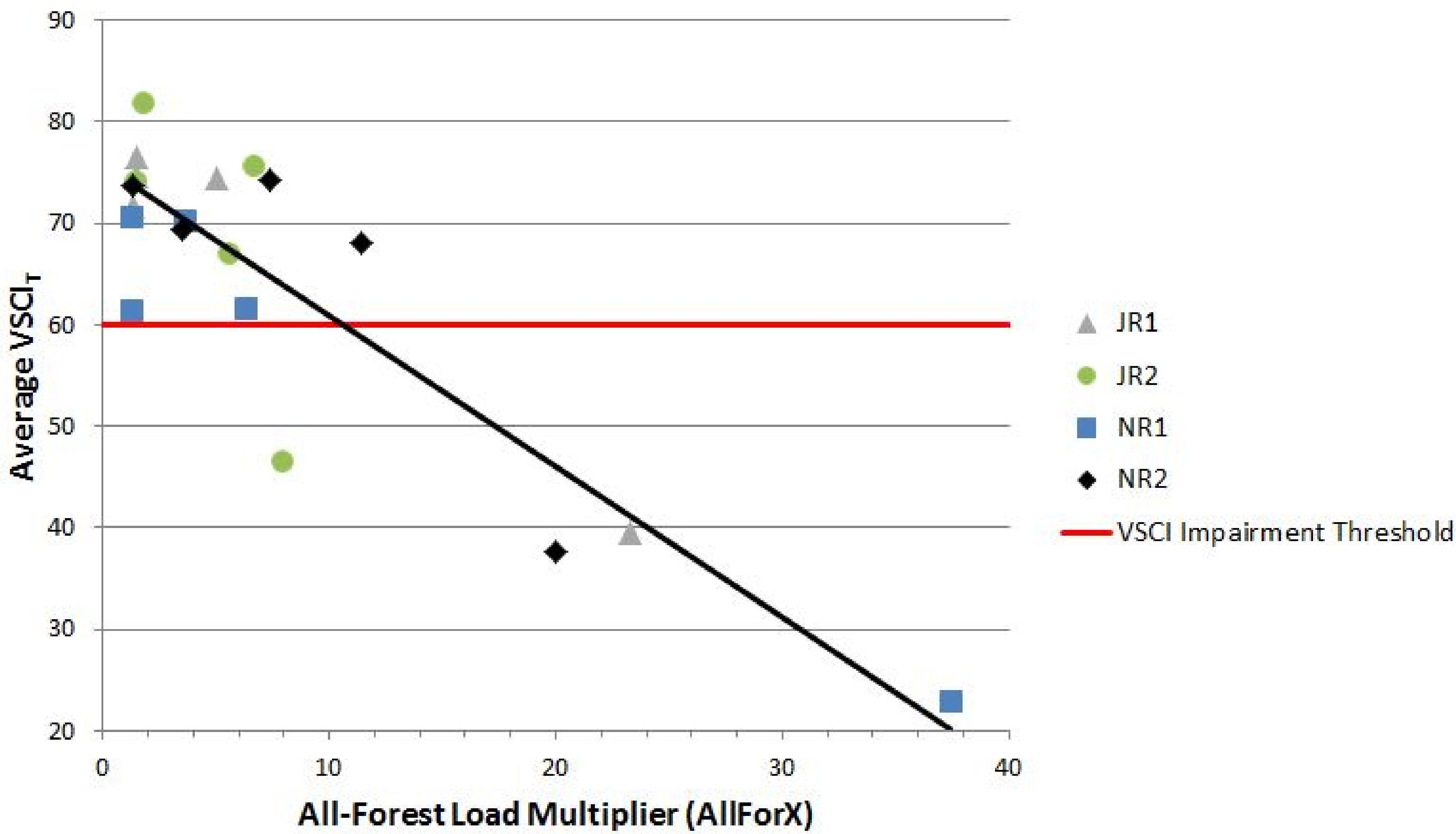

Figure 4-2. Regression of all 20 watersheds

To further evaluate the significance of the comparison watershed selection criteria, each of the four impaired watersheds ($JR1_I$, $JR2_I$, $NR1_I$, $NR2_I$) were plotted using each of the four comparison watershed groups ($JR1_C$, $JR2_C$, $NR1_C$, $NR2_C$). In other words, for a given impaired watershed (e.g., $JR1_I$), a regression line was fit using that impaired watershed and each of the comparison watershed groups for a total of four regression lines. This was repeated for each impaired watershed. A multiple regression analysis was performed along with contrast tests to test for significant differences between slope and y-intercepts for the various lines. This analysis was repeated using each of the impaired watersheds as the basis for comparison between the two criteria (river basin and drainage area).

There were six regression analysis groupings for each impaired watershed. Each regression analysis grouping compared the statistical difference between two regression lines, using the same impaired watershed but different comparison watershed groups. The regression analysis groupings fell into three categories: (1) within the same drainage area but across river basin; (2) across the two river basins (Upper James and New) and across drainage area; and (3) within river basin and across drainage area, Table 4-2. These groupings examined whether river basin or drainage area were significant when selecting comparison watersheds for the AllForX Approach. Regressions that were significantly different are in bold and have p-values less than 0.05, Table 4-2. Significant differences across river basin and across drainage area occurred when the impaired watersheds $JR1_I$, $NR1_I$, and $NR2_I$ were plotted using the comparison watersheds $NR1_C$ and $JR2_C$. Significant differences within river basin and across drainage area occurred when $NR1_I$ was plotted with $NR1_C$ and $NR2_C$. Plots of the regression lines that demonstrated significant differences are shown in Figures 4-3a, 4-3c, 4-3e and 4-3g.

Table 4-2. Regression analysis results with all comparison watersheds

	Within Drainage Area, Across River Basin		Across River Basin, Across Drainage Area		Within River Basin, Across Drainage Area	
Impaired Watershed	**Small ($JR1_C$, $NR1_C$)**	**Large ($JR2_C$, $NR2_C$)**	**$JR1_C$, $NR2_C$**	**$NR1_C$, $JR2_C$**	**New River ($NR1_C$, $NR2_C$)**	**James River ($JR1_C$, $JR2_C$)**
$JR1_I$	0.089[†]	0.714	0.770	**0.025**	0.068	0.458
$JR2_I$	0.389	0.346	0.557	0.298	0.850	0.745
$NR1_I$	0.066	0.788	0.668	**0.019**	**0.040**	0.467
$NR2_I$	0.143	0.718	0.759	**0.044**	0.124	0.452

[†]p-value

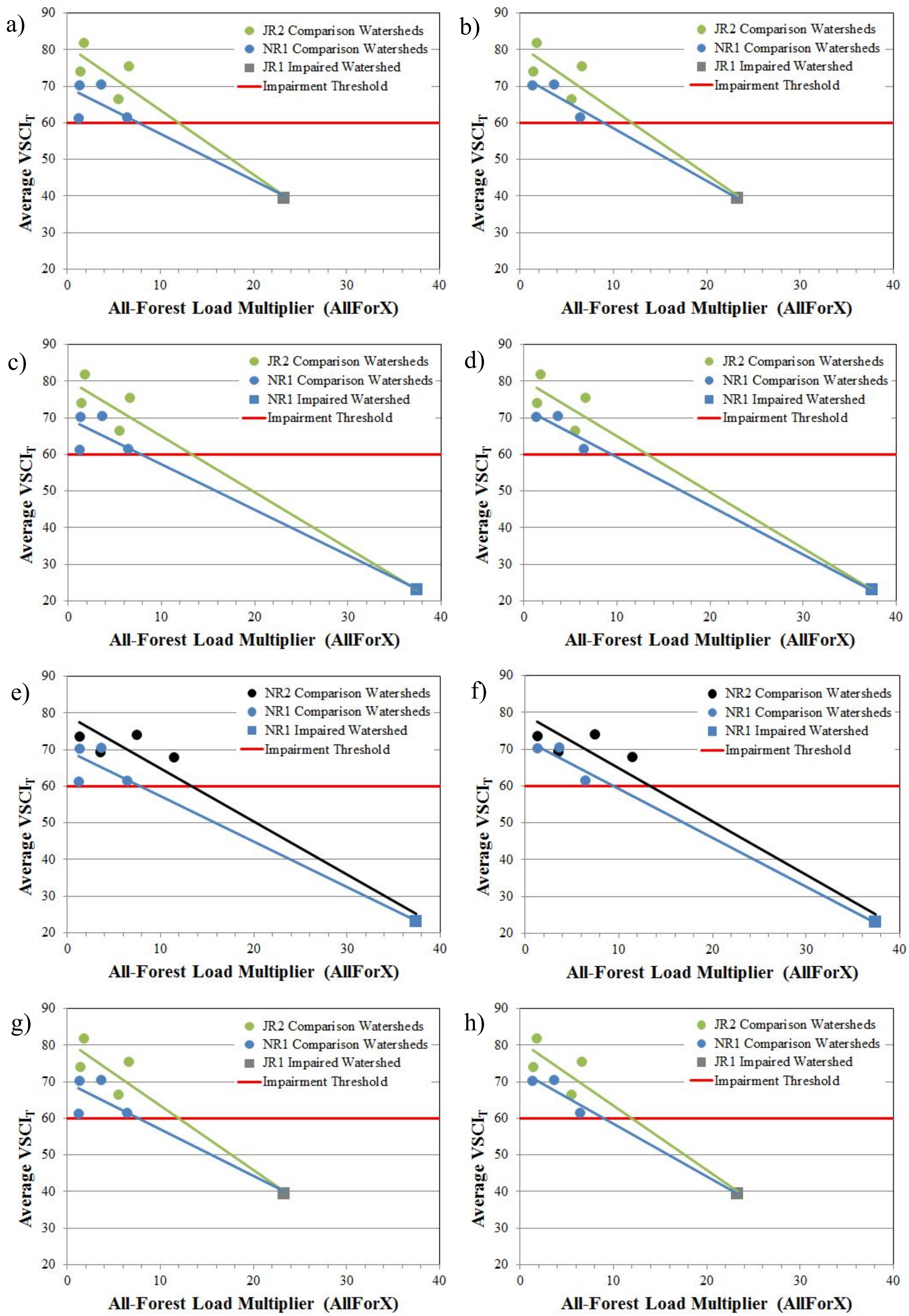

Figure 4-3. Regressions showing significant differences with NR1c; regressions with NR1c removed

A commonality between all of the significant differences shown in Table 4-2 is the New River small comparison watershed group ($NR1_c$). Within that group, the left most data point shown in Figures 4-3a, 4-3c, 4-3e and 4-3g is Reed Creek. Reed Creek is a heavily forested watershed (98.4%) with a comparatively small AllForX value (1.2) as one would expect, but that has an average VSCI score just above the VSCI impairment threshold (61.5). This watershed does not follow the expected sediment load to biological condition relationship when using the AllForX Approach. When differences between existing condition sediment load and the all-forested sediment loads are small (represented by a small AllForX value), one would expect a healthy biological condition to exist, i.e., an average VSCI score well above the threshold value of 60. In Reed Creek, the comparatively low average VSCI score (61.5) indicates that factors other than sediment are likely stressing the benthic community causing the low average VSCI score. Because Reed Creek does not conform to the expected relationship between AllForX and VSCI score, the watershed was removed from the $NR1_C$ group, and the multiple regression analysis and contrast tests discussed previously were repeated.

Removing Reed Creek from the $NR1_C$ group resulted in no significant differences across all regression analysis groupings, Table 4-3, and Figures 4-3b, 4-3d, 4-3f, and 4-3h. With the removal of Reed Creek, the results indicate that within the Ridge and Valley physiographic region, for the 19 modeled watersheds (Reed Creek excluded), any combination of properly screened comparison watersheds used in conjunction with any impaired watershed will result in statistically-similar TMDL target threshold values when using the AllForX Approach.

Table 4-3. Regression analysis results excluding Reed Creek (NR1 comparison group)

	Within Drainage Area, Across River Basin		Across River Basin, Across Drainage Area		Within River Basin, Across Drainage Area	
Impaired Watershed	**Small ($JR1_C$, $NR1_C$)**	**Large ($JR2_C$, $NR2_C$)**	**$JR1_C$, $NR2_C$**	**$NR1_C$, $JR2_C$**	**New River ($NR1_C$, $NR2_C$)**	**James River ($JR1_C$, $JR2_C$)**
$JR1_I$	0.299	0.697	0.756	0.097	0.208	0.431
$JR2_I$	0.826	0.348	0.558	0.651	0.764	0.746
$NR1_I$	0.222	0.773	0.645	0.071	0.129	0.436
$NR2_I$	0.426	0.705	0.748	0.158	0.332	0.432

† p-value

Objective 2: Evaluating the topographic index (TI) as a potential quantitative criterion for selecting comparison watersheds for the AllForX Approach

The second objective of this study was to evaluate the utility of the TI as a potential quantitative criterion for use when selecting comparison watersheds for the AllForX Approach. To address this objective, a TI distribution was developed for each of the 20 modeled watersheds. The TI values for each watershed were calculated using ArcGIS. The values were normalized and plotted as distributions. Visually, the general shape of the distributions across all 20 watersheds is similar. The distributions for all 20 watersheds are positively skewed, as indicated by the TI distribution for Buffalo Creek watershed in Figure 4-4. Lower TI values represent areas with small upland contributing areas and/or a steep slope.

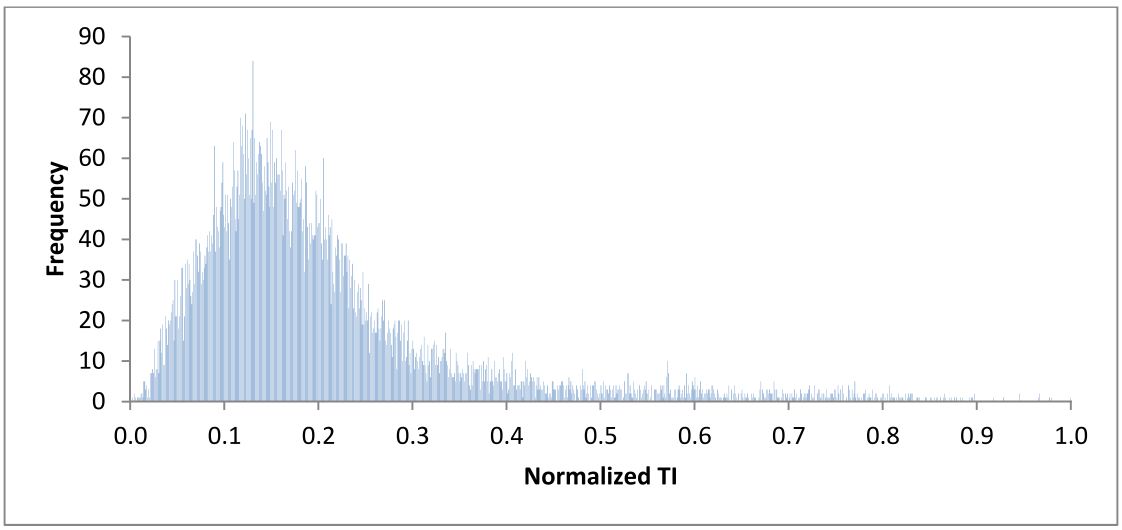

Figure 4-4. TI distribution for Buffalo Creek watershed in group JR2

Boxplots were generated for each of the four groups of watersheds to visually compare the median, quartiles and outliers for each distribution, Figures 4-5 through Figure 4-8. The medians are similar within each group of watersheds and across the groups. In addition each of the TI distributions are positively skewed. Given the similar appearance of the distributions, one would think that a statistical analysis would not show a significant difference between the watersheds; however, the results of the Pairwise Wilcoxon Rank Sum Test did show a statistically significant difference between all watersheds, Appendix D. Because each of the watershed's TI distributions include so many individual TI values (data points, as many as 354,936 for the largest watersheds), the effect of the sample size was calculated to determine its significance on the statistical comparison. The effect size quantifies the size of the difference between two watersheds. The effect size for each group was small, less than 0.2; therefore, the differences between the medians were small, and while statistically significant, from a practical perspective the TI distributions were not different. These results indicate that within the Ridge and Valley physiographic region, for the 20 watersheds modeled for this study, the TI distributions were not statistically different.

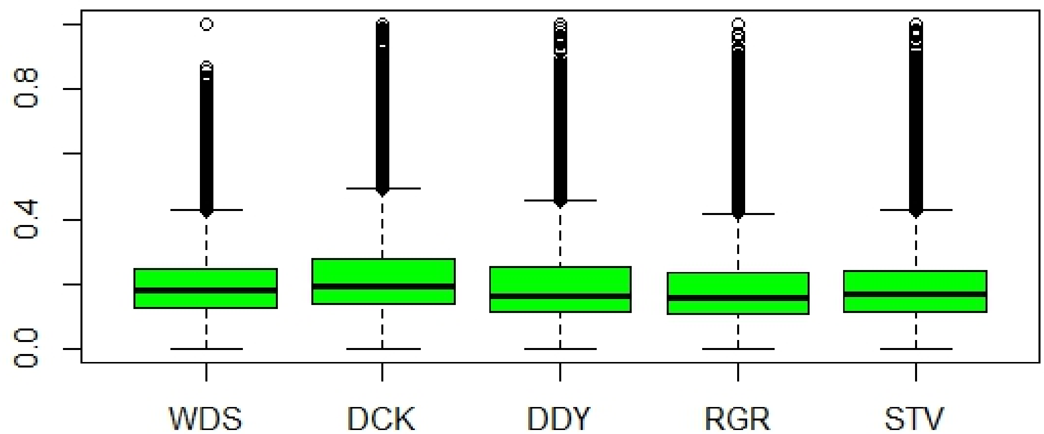

Figure 4-5. Boxplot of Normalized TI values for James River smaller watersheds (JR1)

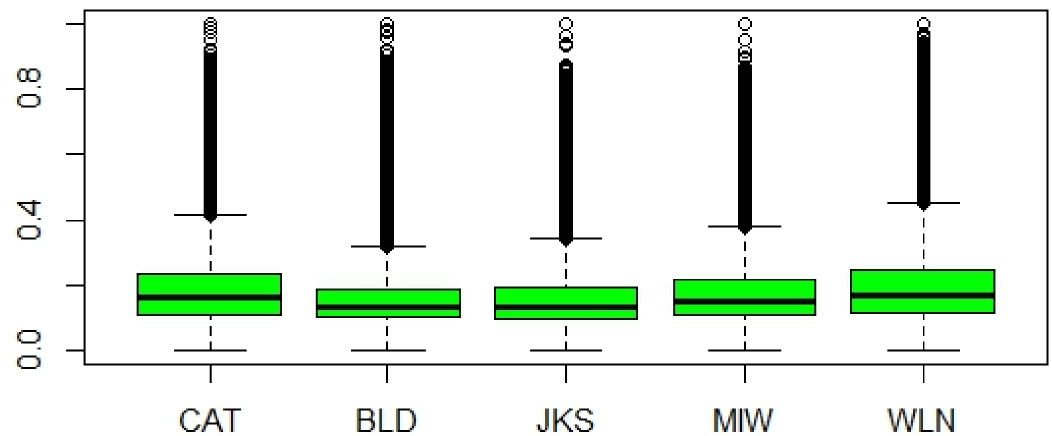

Figure 4-6. Boxplot of Normalized TI values for James River larger watersheds (JR2)

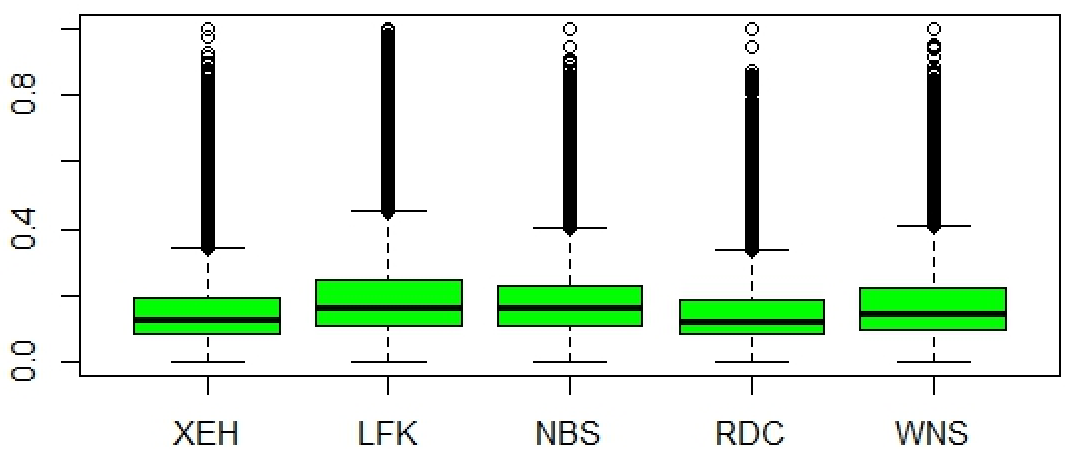

Figure 4-7. Boxplot of Normalized TI values for New River smaller watersheds (NR1)

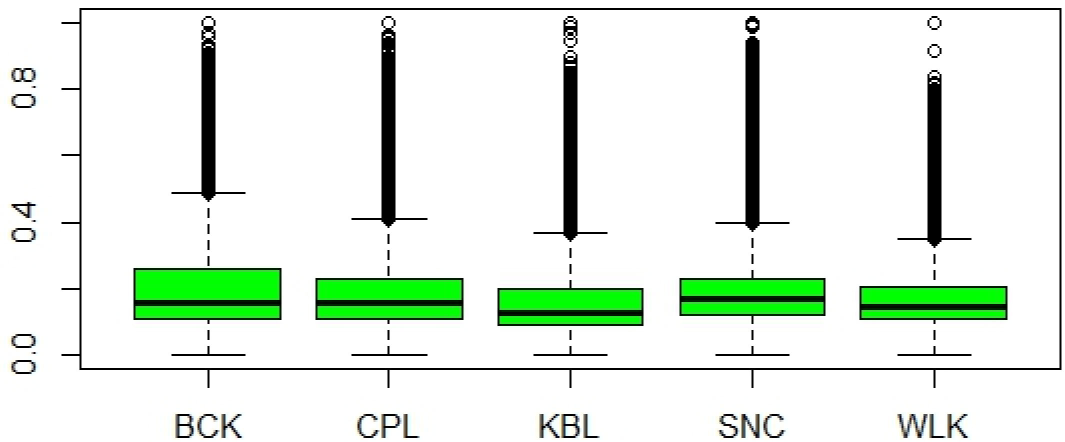

Figure 4-8. Boxplot of Normalized TI values for New River larger watersheds (NR2)

Objective 3: Compare the TMDL AllForX threshold value when using the entire period of record of VSCI scores versus the two most recent VSCI scores

The third objective of this study was to compare how the AllForX threshold value ($AllForX_{TV}$) differs when using the entire period of record of VSCI scores ($VSCI_T$) for the comparison and impaired watersheds versus the two most recent VSCI ($VSCI_2$) scores. In other words, how did $AllForX_{TV}$ values compare with $AllForX_{TV2}$ values? To address this objective, AllForX values developed for objective one (Table 4-1) were plotted against the arithmetic average VSCI score that was computed using the two most recent VSCI scores ($VSCI_2$), Table 4-1. Again, a unique linear regression was fit to each of the impaired watersheds and each of the four comparison watershed groups, Figure 4-9. A multiple regression analysis was performed to systematically compare the slope and y-intercepts of regressions, formed using an impaired watershed and a comparison watershed group, of every group with the three remaining groups. Additional linear contrasts were generated to systematically compare the slope and y-intercepts of each regression created using the $VSCI_T$ scores and using the $VSCI_2$ scores. The hypothesis for all three analyses was that the slope and y-intercepts were not different across any of the groups.

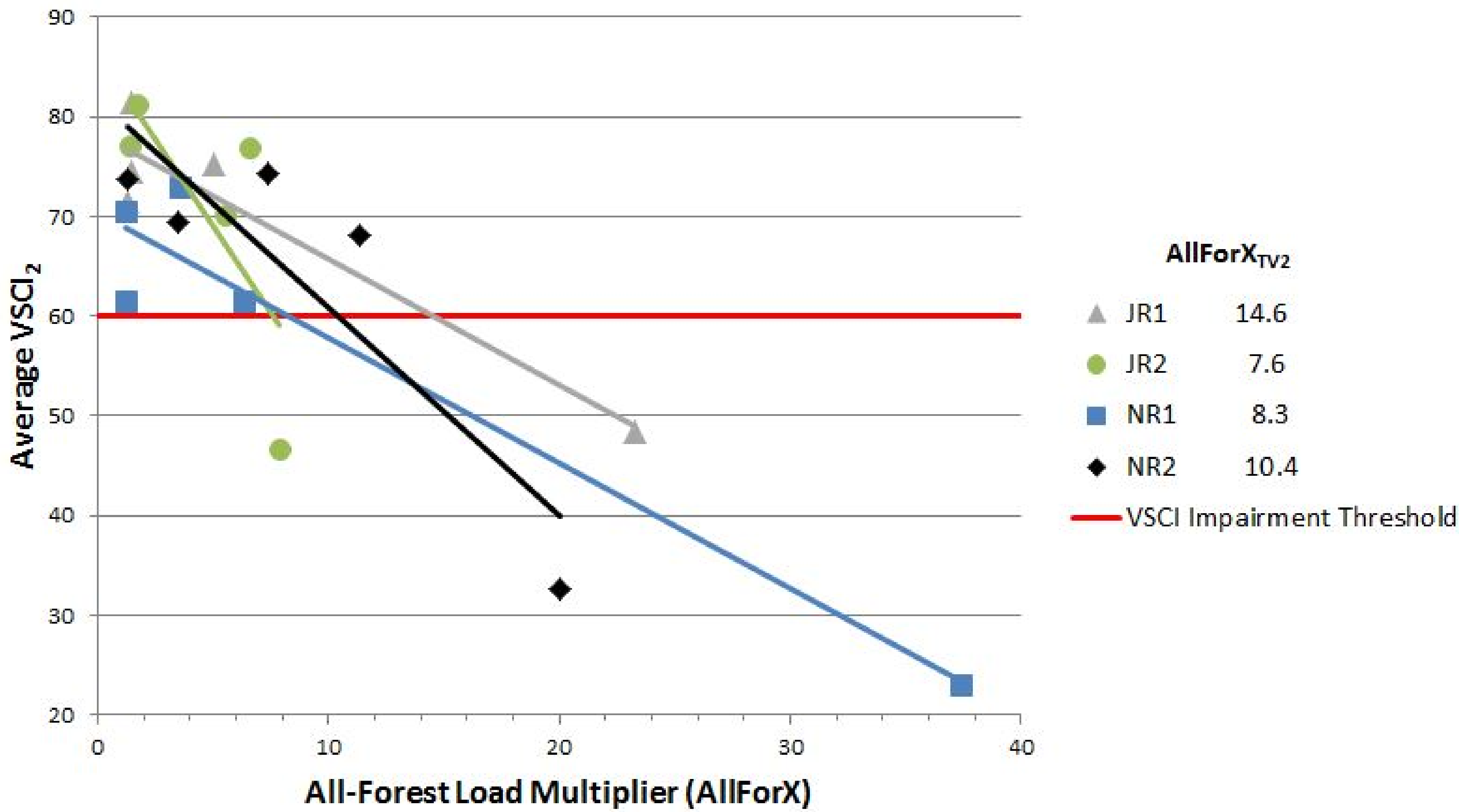

Figure 4-9. Regressions and AllForX_{TV2} for four watershed groups using $VSCI_2$ (2 most recent samples)

Again, as was the case for the objective one analysis, a cursory visual examination of Figure 4-9 could lead one to conclude that the regression lines for three of the four watershed groups (JR1, NR1, and NR2) are similar and that the regression for the JR2 group has a different slope and intercept from the other three groups. However, the results of the statistical analysis indicate that, again, there is no statistically significant difference between regression lines. As expected, these results are consistent with the findings for objective one.

Because the groups are not significantly different, one can conclude that the AllForX threshold value that corresponds to the two most recent VSCI scores ($AllForX_{TV2}$) for each of the four groups is also not significantly different. Figure 4-9 shows the $AllForX_{TV2}$ values for the four watershed groups. Since the $AllForX_{TV2}$ values are not significantly different, the $AllForX_{TV2}$ value using all 20 watersheds (11.2, Figure 4-10) is also not significantly different.

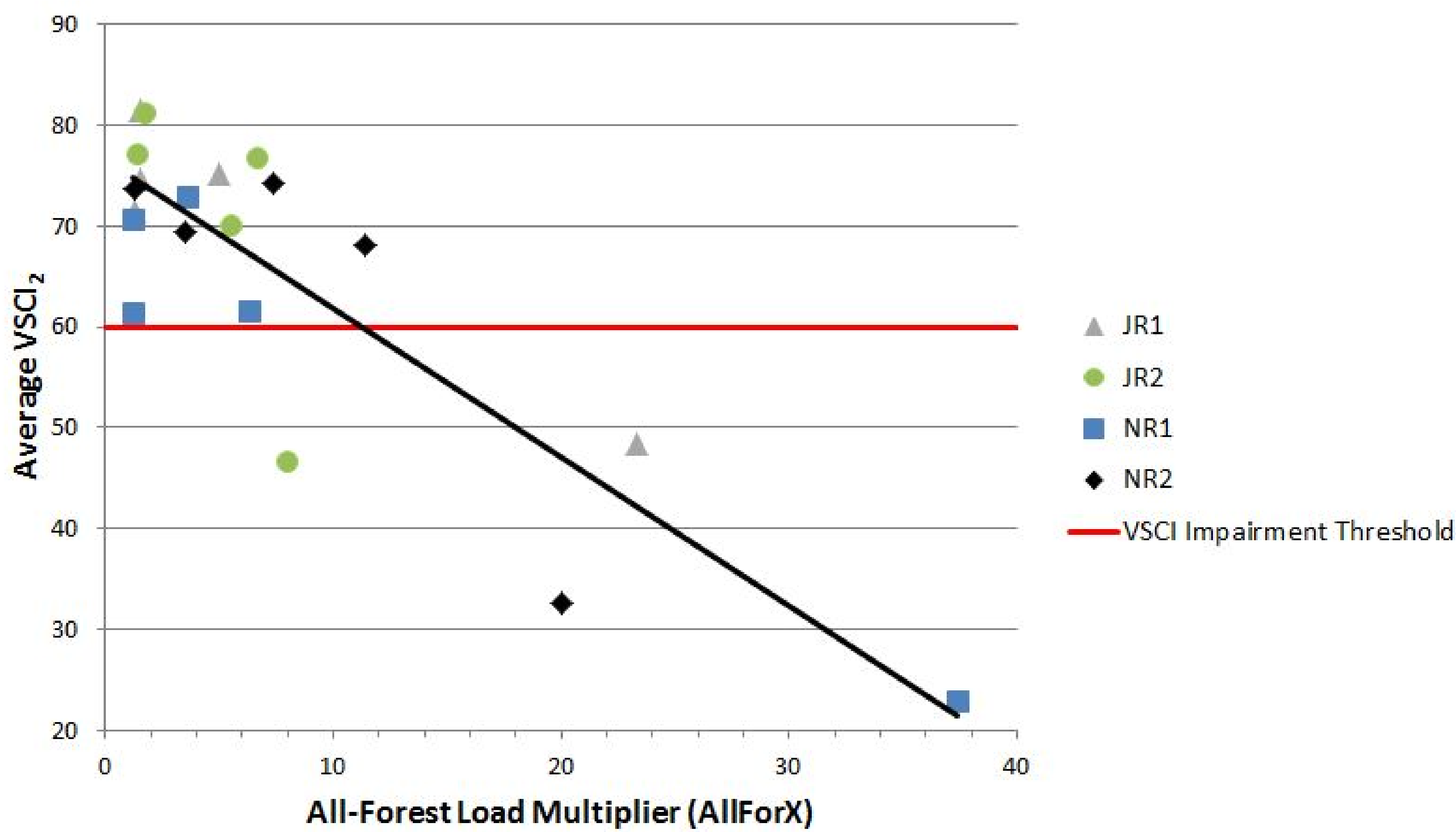

Figure 4-10. Regression for all 20 watersheds using the two most recent VSCI scores

Because the statistical comparisons showed no significant difference among the four groups of watersheds using the entire period of record of VSCI data or when evaluating the four groups of watersheds using the two most recent VSCI scores, one could expect that there would not be a significant difference when comparing the watershed groups when using either the entire period of record to compute average VSCI scores or the two most recent. Analysis confirmed there was no significant difference between regressions when using $VSCI_T$ or $VSCI_2$. Figure 4-11 shows an example of the $VSCI_T$ and $VSCI_2$ comparison for the James River small watershed groups, JR1. For the 20 watersheds modeled for this study, it appears to make no difference if the entire period of record or the two most recent data is used to calculate the VSCI score arithmetic average when using the AllForX Approach.

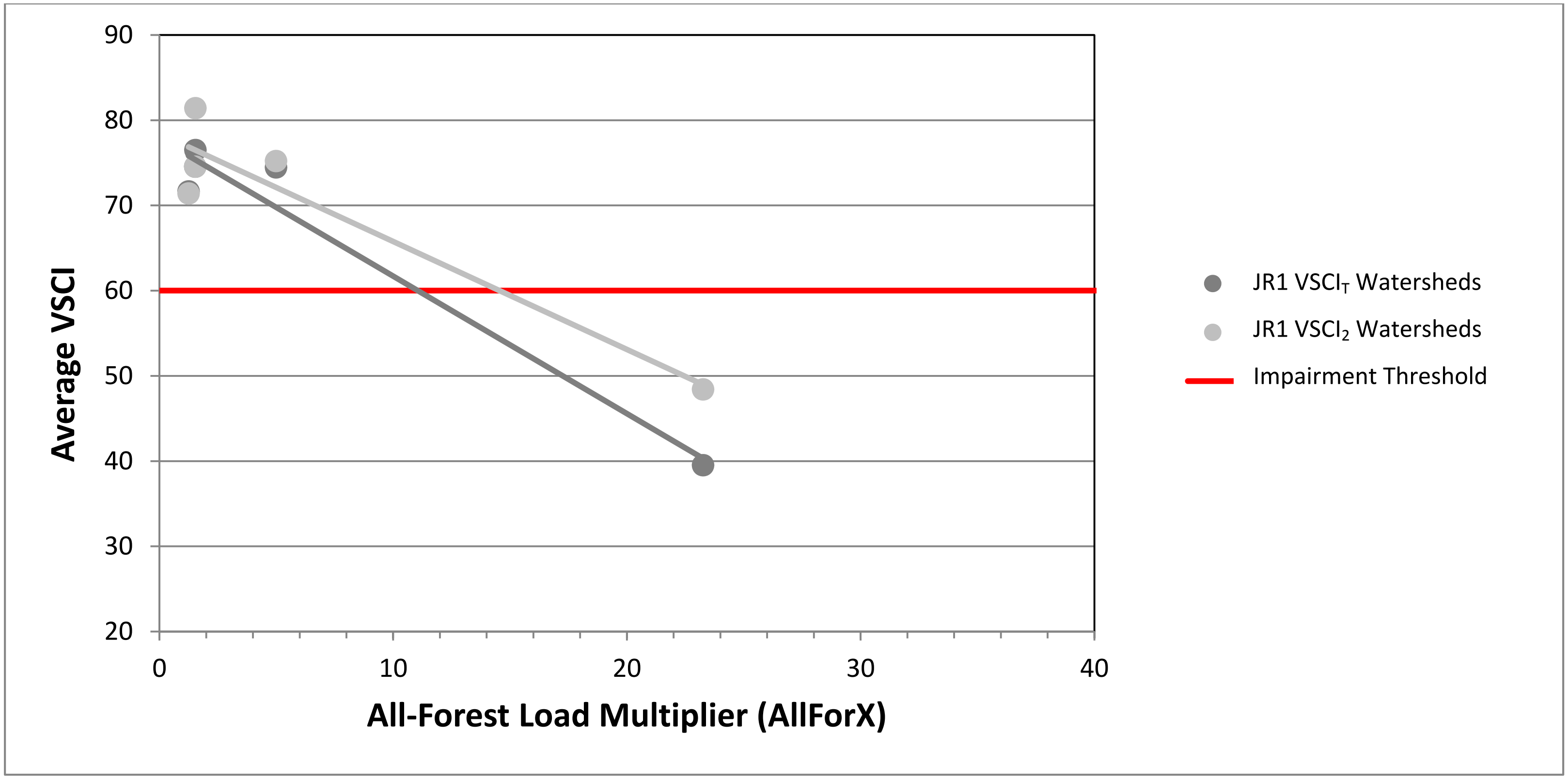

Figure 4-11. Example of regressions compared using average $VSCI_T$ and $VSCI_2$ scores for each combination of impaired watershed and comparison watershed group (e.g., $JR1_I$ and $JR1_C$)

CHAPTER 5: CONCLUSIONS

The purpose of this study was to evaluate the criteria (based on watershed characteristics) used when selecting comparison watersheds for the AllForX Approach as well as to evaluate an additional quantitative watershed characteristic as a potential comparison watershed selection criteria. The AllForX Approach uses a regression relationship between Virginia Stream Condition Index (VSCI) scores and AllForX values (a unit-less multiplier that is the ratio of modeled existing sediment load divided by a modeled all-forested load condition), for an impaired watershed and several comparison (healthy) watersheds to develop TMDL target loads for watersheds where sediment is the offending pollutant. Using the VSCI vs. AllForX regression, an AllForX threshold value ($AllForX_{TV}$) is determined for a VSCI of 60 (the impairment threshold). The $AllForX_{TV}$ is multiplied by the all-forested load of the impaired watershed to determine the TMDL target load. The TMDL allocation load is determined by subtracting the margin of safety (MOS) from the TMDL target load. The resulting TMDL allocation load is used to determine the type and degree of sediment source reduction needed to meet the TMDL, and eventually restore the biological integrity of the stream to meet water quality standards. The AllForX Approach builds on an earlier effort in Maryland, which was developed to provide a direct linkage between biological integrity and in-stream sediment loads. The application of the AllForX Approach provides an alternative to the Reference Watershed Approach (RWA), which compares only two watersheds, one impaired and the other healthy, to determine the TMDL target sediment load. While the RWA has been used to determine TMDL target sediment loads, there are issues/drawbacks with using the RWA. Chief among them is the ability to find a suitable reference watershed that is comparable with the impaired watershed. Further, because there is no Virginia sediment water quality criterion, determining the sediment load that is appropriate for restoring the biological community to healthy limits is difficult. Therefore, when using the RWA, the TMDL target load determined for the impaired watershed could be more (or less) conservative than the load actually needed to address the benthic impairment. The AllForX Approach aims to reduce this uncertainty with the use of multiple comparison watersheds and the relationship between the watersheds' AllForX values and their VSCI scores. To date, comparison watersheds used in the AllForX Approach have been chosen based on their similarity and proximity to the impaired watershed and best professional judgment.

This study addressed three objectives. The first was to determine if the watershed characteristics used to select comparison (healthy) watersheds when applying the AllForX Approach (i.e., stream order or watershed size and the proximity of the comparison and impaired watersheds, as defined by them lying within the same river basin) are significant. The second objective was to evaluate the utility of the topographic index (TI) as a potential quantitative criteria for use when selecting comparison watersheds for the AllForX Approach. The third objective was to compare how the TMDL AllForX threshold value ($AllForX_{TV}$) differs when using the entire period of record of VSCI scores versus the two most recent VSCI scores. In other words, what impact does applying recent VSCI scores that maybe more reflective of current conditions in the stream have on the AllForX threshold value? To address these objectives, the GWLF model was used to simulate sediment loads for 20 watersheds (four impaired and 16 comparison) in the Upper James and New River watersheds in the Ridge and Valley physiographic region of Virginia.

The results of this study indicate that within the Ridge and Valley physiographic region, for 19 of the 20 watersheds modeled for this study, river basin and drainage area are not significant variables that must be considered when selecting comparison watersheds for use in the AllForX Approach. The one exception is Reed Creek, a smaller (2.6 - 26 km^2) watershed in the New River basin comparison watershed group ($NR1_c$). The lower average VSCI score in Reed Creek (61.5) is not indicative of the highly forested land use. Therefore, it is believed that non-sediment related issues could be stressing the Reed Creek benthic community. Given this, it was determined that Reed Creek was not a suitable choice as a comparison watershed, despite its average VSCI scores being greater than the threshold value of 60. To investigate the impact of Reed Creek on the analysis of comparison watershed selection criteria significance, Reed Creek was removed from NRI_c. When Reed Creek was removed, there were no significant differences between regression lines for any combination of river basin and drainage area criteria. Therefore, for the four impaired watersheds considered in this study, any combination of the remaining 19 comparison watersheds within the Upper James or New River basin assessed for this study could be used as comparison watersheds for any one of the impaired watersheds when using the AllForX Approach.

In addition to examining the significance of stream order and river basin, an alternate metric/criteria that has not previously been used when selecting comparison watersheds for the AllForX Approach was examined for its utility. The Topographic Index (TI) is a quantitative measure of watershed topography, which controls hydrologic processes. The TI was evaluated as a potential metric for selecting comparison (healthy) watersheds that are hydrologically similar to the impaired watersheds when using the AllForX Approach. To compare the TI characteristic, a TI distribution was created for each of the 20 watersheds modeled for this study. The distributions were compared within each of the four watershed groups and across the groups. For practical purposes, there was no significant difference among the TI distributions for the 20 modeled watersheds. Since the TI distributions were not different, within the Upper James and New River basins, the similarities in TI distributions support the results found in objective one.

The results also showed that there was no significant difference when using either the entire period of record of VSCI data ($VSCI_T$) versus more recently collected VSCI data ($VSCI_2$). However, for the watersheds modeled for this study, there was a general trend of improvement in VSCI scores over time. Therefore, one is encouraged to critically examine the available VSCI data when using the AllForX Approach, as an argument could be made that using the most recent VSCI is more reflective of current conditions in the impaired and comparison watersheds and the needed mitigation in the impaired watersheds.

Based on the results of this study, it appears that it may be possible to select comparison watersheds for the AllForX Approach that are of a different stream order from the impaired watershed (watershed size), and that the comparison watersheds do not have to be proximate to the impaired watershed (i.e., the impaired and comparison watersheds can lie in different river basins). It must be noted that the watersheds selected in this study are located in one portion of one physiographic province in Virginia (Ridge and Valley). Additional data and additional comparisons similar to those performed here are needed to extrapolate the conclusions from this work to other parts of Virginia. Further, given the watersheds selected for this study, it appears that TI and the TI distribution of a given watershed may hold as a comparison watershed selection criterion for the AllForX Approach. Further research is needed to confirm this result. Finally, results indicated that for the watersheds modeled for this study, the period of data used to compute the averaged VSCI score used in the AllForX Approach were not significantly different. Therefore, it is recommended that the most recent VSCI scores be used when applying the AllForX Approach.

CHAPTER 6: RECOMMENDATIONS FOR FURTHER STUDY

The results of this study showed that for the watersheds modeled for this study, river basin and drainage area (stream order) were not important criteria when selecting comparison watersheds for the AllForX Approach. To evaluate the importance of these criteria across Virginia, it is recommended that additional groups of watersheds be selected in other physiographic regions. Additional comparisons to those performed in this study would provide a more robust guidance for selecting comparison watersheds for the AllForX Approach. When selecting reference monitoring sites for comparison watersheds, it is recommended that additional screening measures be applied to filter out the watersheds that are being impacted by pollutants other than sediment.

Similar topographic features, steep slopes and narrow valleys, were found in the Ridge and Valley physiographic region, which led to similar topographic indices across the 20 selected watersheds. As topography changes across the state, expectations are that TI distributions would vary across physiographic regions, potentially providing the quantitative criterion sought after in this study. It is recommended that TI distributions be compared for any additional watershed groups selected in other physiographic regions to determine if TI distributions are significantly different in watersheds that contain different topographic characteristics.

While there was no significant difference between the four watershed groups, visually the slope of JR2 appeared steeper than the other three groups, due to a small AllForX value for the impaired watershed, Catawba Creek. It was believed that this difference was due to the large percentage of forested land in the Catawba Creek watershed. For future studies, it is recommended that comparison and impaired watersheds with a wide range of forested, urban, and agricultural land use percentages are chosen to see if high percentages of forested land use are the driving force behind the small AllForX value for the JR2 impaired watershed.

Due to time constraints, a stressor analysis was not performed for any of the 20 watersheds modeled for this study. Impaired stream segments were chosen solely based on the sediment related suggested sources of benthic impairments in the 303(d) report. Performing a stressor analysis for each watershed in the future would ensure that the watersheds are in fact impaired for sediment.

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APPENDIX A: LAND USE DISTRIBUTIONS FOR EACH WATERSHED

Watershed Abbrev.	hit†	lot	pas_g	pas_f	pas_p	trp	afo	hay	for	hvf	barren	pur_LDI	pur_MDI	pur_HDI	imp_LDI	imp_MDI	imp_HDI	Total
James River basin, 2.6-26 km^2 **(JR1)**																		
WDS	0.19	5.15	60.11	420.74	120.21	10.50	1.77	210.43	414.52	4.19	8.34	492.92	15.93	50.09	50.09	15.93	200.37	2081.5
DCK	0.00	0.00	0.18	1.23	0.35	0.05	0.01	0.70	516.53	5.53	0.07	6.61	0.00	0.00	0.00	0.00	0.00	531.2
DDY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	392.40	3.96	0.19	19.28	0.00	0.00	0.00	0.00	0.00	415.8
RGR	0.02	0.61	5.47	38.29	10.94	1.06	0.18	24.51	748.14	7.56	0.21	21.23	0.00	0.00	0.00	0.00	0.00	858.2
STV	0.00	0.00	0.42	2.91	0.83	0.09	0.01	1.70	1037.21	10.48	0.27	26.59	0.00	0.00	0.00	0.00	0.00	1080.5
James River basin, 26-518 km^2 **(JR2)**																		
CAT	0.91	2.85	92.07	644.46	184.13	22.95	4.34	406.75	4601.07	46.48	2.90	278.07	1.25	0.00	6.91	1.25	0.00	6296.4
BLD1x	6.59	181.57	483.89	3387.22	967.78	51.90	13.61	1679.56	23048.26	233.12	18.62	1806.04	1.72	0.06	33.33	1.72	0.25	31915.2
JKS1x	2.64	8.34	505.34	3537.39	1010.68	116.75	9.37	896.16	24032.41	242.75	10.39	1026.20	0.67	0.00	1.01	0.67	0.00	31400.8
MIW	0.07	0.24	3.84	26.91	7.69	0.50	0.04	12.41	3830.84	38.70	1.30	129.18	0.00	0.00	0.00	0.00	0.00	4051.7
WLN	0.08	0.24	0.93	6.48	1.85	0.12	0.01	3.74	3746.06	37.84	1.53	112.37	15.63	0.68	4.41	15.63	2.71	3950.3
New River basin, 2.6-26 km^2 **(NR1)**																		
XEH	1.08	9.48	3.41	23.85	6.81	1.14	0.13	12.44	4.80	0.05	2.47	100.65	36.11	11.20	15.93	36.11	44.78	310.4
LFK	0.06	0.56	8.91	62.34	17.81	3.46	0.08	24.67	1589.34	16.05	0.76	73.10	0.31	0.00	1.76	0.31	0.00	1799.6
NBS	0.00	0.00	0.21	1.47	0.42	0.07	0.01	0.58	2386.94	24.11	0.27	26.55	0.00	0.00	0.00	0.00	0.00	2440.6
RDC	0.00	0.00	0.73	5.09	1.45	0.27	0.00	2.66	1839.55	18.58	0.01	0.62	0.00	0.00	0.00	0.00	0.00	1869.0
WNS	0.06	0.56	17.07	119.48	34.14	6.99	0.04	47.35	1204.47	12.17	0.47	46.08	0.00	0.06	0.31	0.00	0.25	1489.5
New River basin, 26-518 km^2 **(NR2)**																		
BCK	0.67	248.08	216.99	1518.95	433.99	73.54	0.46	826.81	1982.28	20.02	1.64	153.74	1.53	0.12	5.42	1.53	0.47	5486.2
CPL1x	65.12	191.55	612.25	4285.76	1224.50	227.68	4.62	2082.00	16196.52	180.54	9.25	906.62	1.10	0.00	7.06	1.10	0.00	25995.7
KBL1x	13.80	123.55	129.72	908.02	259.43	15.82	18.95	353.81	15389.31	162.03	3.69	358.53	2.12	0.06	2.56	2.12	0.25	17743.8
SNC	0.04	0.28	1.69	11.82	3.38	0.64	0.08	4.32	8938.67	90.29	1.28	126.33	0.00	0.00	0.06	0.00	0.00	9178.9
WLKx	3.48	32.33	361.14	2527.96	722.27	147.96	0.84	1002.06	7810.02	122.17	6.59	596.75	16.75	0.50	19.53	16.75	2.01	13389.1

†hit = hi till, lot = low till, pas_g = pasture good cond., pas_f = pasture fair cond., pas_p=pasture poor cond., trp=trampled riparian pasture, afo=animal feeding operations, hay=hay fields, for=forest, hvf=harvested forest, barren=barren land, pur_LDI=pervious low intensity developed, pur_MDI=pervious medium intensity developed, pur_HDI=pervious high intensity developed, imp_LDI=impervious low intensity developed, imp_MDI=impervious medium intensity developed, imp_HDI=impervious high intensity developed, total=total land use

APPENDIX B: GWLF PARAMETER DESCRIPTIONS

Descriptions of watershed-, month-, land-use-, and channel erosion parameters used in the GWLF transport file are listed in the text below. This text was written by Dr. Gene Yagow (Yagow, 2004). Page numbers refer to the GWLF Manual (Haith et al., 1992).

Watershed-Related Parameter Descriptions

No. of Rural Land Uses: The number of land uses simulated with both runoff and sediment components.

No. of Urban Land Uses: The number of land uses simulated with a build-up/wash off component.

Recession coefficient (day^{-1}): The recession coefficient is a measure of the rate at which stream flow recedes following the cessation of a storm, and is approximated by averaging the ratios of stream flow on any given day to that on the following day during a wide range of weather conditions, all during the recession limb of each storm's hydrograph. Calculate using GWLF manual guidance (p.30), or use a default value = 0.0, then calibrate.

Seepage coefficient (day-1): The seepage coefficient represents the amount of flow lost as seepage to deep storage. Use a default value = 0.0, then calibrate (GWLF Manual p.30).

Initial unsaturated storage (cm): Initial depth of water stored in the unsaturated (surface) zone. Use the recommended default value of 10 cm (GWLF Manual, p.36).

Initial saturated storage (cm): Initial depth of water stored in the saturated zone. Use the recommended default value of 0 cm.

Initial snow (cm): Initial amount of snow on the ground at the beginning of the simulation. Use the recommended default value of 0 cm.

Sediment delivery ratio: The fraction of erosion – detached sediment – that is transported or delivered to the edge of the stream. The GWLF Manual (p.31-32) presents a graphical procedure, but for our modeling, the following algorithms from AVGWLF were used to calculate SDR based on the square kilometers of land (Land_sqkm) in each watershed:

$$\text{Land\_sqkm} < 50: \text{SDR} = 0.000005 * \text{Land\_sqkm}^2 - 0.0014 * \text{Land\_sqkm} + 0.198 \quad \textbf{Eq. B.1.}$$

$$\text{Land\_sqkm} >= 50: \text{SDR} = 0.4518 * (\text{Land\_sqkm})^{-0.298} \quad \textbf{Eq. B.2.}$$

Unsaturated Soil Moisture Capacity (SMC): The amount of moisture in the root zone. SMC was estimated as the depth of the rooting zone times the soil volumetric available water capacity (AWC). An average rooting depth of 100 cm was used as recommended in the GWLF manual (p.30). AWC was calculated as an area-weighted average available water capacity SSURGO attribute in cm/cm, from all soils within each watershed. SMC was calculated as 100 * AWC.

Climatic Records: Model simulations are run from April through December in the first year to initialize storages denoted by and were not included in the model output load summaries. Therefore, the number of years that need to be input to GWLF is the full number of calendar years of data + 1 for the initialization period.

A. No. of Years: The number of years of weather data in the **weather.dat** file to be used in any given simulation run.

B. Beg. Year: The 4-digit calendar year corresponding to the beginning month of weather data.

C. End Year: The 4-digit calendar year corresponding to the last month of weather data.

Antecedent Rainfall for each of 5 previous days (cm): The amount of rainfall on each of the five days preceding the first day in the weather file. Use a default value = 0 for each day.

Month-Related Parameter Descriptions

Month: Months are ordered, starting with April and ending with March – in keeping with the design of the model and its assumption that stored sediment is flushed from the system at the end of each Apr-Mar cycle.

ET_CV: The composite evapotranspiration cover coefficient for each watershed. A CV is assigned to each land use for dormant (Ket_Dorm) and growing (Ket_Grow) months, based on GWLF guidance (p.23, 28-29). A composite area-weighted Ket_Dorm and Ket_Grow is calculated in the spreadsheets, based on the distribution of land uses within each watershed. A routine from AVGWLF was modified to vary the ET_CV from month to month, based on the composite Ket_Dorm and Ket_Grow values for each watershed.

Hours per Day: Mean number of daylight hours. The centroid latitude was calculated for each watershed, and monthly values interpolated from Table B-9 in the GWLF manual (p.29).

Growing Season: This flag is set to "0" for dormant months and "1" for months during the growing season. The growing season was defined as the period between the 50% Probabilities of occurrence of the Last Freeze Date in Spring and the First Freeze Date in Fall (Climatology of the U.S., No. 20, April 1978, NOAA). These dates were obtained for 87 National Weather Stations across the state, and contour plots generated in ArcView to define monthly boundaries for beginning and ending months. Beginning and ending months were then assigned to each watershed.

Erosion Coefficient: This is a regional coefficient used in Richardson's equation for calculating daily rainfall erosivity. Values for this two-part coefficient were assigned to watersheds based on the Rainfall Erosivity Zones defined in the GWLF manual (p.31, 36). Separate values were assigned to the months October-March (the "Rain_Cool" parameter), and for April-September (the "Rain_Warm" parameter). Assignment to individual watersheds was enhanced by relating the Erosivity Zones to the Virginia Climatic Zones in RUSLE, which provided a clearer basis for delineating the zones. Zone 21 values were used for the mountainous zone in Virginia (Clim_zone 110).

Land use-Related Parameter Descriptions

Land Use: A descriptor for the various land uses simulated in the model.

Area_ha: The area of each land use in a watershed in hectares. The area of each land use in a watershed was determined from GIS cross-tabulation of the watershed/sub-watershed boundary and either DOQQ or MRLC land cover. The split between hi-till and lo-till cropland came from a 2002 DCR land use inventory (Yagow et al., 2002), and division between pervious and impervious urban land uses was based on standard definitions in TR-55 (USDA, 1986).

Curve Number: The SCS curve number (CN) is used in calculating runoff associated with a daily rainfall event. The SCS curve number (CN) for any land use is a function of the hydrologic soil group (HSG) characteristic of the associated soils in each watershed. The GWLF manual provides general guidance (p.23-27). The CN values need to be calculated as an area-weighted average of CNs related to the watershed-specific proportionate extent of soils in each of the four HSG groups – A, B, C, and D. Values associated with each land use/HSG combination are included in Table C.1

KLSCP: This parameter is the product of the K, LS, C, and P factors from the universal soil loss equation (USLE). General GWLF guidance is provided (p.30-35). This product was calculated after evaluating the following individual USLE factors:

K-factor: obtained as an attribute of SSURGO soils

LS-factor: calculated according to the metric version of USLE procedures (Wischmeier and Smith, 1978) as:

$LS = 5.8 \cdot (L/22.13)^{m} \cdot (0.065 + 0.043 \cdot S + 0.0065 \cdot S^{2})$ **Eq. B.3.**

where $m = 0.2$, for $S \leq 1.0$,

$m = 0.3$, $1.0 < S \leq 3.5$,

$m = 0.4$, $3.5 < S \leq 4.5$,

$m = 0.5$, for $S > 4.5$,

S = slope, (%),

Slope was evaluated from 30-m DEMs as the average slope within each HRU.

L = slope length, (m).

Slope length (L) was calculated by watershed based on the expected inverse relationship with average slope shown in the equation below:

L = 121.92 – 3.556 * (% slope)

a. C-factor: evaluated as a function of both land use and physiographic region. The initial C-factor values by land use and the 10 regions used in the 2002 Statewide NPS Assessment and their respective sources, are included in Table C.1. (Yagow et al., 2002)

b. P-factor: currently assigned a default value = 1. This factor could also be used to account for BMP implementation by land use.

Channel Erosion Parameters (Evans, 2003)

% Developed land: percentage of the watershed with urban-related land uses – defined as all land in MDR, HDR, and COM land uses, as well as the impervious portions of LDR.

Animal density: calculated as the number of beef and dairy 1000-lb equivalent animal units (AU) divided by the watershed area in acres.

Stream length: calculated as the total stream length of natural stream channel, in meters. Excludes the non-erosive hardened and piped sections of the stream.

Stream length with livestock access: calculated as the total stream length in the watershed where livestock have unrestricted access to streams, resulting in stream bank trampling, in meters.

Mean channel depth (m): calculated from relationships developed for the Chesapeake Bay Watershed Model by physiographic region, of the general form y = a * Ab, where y = mean channel depth in ft., A = drainage area in square miles, and "a" and "b" are regional coefficients.

Additional GWLF Parameters

The following descriptions were written to explain parameters not addressed described by Yagow (2004).

ET Adjustment Factor: An additive factor for adjusting all ET cover coefficients; used for calibration; default is zero.

ET Flag: Value of 0 means that evapotranspiration is calculated from saturated vapor pressure using the Hamon equation; value of 1 means that evapotranspiration is calculated using the Blaney-Criddle formula.

a Factor: "The value of the empirically-derived 'a' constant is related to a wide variety of watershed characteristics such as the amount of infiltration, runoff, inherent soil erodibility, amount of rainfall, and other watershed-related factors (Prosser et al., 2001; Rutherford, 2000)." (Evans et al., 2003) This parameter is calculated as:

a = (0.000452 * PD) + (0.000033 * AD) + (0.000005 * CN) + (0.000522 * K) - 0.000514
where : a = the empirical constant for calculating LER as described above,
PD = percent developed land in watershed,
AD = animal density measured in Animal Units/acre, **Eq. B.4**
CN = area-weighted curve number,
K = area-weighted soil erodibility factor.
A minimum value of 1x10-7 is required. (Evans et al., 2003)

Sediment Build-up Rate: in units of kg/ha-day, the mass of suspended solids that is expected to accumulate on an impervious surface. This parameter is in the nutrient file.

APPENDIX C: GWLF INPUT FILES

Woods Creek (WDS) Transport Input File Parameters

	vahup95 col. B	vahup95 line no.	StrBnk2 line no.	HRU beg line no.	HRU end line no.
Watershed / Sub-Watershed Code =	WDS	2	5	2	18
No. of Rural Land Uses =	14				
No. of Urban Land Uses =	3				
ETadjust =	0.0	ignore!			
WATERSHED COEFFICIENTS					
Recession coefficient (day-1) =	0.0985				
Seepage coefficient (day-1) =	0.0000		0.0000		
Leakage coefficient (day-1) =	0.0000		0.0000		
Initial unsaturated storage (cm) =	10				
Initial saturated storage (cm) =	0				
Initial snow (cm) =	0				
Sediment delivery ratio =	0.1710				
Unsaturated Available Water Capacity (AWC) =	0.0000				
Antecedent Rainfall for each of 5 previous days (cm) =	0	0	0	0	0
Climatic Records (No. of Years, Beg. Year, End Year):					
No. of Years =	21		21 is the Maximum Allowable		
Beg. Year =	1990		No. of Years!!		
End Year =	2010				
ETflag =	0	ignore!			
CHANNEL EROSION COEFFICIENTS					
aFactor =	0.0006771				
Total Stream Length (m) =	11624.88				
mean channel depth =	0.7993				
SEASONAL COEFFICIENTS			*GROWING*	*EROS.*	
MONTH	*ET_CV*	*DAY HRS*	*SEASON*	*COEFF.*	
"APR"	0.861	12.99	0	0.13	
"MAY"	0.865	13.98	1	0.22	
"JUN"	0.866	14.48	1	0.22	
"JUL"	0.862	14.28	1	0.22	
"AUG"	0.854	13.39	1	0.22	
"SEP"	0.841	12.20	1	0.22	
"OCT"	0.829	11.01	0	0.13	
"NOV"	0.804	10.01	0	0.13	
"DEC"	0.792	9.42	0	0.13	
"JAN"	0.783	9.72	0	0.13	
"FEB"	0.825	10.61	0	0.13	
"MAR"	0.853	11.80	0	0.13	
LAND USE COEFFICIENTS					
LAND_USE	*AREA(ha)*	*Curve NO*	*KLSCP*	*Tag*	17
"HIGH_TILL"	0.186	80.06	0.4081	"hit"	
"LOW_TILL"	5.145	79.30	0.0991	"lot"	
"pasture1"	60.106	68.40	0.0355	"pag"	
"pasture2"	420.742	74.70	0.1421	"pa2"	
"pasture3"	120.212	82.98	0.2522	"pa3"	
"riparian_pas"	10.502	82.98	2.1585	"trp"	
"afo"	1.773	91.00	0.0000	"afo"	
"hay"	210.434	74.14	0.1057	"hay"	
"forest"	414.519	67.40	0.0093	"for"	
"harvested_for"	4.187	72.28	0.0933	"hvf"	
"barren"	8.337	88.86	2.2341	"trn"	
"pur_LDI"	492.920	74.70	0.0353	"puL"	
"pur_MDI"	15.927	74.70	0.0277	"puM"	
"pur_HDI"	50.092	74.70	0.0343	"puH"	
"imp_LDI"	50.092	90.70	0.0000	"iuL"	
"imp_MDI"	15.927	98.00	0.0000	"iuM"	
"imp_HDI"	200.368	98.00	0.0000	"iuH"	

Dicks Creek (DCK) Transport Input File Parameters

	vahup95 col. B	vahup95 line no.	StrBnk2 line no.	HRU beg line no.	HRU end line no.
Watershed / Sub-Watershed Code =	DCK	4	7	36	52
No. of Rural Land Uses =	14				
No. of Urban Land Uses =	3				
ETadjust =	0.0	ignore!			
WATERSHED COEFFICIENTS					
Recession coefficient (day-1) =	0.2461				
Seepage coefficient (day-1) =	0.0000		0.0000		
Leakage coefficient (day-1) =	0.0000		0.0000		
Initial unsaturated storage (cm) =	10				
Initial saturated storage (cm) =	0				
Initial snow (cm) =	0				
Sediment delivery ratio =	0.1907				
Unsaturated Available Water Capacity (AWC) =	0.0000				
Antecedent Rainfall for each of 5 previous days (cm) =	0	0	0	0	0
Climatic Records (No. of Years, Beg. Year, End Year):					
No. of Years =	21		21 is the Maximum Allowable		
Beg. Year =	1990		No. of Years!!		
End Year =	2010				
ETflag =	0	ignore!			
CHANNEL EROSION COEFFICIENTS					
aFactor =	0.0000402				
Total Stream Length (m) =	2790.56				
mean channel depth =	0.5474				
SEASONAL COEFFICIENTS			*GROWING*	*EROS.*	
MONTH	*ET_CV*	*DAY HRS*	*SEASON*	*COEFF.*	
"APR"	0.988	12.99	0	0.08	
"MAY"	0.997	13.98	1	0.20	
"JUN"	1.000	14.48	1	0.20	
"JUL"	0.990	14.28	1	0.20	
"AUG"	0.970	13.39	1	0.20	
"SEP"	0.941	12.20	1	0.20	
"OCT"	0.911	11.01	0	0.08	
"NOV"	0.852	10.01	0	0.08	
"DEC"	0.822	9.42	0	0.08	
"JAN"	0.803	9.72	0	0.08	
"FEB"	0.901	10.61	0	0.08	
"MAR"	0.968	11.80	0	0.08	
LAND USE COEFFICIENTS					
LAND_USE	*AREA(ha)*	*Curve NO*	*KLSCP*	*Tag*	17
"HIGH_TILL"	0.000	80.35	0.8582	"hit"	
"LOW_TILL"	0.000	79.58	0.2085	"lot"	
"pasture1"	0.175	68.82	0.0127	"pag"	
"pasture2"	1.228	75.06	0.0508	"pa2"	
"pasture3"	0.351	83.18	0.0902	"pa3"	
"riparian_pas"	0.045	83.18	0.7757	"trp"	
"afo"	0.005	91.00	0.0000	"afo"	
"hay"	0.704	74.57	0.0346	"hay"	
"forest"	516.527	67.81	0.0073	"for"	
"harvested_for"	5.531	72.75	0.0733	"hvf"	
"barren"	0.067	89.12	2.4728	"trn"	
"pur_LDI"	6.605	75.06	0.0206	"puL"	
"pur_MDI"	0.000	75.06	0.0485	"puM"	
"pur_HDI"	0.000	75.06	0.0485	"puH"	
"imp_LDI"	0.000	90.73	0.0000	"iuL"	
"imp_MDI"	0.000	98.00	0.0000	"iuM"	
"imp_HDI"	0.000	98.00	0.0000	"iuH"	

Daddy Run (DDY) Transport Input File Parameters

	vahup95 col. B	vahup95 line no.	StrBnk2 line no.	HRU beg line no.	HRU end line no.
Watershed / Sub-Watershed Code =	DDY	6	9	70	86
No. of Rural Land Uses =	14				
No. of Urban Land Uses =	3				
ETadjust =	0.0	ignore!			
WATERSHED COEFFICIENTS					
Recession coefficient (day-1) =	0.2981				
Seepage coefficient (day-1) =	0.0000		0.0000		
Leakage coefficient (day-1) =	0.0000		0.0000		
Initial unsaturated storage (cm) =	10				
Initial saturated storage (cm) =	0				
Initial snow (cm) =	0				
Sediment delivery ratio =	0.1923				
Unsaturated Available Water Capacity (AWC) =	0.0000				
Antecedent Rainfall for each of 5 previous days (cm) =	0	0	0	0	0
Climatic Records (No. of Years, Beg. Year, End Year):					
No. of Years =	21		21 is the Maximum Allowable		
Beg. Year =	1990		No. of Years!!		
End Year =	2010				
ETflag =	0	ignore!			
CHANNEL EROSION COEFFICIENTS					
aFactor =	0.0001008				
Total Stream Length (m) =	3251.43				
mean channel depth =	0.5115				
SEASONAL COEFFICIENTS			*GROWING*	*EROS.*	
MONTH	*ET_CV*	*DAY HRS*	*SEASON*	*COEFF.*	
"APR"	0.988	12.99	0	0.10	
"MAY"	0.997	13.98	1	0.20	
"JUN"	1.000	14.48	1	0.20	
"JUL"	0.990	14.28	1	0.20	
"AUG"	0.971	13.39	1	0.20	
"SEP"	0.942	12.20	1	0.20	
"OCT"	0.914	11.01	0	0.10	
"NOV"	0.857	10.01	0	0.10	
"DEC"	0.828	9.42	0	0.10	
"JAN"	0.809	9.72	0	0.10	
"FEB"	0.904	10.61	0	0.10	
"MAR"	0.969	11.80	0	0.10	
LAND USE COEFFICIENTS					
LAND_USE	*AREA(ha)*	*Curve NO*	*KLSCP*	*Tag*	17
"HIGH_TILL"	0.000	80.77	0.9905	"hit"	
"LOW_TILL"	0.000	80.00	0.2406	"lot"	
"pasture1"	0.000	69.48	0.0560	"pag"	
"pasture2"	0.000	75.56	0.2238	"pa2"	
"pasture3"	0.000	83.53	0.3973	"pa3"	
"riparian_pas"	0.000	83.53	2.7703	"trp"	
"afo"	0.000	91.00	0.0000	"afo"	
"hay"	0.000	75.04	0.1511	"hay"	
"forest"	392.399	68.46	0.0084	"for"	
"harvested_for"	3.964	73.31	0.0844	"hvf"	
"barren"	0.195	89.38	2.8540	"trn"	
"pur_LDI"	19.278	75.56	0.0368	"puL"	
"pur_MDI"	0.000	75.56	0.0560	"puM"	
"pur_HDI"	0.000	75.56	0.0560	"puH"	
"imp_LDI"	0.000	90.88	0.0000	"iuL"	
"imp_MDI"	0.000	98.00	0.0000	"iuM"	
"imp_HDI"	0.000	98.00	0.0000	"iuH"	

Roaring Run (RGR) Transport Input File Parameters

	vahup95 col. B	vahup95 line no.	StrBnk2 line no.	HRU beg line no.	HRU end line no.
Watershed / Sub-Watershed Code =	RGR	8	11	104	120
No. of Rural Land Uses =	14				
No. of Urban Land Uses =	3				
ETadjust =	0.0	ignore!			
WATERSHED COEFFICIENTS					
Recession coefficient (day-1) =	0.1721				
Seepage coefficient (day-1) =	0.0000		0.0000		
Leakage coefficient (day-1) =	0.0000		0.0000		
Initial unsaturated storage (cm) =	10				
Initial saturated storage (cm) =	0				
Initial snow (cm) =	0				
Sediment delivery ratio =	0.1864				
Unsaturated Available Water Capacity (AWC) =	0.0000				
Antecedent Rainfall for each of 5 previous days (cm) =	0	0	0	0	0
Climatic Records (No. of Years, Beg. Year, End Year):					
No. of Years =	21		21 is the Maximum Allowable		
Beg. Year =	1990		No. of Years!!		
End Year =	2010				
ETflag =	0	ignore!			
CHANNEL EROSION COEFFICIENTS					
aFactor =	0.0000673				
Total Stream Length (m) =	2467.41				
mean channel depth =	0.6252				
SEASONAL COEFFICIENTS			*GROWING*	*EROS.*	
MONTH	*ET_CV*	*DAY HRS*	*SEASON*	*COEFF.*	
"APR"	0.988	12.99	0	0.11	
"MAY"	0.996	13.98	1	0.23	
"JUN"	0.999	14.48	1	0.23	
"JUL"	0.990	14.28	1	0.23	
"AUG"	0.971	13.39	1	0.23	
"SEP"	0.943	12.20	1	0.23	
"OCT"	0.914	11.01	0	0.11	
"NOV"	0.858	10.01	0	0.11	
"DEC"	0.830	9.42	0	0.11	
"JAN"	0.811	9.72	0	0.11	
"FEB"	0.905	10.61	0	0.11	
"MAR"	0.969	11.80	0	0.11	
LAND USE COEFFICIENTS					
LAND_USE	*AREA(ha)*	*Curve NO*	*KLSCP*	*Tag*	17
"HIGH_TILL"	0.022	79.25	0.5612	"hit"	
"LOW_TILL"	0.605	78.48	0.1363	"lot"	
"pasture1"	5.470	67.12	0.0465	"pag"	
"pasture2"	38.291	73.75	0.1858	"pa2"	
"pasture3"	10.940	82.26	0.3298	"pa3"	
"riparian_pas"	1.061	82.26	2.6379	"trp"	
"afo"	0.184	91.00	0.0000	"afo"	
"hay"	24.506	73.35	0.1288	"hay"	
"forest"	748.138	66.11	0.0081	"for"	
"harvested_for"	7.557	71.30	0.0808	"hvf"	
"barren"	0.214	88.44	2.7622	"trn"	
"pur_LDI"	21.228	73.75	0.0406	"puL"	
"pur_MDI"	0.000	73.75	0.0542	"puM"	
"pur_HDI"	0.000	73.75	0.0542	"puH"	
"imp_LDI"	0.000	90.36	0.0000	"iuL"	
"imp_MDI"	0.000	98.00	0.0000	"iuM"	
"imp_HDI"	0.000	98.00	0.0000	"iuH"	

Shawvers Run (STV) Transport Input File Parameters

	vahup95 col. B	vahup95 line no.	StrBnk2 line no.	HRU beg line no.	HRU end line no.
Watershed / Sub-Watershed Code =	STV	10	13	138	154
No. of Rural Land Uses =	14				
No. of Urban Land Uses =	3				
ETadjust =	0.0	ignore!			
WATERSHED COEFFICIENTS					
Recession coefficient (day-1) =	0.1467				
Seepage coefficient (day-1) =	0.0000		0.0000		
Leakage coefficient (day-1) =	0.0000		0.0000		
Initial unsaturated storage (cm) =	10				
Initial saturated storage (cm) =	0				
Initial snow (cm) =	0				
Sediment delivery ratio =	0.1835				
Unsaturated Available Water Capacity (AWC) =	0.0000				
Antecedent Rainfall for each of 5 previous days (cm) =	0	0	0	0	0
Climatic Records (No. of Years, Beg. Year, End Year):					
No. of Years =	21		21 is the Maximum Allowable		
Beg. Year =	1990		No. of Years!!		
End Year =	2010				
ETflag =	0	ignore!			
CHANNEL EROSION COEFFICIENTS					
aFactor =	0.0000574				
Total Stream Length (m) =	2544.64				
mean channel depth =	0.6664				
SEASONAL COEFFICIENTS			*GROWING*	*EROS.*	
MONTH	*ET_CV*	*DAY HRS*	*SEASON*	*COEFF.*	
"APR"	0.988	12.99	0	0.13	
"MAY"	0.997	13.98	1	0.24	
"JUN"	1.000	14.48	1	0.24	
"JUL"	0.990	14.28	1	0.24	
"AUG"	0.971	13.39	1	0.24	
"SEP"	0.941	12.20	1	0.24	
"OCT"	0.912	11.01	0	0.13	
"NOV"	0.854	10.01	0	0.13	
"DEC"	0.825	9.42	0	0.13	
"JAN"	0.805	9.72	0	0.13	
"FEB"	0.902	10.61	0	0.13	
"MAR"	0.969	11.80	0	0.13	
LAND USE COEFFICIENTS					
LAND_USE	*AREA(ha)*	*Curve NO*	*KLSCP*	*Tag*	17
"HIGH_TILL"	0.000	79.36	0.8797	"hit"	
"LOW_TILL"	0.000	78.59	0.2137	"lot"	
"pasture1"	0.416	67.29	0.0287	"pag"	
"pasture2"	2.909	73.89	0.1147	"pa2"	
"pasture3"	0.831	82.35	0.2036	"pa3"	
"riparian_pas"	0.086	82.35	1.7041	"trp"	
"afo"	0.014	91.00	0.0000	"afo"	
"hay"	1.704	73.47	0.0895	"hay"	
"forest"	1037.207	66.29	0.0075	"for"	
"harvested_for"	10.477	71.45	0.0749	"hvf"	
"barren"	0.269	88.51	2.5346	"trn"	
"pur_LDI"	26.588	73.89	0.0425	"puL"	
"pur_MDI"	0.000	73.89	0.0497	"puM"	
"pur_HDI"	0.000	73.89	0.0497	"puH"	
"imp_LDI"	0.000	90.40	0.0000	"iuL"	
"imp_MDI"	0.000	98.00	0.0000	"iuM"	
"imp_HDI"	0.000	98.00	0.0000	"iuH"	

Catawba Creek (CAT) Transport Input File Parameters

	vahup95 col. B	vahup95 line no.	StrBnk2 line no.	HRU beg line no.	HRU end line no.
Watershed / Sub-Watershed Code =	CAT	2	5	2	18
No. of Rural Land Uses =	14				
No. of Urban Land Uses =	3				
ETadjust =	0.0	ignore!			
WATERSHED COEFFICIENTS					
Recession coefficient (day-1) =	0.0629				
Seepage coefficient (day-1) =	0.0000		0.0000		
Leakage coefficient (day-1) =	0.0000		0.0000		
Initial unsaturated storage (cm) =	10				
Initial saturated storage (cm) =	0				
Initial snow (cm) =	0				
Sediment delivery ratio =	0.1315				
Unsaturated Available Water Capacity (AWC) =	0.0000				
Antecedent Rainfall for each of 5 previous days (cm) =	0	0	0	0	0
Climatic Records (No. of Years, Beg. Year, End Year):					
No. of Years =	21		21 is the Maximum Allowable		
Beg. Year =	1990		No. of Years!!		
End Year =	2010				
ETflag =	0	ignore!			
CHANNEL EROSION COEFFICIENTS					
aFactor =	0.0001211				
Total Stream Length (m) =	26665.67				
mean channel depth =	1.0863				
SEASONAL COEFFICIENTS			*GROWING*	*EROS.*	
MONTH	*ET_CV*	*DAY HRS*	*SEASON*	*COEFF.*	
"APR"	0.986	12.97	0	0.27	
"MAY"	0.993	13.94	1	0.21	
"JUN"	0.996	14.44	1	0.21	
"JUL"	0.987	14.24	1	0.21	
"AUG"	0.970	13.37	1	0.21	
"SEP"	0.944	12.20	1	0.21	
"OCT"	0.918	11.03	1	0.21	
"NOV"	0.865	10.03	0	0.27	
"DEC"	0.839	9.46	0	0.27	
"JAN"	0.822	9.76	0	0.27	
"FEB"	0.909	10.63	0	0.27	
"MAR"	0.968	11.80	0	0.27	
LAND USE COEFFICIENTS					
LAND_USE	*AREA(ha)*	*Curve NO*	*KLSCP*	*Tag*	17
"HIGH_TILL"	0.914	78.89	0.5163	"hit"	
"LOW_TILL"	2.849	80.32	0.1254	"lot"	
"pasture1"	92.066	66.56	0.0441	"pag"	
"pasture2"	644.465	73.30	0.1762	"pa2"	
"pasture3"	184.133	81.98	0.3128	"pa3"	
"riparian_pas"	22.946	81.98	2.6018	"trp"	
"afo"	4.338	91.00	0.0000	"afo"	
"hay"	406.755	72.93	0.1080	"hay"	
"forest"	4601.068	65.56	0.0094	"for"	
"harvested_for"	46.475	70.78	0.0944	"hvf"	
"barren"	2.904	88.20	3.0994	"trn"	
"pur_LDI"	278.067	73.30	0.0337	"puL"	
"pur_MDI"	1.254	73.30	0.0185	"puM"	
"pur_HDI"	0.000	73.30	0.0608	"puH"	
"imp_LDI"	6.913	90.25	0.0000	"iuL"	
"imp_MDI"	1.254	98.00	0.0000	"iuM"	
"imp_HDI"	0.000	98.00	0.0000	"iuH"	

Buffalo Creek (BLD) Transport Input File Parameters

		vahup95 col. B	vahup95 line no.	StrBnk2 line no.	HRU beg line no.	HRU end line no.
Watershed / Sub-Watershed Code =		BLD1x	12	15	172	188
No. of Rural Land Uses =		14				
No. of Urban Land Uses =		3				
ETadjust =		0.0	ignore!			
WATERSHED COEFFICIENTS						
Recession coefficient (day-1) =		0.0485				
Seepage coefficient (day-1) =		0.0000		0.0000		
Leakage coefficient (day-1) =		0.0000		0.0000		
Initial unsaturated storage (cm) =		10				
Initial saturated storage (cm) =		0				
Initial snow (cm) =		0				
Sediment delivery ratio =		0.0811				
Unsaturated Available Water Capacity (AWC) =		0.0000				
Antecedent Rainfall for each of 5 previous days (cm) =		0	0	0	0	0
Climatic Records (No. of Years, Beg. Year, End Year):						
	No. of Years =	21		21 is the Maximum Allowable		
	Beg. Year =	1990		No. of Years!!		
	End Year =	2010				
ETflag =		0	ignore!			
CHANNEL EROSION COEFFICIENTS						
aFactor =		0.0001543				
Total Stream Length (m) =		148295.01				
mean channel depth =		1.7035				

SEASONAL COEFFICIENTS

MONTH	*ET_CV*	*DAY HRS*	*GROWING SEASON*	*EROS. COEFF.*
"APR"	0.987	12.97	0	0.11
"MAY"	0.995	13.94	1	0.18
"JUN"	0.997	14.44	1	0.18
"JUL"	0.989	14.24	1	0.18
"AUG"	0.972	13.37	1	0.18
"SEP"	0.946	12.20	1	0.18
"OCT"	0.921	11.03	1	0.18
"NOV"	0.870	10.03	0	0.11
"DEC"	0.844	9.46	0	0.11
"JAN"	0.827	9.76	0	0.11
"FEB"	0.912	10.63	0	0.11
"MAR"	0.970	11.80	0	0.11

LAND USE COEFFICIENTS

LAND_USE	*AREA(ha)*	*Curve NO*	*KLSCP*	*Tag*	17
"HIGH_TILL"	6.594	79.31	0.4200	"hit"	
"LOW_TILL"	181.566	80.68	0.1020	"lot"	
"pasture1"	483.888	67.23	0.0502	"pag"	
"pasture2"	3387.215	73.81	0.2007	"pa2"	
"pasture3"	967.776	82.35	0.3562	"pa3"	
"riparian_pas"	51.896	82.35	2.9690	"trp"	
"afo"	13.608	91.00	0.0000	"afo"	
"hay"	1679.556	73.35	0.1264	"hay"	
"forest"	23048.258	66.23	0.0106	"for"	
"harvested_for"	233.124	71.31	0.1063	"hvf"	
"barren"	18.617	88.42	3.2881	"trn"	
"pur_LDI"	1806.038	73.81	0.0284	"puL"	
"pur_MDI"	1.725	73.81	0.0589	"puM"	
"pur_HDI"	0.063	73.81	0.0159	"puH"	
"imp_LDI"	33.327	90.42	0.0000	"iuL"	
"imp_MDI"	1.725	98.00	0.0000	"iuM"	
"imp_HDI"	0.251	98.00	0.0000	"iuH"	

Jackson River (JKS) Transport Input File Parameters

	vahup95 col. B	vahup95 line no.	StrBnk2 line no.	HRU beg line no.	HRU end line no.
Watershed / Sub-Watershed Code =	JKS1x	20	23	308	324
No. of Rural Land Uses =	14				
No. of Urban Land Uses =	3				
ETadjust =	0.0	ignore!			
WATERSHED COEFFICIENTS					
Recession coefficient (day-1) =	0.0486				
Seepage coefficient (day-1) =	0.0000		0.0000		
Leakage coefficient (day-1) =	0.0000		0.0000		
Initial unsaturated storage (cm) =	10				
Initial saturated storage (cm) =	0				
Initial snow (cm) =	0				
Sediment delivery ratio =	0.0814				
Unsaturated Available Water Capacity (AWC) =	0.0000				
Antecedent Rainfall for each of 5 previous days (cm) =	0	0	0	0	0
Climatic Records (No. of Years, Beg. Year, End Year):					
No. of Years =	21		21 is the Maximum Allowable		
Beg. Year =	1990		No. of Years!!		
End Year =	2010				
ETflag =	0	ignore!			
CHANNEL EROSION COEFFICIENTS					
aFactor =	0.0000865				
Total Stream Length (m) =	136159.94				
mean channel depth =	1.6959				
SEASONAL COEFFICIENTS			*GROWING*	*EROS.*	
MONTH	*ET_CV*	*DAY HRS*	*SEASON*	*COEFF.*	
"APR"	0.988	12.97	0	0.12	
"MAY"	0.995	13.94	1	0.19	
"JUN"	0.998	14.44	1	0.19	
"JUL"	0.989	14.24	1	0.19	
"AUG"	0.973	13.37	1	0.19	
"SEP"	0.948	12.20	1	0.19	
"OCT"	0.923	11.03	1	0.19	
"NOV"	0.872	10.03	0	0.12	
"DEC"	0.847	9.46	0	0.12	
"JAN"	0.831	9.76	0	0.12	
"FEB"	0.914	10.63	0	0.12	
"MAR"	0.971	11.80	0	0.12	
LAND USE COEFFICIENTS					
LAND_USE	*AREA(ha)*	*Curve NO*	*KLSCP*	*Tag*	17
"HIGH_TILL"	2.636	79.32	0.3902	"hit"	
"LOW_TILL"	8.340	80.68	0.0948	"lot"	
"pasture1"	505.342	67.24	0.0389	"pag"	
"pasture2"	3537.393	73.83	0.1556	"pa2"	
"pasture3"	1010.684	82.34	0.2762	"pa3"	
"riparian_pas"	116.751	82.34	2.2888	"trp"	
"afo"	9.368	91.00	0.0000	"afo"	
"hay"	896.163	73.42	0.0811	"hay"	
"forest"	24032.413	66.23	0.0080	"for"	
"harvested_for"	242.752	71.38	0.0803	"hvf"	
"barren"	10.389	88.48	2.4010	"trn"	
"pur_LDI"	1026.197	73.83	0.0276	"puL"	
"pur_MDI"	0.672	73.83	0.0067	"puM"	
"pur_HDI"	0.000	73.83	0.0513	"puH"	
"imp_LDI"	1.011	90.39	0.0000	"iuL"	
"imp_MDI"	0.672	98.00	0.0000	"iuM"	
"imp_HDI"	0.000	98.00	0.0000	"iuH"	

Mill Creek (MIW) Transport Input File Parameters

	vahup95 col. B	vahup95 line no.	StrBnk2 line no.	HRU beg line no.	HRU end line no.
Watershed / Sub-Watershed Code =	MIW	22	25	342	358
No. of Rural Land Uses =	14				
No. of Urban Land Uses =	3				
ETadjust =	0.0	ignore!			
WATERSHED COEFFICIENTS					
Recession coefficient (day-1) =	0.0727				
Seepage coefficient (day-1) =	0.0000		0.0000		
Leakage coefficient (day-1) =	0.0000		0.0000		
Initial unsaturated storage (cm) =	10				
Initial saturated storage (cm) =	0				
Initial snow (cm) =	0				
Sediment delivery ratio =	0.1495				
Unsaturated Available Water Capacity (AWC) =	0.0000				
Antecedent Rainfall for each of 5 previous days (cm) =	0	0	0	0	0
Climatic Records (No. of Years, Beg. Year, End Year):					
No. of Years =	21		21 is the Maximum Allowable		
Beg. Year =	1990		No. of Years!!		
End Year =	2010				
ETflag =	0	ignore!			
CHANNEL EROSION COEFFICIENTS					
aFactor =	0.0000678				
Total Stream Length (m) =	18704.74				
mean channel depth =	0.9613				

SEASONAL COEFFICIENTS

MONTH	*ET_CV*	*DAY HRS*	*GROWING SEASON*	*EROS. COEFF.*
"APR"	0.988	12.97	0	0.11
"MAY"	0.997	13.94	1	0.23
"JUN"	1.000	14.44	1	0.23
"JUL"	0.990	14.24	1	0.23
"AUG"	0.971	13.37	1	0.23
"SEP"	0.942	12.20	1	0.23
"OCT"	0.913	11.03	1	0.23
"NOV"	0.855	10.03	0	0.11
"DEC"	0.827	9.46	0	0.11
"JAN"	0.807	9.76	0	0.11
"FEB"	0.904	10.63	0	0.11
"MAR"	0.969	11.80	0	0.11

LAND USE COEFFICIENTS

LAND_USE	*AREA(ha)*	*Curve NO*	*KLSCP*	*Tag*	17
"HIGH_TILL"	0.072	80.12	0.7210	"hit"	
"LOW_TILL"	0.242	81.36	0.1752	"lot"	
"pasture1"	3.844	68.48	0.0227	"pag"	
"pasture2"	26.910	74.79	0.0909	"pa2"	
"pasture3"	7.689	82.99	0.1614	"pa3"	
"riparian_pas"	0.504	82.99	1.3784	"trp"	
"afo"	0.039	91.00	0.0000	"afo"	
"hay"	12.408	74.32	0.0434	"hay"	
"forest"	3830.844	67.46	0.0071	"for"	
"harvested_for"	38.695	72.46	0.0714	"hvf"	
"barren"	1.305	88.98	2.3999	"trn"	
"pur_LDI"	129.180	74.79	0.0350	"puL"	
"pur_MDI"	0.000	74.79	0.0471	"puM"	
"pur_HDI"	0.000	74.79	0.0471	"puH"	
"imp_LDI"	0.000	90.66	0.0000	"iuL"	
"imp_MDI"	0.000	98.00	0.0000	"iuM"	
"imp_HDI"	0.000	98.00	0.0000	"iuH"	

Wilson Creek (WLN) Transport Input File Parameters

	vahup95 col. B	vahup95 line no.	StrBnk2 line no.	HRU beg line no.	HRU end line no.
Watershed / Sub-Watershed Code =	WLN	24	27	376	392
No. of Rural Land Uses =	14				
No. of Urban Land Uses =	3				
ETadjust =	0.0	ignore!			
WATERSHED COEFFICIENTS					
Recession coefficient (day-1) =	0.0734				
Seepage coefficient (day-1) =	0.0000		0.0000		
Leakage coefficient (day-1) =	0.0000		0.0000		
Initial unsaturated storage (cm) =	10				
Initial saturated storage (cm) =	0				
Initial snow (cm) =	0				
Sediment delivery ratio =	0.1505				
Unsaturated Available Water Capacity (AWC) =	0.0000				
Antecedent Rainfall for each of 5 previous days (cm) =	0	0	0	0	0
Climatic Records (No. of Years, Beg. Year, End Year):					
No. of Years =	21		21 is the Maximum Allowable		
Beg. Year =	1990		No. of Years!!		
End Year =	2010				
ETflag =	0	ignore!			
CHANNEL EROSION COEFFICIENTS					
aFactor =	0.0000811				
Total Stream Length (m) =	13557.19				
mean channel depth =	0.9546				
SEASONAL COEFFICIENTS			*GROWING*	*EROS.*	
MONTH	*ET_CV*	*DAY HRS*	*SEASON*	*COEFF.*	
"APR"	0.982	12.97	0	0.11	
"MAY"	0.991	13.94	1	0.23	
"JUN"	0.994	14.44	1	0.23	
"JUL"	0.984	14.24	1	0.23	
"AUG"	0.965	13.37	1	0.23	
"SEP"	0.936	12.20	1	0.23	
"OCT"	0.908	11.03	1	0.23	
"NOV"	0.850	10.03	0	0.11	
"DEC"	0.821	9.46	0	0.11	
"JAN"	0.802	9.76	0	0.11	
"FEB"	0.898	10.63	0	0.11	
"MAR"	0.963	11.80	0	0.11	
LAND USE COEFFICIENTS					
LAND_USE	*AREA(ha)*	*Curve NO*	*KLSCP*	*Tag*	17
"HIGH_TILL"	0.078	80.05	0.0481	"hit"	
"LOW_TILL"	0.236	81.30	0.0117	"lot"	
"pasture1"	0.926	68.37	0.0180	"pag"	
"pasture2"	6.480	74.71	0.0719	"pa2"	
"pasture3"	1.851	82.93	0.1276	"pa3"	
"riparian_pas"	0.121	82.93	1.0978	"trp"	
"afo"	0.009	91.00	0.0000	"afo"	
"hay"	3.743	74.24	0.0332	"hay"	
"forest"	3746.062	67.36	0.0078	"for"	
"harvested_for"	37.839	72.37	0.0784	"hvf"	
"barren"	1.530	88.94	0.8422	"trn"	
"pur_LDI"	112.369	74.71	0.0165	"puL"	
"pur_MDI"	15.626	74.71	0.0061	"puM"	
"pur_HDI"	0.678	74.71	0.0064	"puH"	
"imp_LDI"	4.410	90.63	0.0000	"iuL"	
"imp_MDI"	15.626	98.00	0.0000	"iuM"	
"imp_HDI"	2.714	98.00	0.0000	"iuH"	

X-Trib to Slate Branch (XEH) Transport Input File Parameters

	vahup95 col. B	vahup95 line no.	StrBnk2 line no.	HRU beg line no.	HRU end line no.
Watershed / Sub-Watershed Code =	XEH	4	7	36	52
No. of Rural Land Uses =	14				
No. of Urban Land Uses =	3				
ETadjust =	0.0	ignore!			
WATERSHED COEFFICIENTS					
Recession coefficient (day-1) =	0.3763				
Seepage coefficient (day-1) =	0.0000		0.0000		
Leakage coefficient (day-1) =	0.0000		0.0000		
Initial unsaturated storage (cm) =	10				
Initial saturated storage (cm) =	0				
Initial snow (cm) =	0				
Sediment delivery ratio =	0.1937				
Unsaturated Available Water Capacity (AWC) =	0.0000				
Antecedent Rainfall for each of 5 previous days (cm) =	0	0	0	0	0
Climatic Records (No. of Years, Beg. Year, End Year):					
No. of Years =	21		21 is the Maximum Allowable		
Beg. Year =	1990		No. of Years!!		
End Year =	2010				
ETflag =	0	ignore!			
CHANNEL EROSION COEFFICIENTS					
aFactor =	0.0012404				
Total Stream Length (m) =	30.48				
mean channel depth =	0.4716				
SEASONAL COEFFICIENTS			*GROWING*	*EROS.*	
MONTH	*ET_CV*	*DAY HRS*	*SEASON*	*COEFF.*	
"APR"	0.678	12.96	0	0.14	
"MAY"	0.680	13.93	1	0.25	
"JUN"	0.680	14.43	1	0.25	
"JUL"	0.679	14.23	1	0.25	
"AUG"	0.675	13.36	1	0.25	
"SEP"	0.670	12.20	1	0.25	
"OCT"	0.664	11.04	0	0.14	
"NOV"	0.654	10.04	0	0.14	
"DEC"	0.648	9.47	0	0.14	
"JAN"	0.645	9.77	0	0.14	
"FEB"	0.663	10.64	0	0.14	
"MAR"	0.675	11.80	0	0.14	
LAND USE COEFFICIENTS					
LAND_USE	*AREA(ha)*	*Curve NO*	*KLSCP*	*Tag*	17
"HIGH_TILL"	1.078	77.56	0.3035	"hit"	
"LOW_TILL"	9.481	76.81	0.0737	"lot"	
"pasture1"	3.407	64.52	0.0219	"pag"	
"pasture2"	23.846	71.71	0.0876	"pa2"	
"pasture3"	6.813	80.90	0.1556	"pa3"	
"riparian_pas"	1.135	80.90	1.3404	"trp"	
"afo"	0.131	91.00	0.0000	"afo"	
"hay"	12.441	71.44	0.0536	"hay"	
"forest"	4.796	63.52	0.0022	"for"	
"harvested_for"	0.048	68.99	0.0224	"hvf"	
"barren"	2.473	87.36	0.5315	"trn"	
"pur_LDI"	100.650	71.71	0.0183	"puL"	
"pur_MDI"	36.114	71.71	0.0170	"puM"	
"pur_HDI"	11.196	71.71	0.0190	"puH"	
"imp_LDI"	15.933	89.81	0.0000	"iuL"	
"imp_MDI"	36.114	98.00	0.0000	"iuM"	
"imp_HDI"	44.785	98.00	0.0000	"iuH"	

Laurel Creek (LFK) Transport Input File Parameters

	vahup95 col. B	vahup95 line no.	StrBnk2 line no.	HRU beg line no.	HRU end line no.
Watershed / Sub-Watershed Code =	LFK	6	9	70	86
No. of Rural Land Uses =	14				
No. of Urban Land Uses =	3				
ETadjust =	0.0	ignore!			
WATERSHED COEFFICIENTS					
Recession coefficient (day-1) =	0.1067				
Seepage coefficient (day-1) =	0.0000		0.0000		
Leakage coefficient (day-1) =	0.0000		0.0000		
Initial unsaturated storage (cm) =	10				
Initial saturated storage (cm) =	0				
Initial snow (cm) =	0				
Sediment delivery ratio =	0.1744				
Unsaturated Available Water Capacity (AWC) =	0.0000				
Antecedent Rainfall for each of 5 previous days (cm) =	0	0	0	0	0
Climatic Records (No. of Years, Beg. Year, End Year):					
No. of Years =	21		21 is the Maximum Allowable		
Beg. Year =	1990		No. of Years!!		
End Year =	2010				
ETflag =	0	ignore!			
CHANNEL EROSION COEFFICIENTS					
aFactor =	0.0000835				
Total Stream Length (m) =	7869.80				
mean channel depth =	0.7677				
SEASONAL COEFFICIENTS			*GROWING*	*EROS.*	
MONTH	*ET_CV*	*DAY HRS*	*SEASON*	*COEFF.*	
"APR"	0.986	12.96	0	0.15	
"MAY"	0.995	13.93	1	0.23	
"JUN"	0.998	14.43	1	0.23	
"JUL"	0.988	14.23	1	0.23	
"AUG"	0.970	13.36	1	0.23	
"SEP"	0.942	12.20	1	0.23	
"OCT"	0.915	11.04	0	0.15	
"NOV"	0.859	10.04	0	0.15	
"DEC"	0.832	9.47	0	0.15	
"JAN"	0.813	9.77	0	0.15	
"FEB"	0.905	10.64	0	0.15	
"MAR"	0.968	11.80	0	0.15	
LAND USE COEFFICIENTS					
LAND_USE	*AREA(ha)*	*Curve NO*	*KLSCP*	*Tag*	17
"HIGH_TILL"	0.064	79.37	0.9445	"hit"	
"LOW_TILL"	0.563	78.60	0.2295	"lot"	
"pasture1"	8.906	67.30	0.0327	"pag"	
"pasture2"	62.343	73.90	0.1309	"pa2"	
"pasture3"	17.812	82.36	0.2324	"pa3"	
"riparian_pas"	3.464	82.36	1.9153	"trp"	
"afo"	0.079	91.00	0.0000	"afo"	
"hay"	24.674	73.48	0.0683	"hay"	
"forest"	1589.338	66.30	0.0072	"for"	
"harvested_for"	16.054	71.46	0.0723	"hvf"	
"barren"	0.763	88.52	2.3910	"trn"	
"pur_LDI"	73.104	73.90	0.0368	"puL"	
"pur_MDI"	0.314	73.90	0.0550	"puM"	
"pur_HDI"	0.000	73.90	0.0253	"puH"	
"imp_LDI"	1.764	90.40	0.0000	"iuL"	
"imp_MDI"	0.314	98.00	0.0000	"iuM"	
"imp_HDI"	0.000	98.00	0.0000	"iuH"	

Nobusiness Creek (NBS) Transport Input File Parameters

	vahup95 col. B	vahup95 line no.	StrBnk2 line no.	HRU beg line no.	HRU end line no.
Watershed / Sub-Watershed Code =	NBS	2	5	2	18
No. of Rural Land Uses =	14				
No. of Urban Land Uses =	3				
ETadjust =	0.0	ignore!			
WATERSHED COEFFICIENTS					
Recession coefficient (day-1) =	0.0907				
Seepage coefficient (day-1) =	0.0000		0.0000		
Leakage coefficient (day-1) =	0.0000		0.0000		
Initial unsaturated storage (cm) =	10				
Initial saturated storage (cm) =	0				
Initial snow (cm) =	0				
Sediment delivery ratio =	0.1668				
Unsaturated Available Water Capacity (AWC) =	0.0000				
Antecedent Rainfall for each of 5 previous days (cm) =	0	0	0	0	0
Climatic Records (No. of Years, Beg. Year, End Year):					
No. of Years =	21		21 is the Maximum Allowable		
Beg. Year =	1990		No. of Years!!		
End Year =	2010				
ETflag =	0	ignore!			
CHANNEL EROSION COEFFICIENTS					
aFactor =	0.0000318				
Total Stream Length (m) =	7755.13				
mean channel depth =	0.8353				

SEASONAL COEFFICIENTS			*GROWING*	*EROS.*
MONTH	*ET_CV*	*DAY HRS*	*SEASON*	*COEFF.*
"APR"	0.988	12.96	0	0.15
"MAY"	0.997	13.93	1	0.23
"JUN"	1.000	14.43	1	0.23
"JUL"	0.990	14.23	1	0.23
"AUG"	0.970	13.36	1	0.23
"SEP"	0.941	12.20	1	0.23
"OCT"	0.911	11.04	0	0.15
"NOV"	0.852	10.04	0	0.15
"DEC"	0.822	9.47	0	0.15
"JAN"	0.802	9.77	0	0.15
"FEB"	0.901	10.64	0	0.15
"MAR"	0.968	11.80	0	0.15

LAND USE COEFFICIENTS					
LAND_USE	*AREA(ha)*	*Curve NO*	*KLSCP*	*Tag*	17
"HIGH_TILL"	0.000	79.30	0.7161	"hit"	
"LOW_TILL"	0.000	78.54	0.1740	"lot"	
"pasture1"	0.210	67.20	0.0193	"pag"	
"pasture2"	1.467	73.82	0.0770	"pa2"	
"pasture3"	0.419	82.31	0.1367	"pa3"	
"riparian_pas"	0.074	82.31	1.1779	"trp"	
"afo"	0.007	91.00	0.0000	"afo"	
"hay"	0.575	73.40	0.0425	"hay"	
"forest"	2386.940	66.20	0.0061	"for"	
"harvested_for"	24.111	71.36	0.0607	"hvf"	
"barren"	0.268	88.47	2.0633	"trn"	
"pur_LDI"	26.550	73.82	0.0381	"puL"	
"pur_MDI"	0.000	73.82	0.0405	"puM"	
"pur_HDI"	0.000	73.82	0.0405	"puH"	
"imp_LDI"	0.000	90.38	0.0000	"iuL"	
"imp_MDI"	0.000	98.00	0.0000	"iuM"	
"imp_HDI"	0.000	98.00	0.0000	"iuH"	

Reed Creek (RDC) Transport Input File Parameters

	vahup95 col. B	vahup95 line no.	StrBnk2 line no.	HRU beg line no.	HRU end line no.
Watershed / Sub-Watershed Code =	RDC	8	11	104	120
No. of Rural Land Uses =	14				
No. of Urban Land Uses =	3				
ETadjust =	0.0	ignore!			
WATERSHED COEFFICIENTS					
Recession coefficient (day-1) =	0.1045				
Seepage coefficient (day-1) =	0.0000		0.0000		
Leakage coefficient (day-1) =	0.0000		0.0000		
Initial unsaturated storage (cm) =	10				
Initial saturated storage (cm) =	0				
Initial snow (cm) =	0				
Sediment delivery ratio =	0.1736				
Unsaturated Available Water Capacity (AWC) =	0.0000				
Antecedent Rainfall for each of 5 previous days (cm) =	0	0	0	0	0
Climatic Records (No. of Years, Beg. Year, End Year):					
No. of Years =	21		21 is the Maximum Allowable		
Beg. Year =	1990		No. of Years!!		
End Year =	2010				
ETflag =	0	ignore!			
CHANNEL EROSION COEFFICIENTS					
aFactor =	0.0000374				
Total Stream Length (m) =	25298.17				
mean channel depth =	0.7758				
SEASONAL COEFFICIENTS			GROWING	EROS.	
MONTH	*ET_CV*	*DAY HRS*	*SEASON*	*COEFF.*	
"APR"	0.988	12.96	0	0.13	
"MAY"	0.997	13.93	1	0.25	
"JUN"	1.000	14.43	1	0.25	
"JUL"	0.990	14.23	1	0.25	
"AUG"	0.970	13.36	1	0.25	
"SEP"	0.940	12.20	1	0.25	
"OCT"	0.910	11.04	0	0.13	
"NOV"	0.850	10.04	0	0.13	
"DEC"	0.820	9.47	0	0.13	
"JAN"	0.800	9.77	0	0.13	
"FEB"	0.900	10.64	0	0.13	
"MAR"	0.968	11.80	0	0.13	
LAND USE COEFFICIENTS					
LAND_USE	*AREA(ha)*	*Curve NO*	*KLSCP*	*Tag*	17
"HIGH_TILL"	0.000	83.18	1.0035	"hit"	
"LOW_TILL"	0.000	82.40	0.2438	"lot"	
"pasture1"	0.727	73.21	0.0409	"pag"	
"pasture2"	5.087	78.40	0.1635	"pa2"	
"pasture3"	1.454	85.54	0.2903	"pa3"	
"riparian_pas"	0.266	85.54	2.3455	"trp"	
"afo"	0.005	91.00	0.0000	"afo"	
"hay"	2.660	77.70	0.0574	"hay"	
"forest"	1839.550	72.15	0.0085	"for"	
"harvested_for"	18.581	76.49	0.0852	"hvf"	
"barren"	0.006	90.85	2.8915	"trn"	
"pur_LDI"	0.620	78.40	0.0551	"puL"	
"pur_MDI"	0.000	78.40	0.0567	"puM"	
"pur_HDI"	0.000	78.40	0.0567	"puH"	
"imp_LDI"	0.000	91.69	0.0000	"iuL"	
"imp_MDI"	0.000	98.00	0.0000	"iuM"	
"imp_HDI"	0.000	98.00	0.0000	"iuH"	

Wilderness Creek (WNS) Transport Input File Parameters

	vahup95 col. B	vahup95 line no.	StrBnk2 line no.	HRU beg line no.	HRU end line no.
Watershed / Sub-Watershed Code =	WNS	10	13	138	154
No. of Rural Land Uses =	14				
No. of Urban Land Uses =	3				
ETadjust =	0.0	ignore!			
WATERSHED COEFFICIENTS					
Recession coefficient (day-1) =	0.1193				
Seepage coefficient (day-1) =	0.0000		0.0000		
Leakage coefficient (day-1) =	0.0000		0.0000		
Initial unsaturated storage (cm) =	10				
Initial saturated storage (cm) =	0				
Initial snow (cm) =	0				
Sediment delivery ratio =	0.1783				
Unsaturated Available Water Capacity (AWC) =	0.0000				
Antecedent Rainfall for each of 5 previous days (cm) =	0	0	0	0	0
Climatic Records (No. of Years, Beg. Year, End Year):					
No. of Years =	21		21 is the Maximum Allowable		
Beg. Year =	1990		No. of Years!!		
End Year =	2010				
ETflag =	0	ignore!			
CHANNEL EROSION COEFFICIENTS					
aFactor =	0.0000842				
Total Stream Length (m) =	9827.34				
mean channel depth =	0.7285				
SEASONAL COEFFICIENTS			*GROWING*	*EROS.*	
MONTH	*ET_CV*	*DAY HRS*	*SEASON*	*COEFF.*	
"APR"	0.986	12.96	0	0.15	
"MAY"	0.994	13.93	1	0.25	
"JUN"	0.997	14.43	1	0.25	
"JUL"	0.988	14.23	1	0.25	
"AUG"	0.970	13.36	1	0.25	
"SEP"	0.944	12.20	1	0.25	
"OCT"	0.917	11.04	0	0.15	
"NOV"	0.864	10.04	0	0.15	
"DEC"	0.838	9.47	0	0.15	
"JAN"	0.820	9.77	0	0.15	
"FEB"	0.908	10.64	0	0.15	
"MAR"	0.969	11.80	0	0.15	
LAND USE COEFFICIENTS					
LAND_USE	*AREA(ha)*	*Curve NO*	*KLSCP*	*Tag*	17
"HIGH_TILL"	0.064	81.85	0.5986	"hit"	
"LOW_TILL"	0.563	81.08	0.1454	"lot"	
"pasture1"	17.069	71.15	0.0352	"pag"	
"pasture2"	119.480	76.83	0.1407	"pa2"	
"pasture3"	34.137	84.43	0.2498	"pa3"	
"riparian_pas"	6.993	84.43	2.0733	"trp"	
"afo"	0.040	91.00	0.0000	"afo"	
"hay"	47.355	76.23	0.0851	"hay"	
"forest"	1204.472	70.11	0.0081	"for"	
"harvested_for"	12.166	74.73	0.0809	"hvf"	
"barren"	0.472	90.04	2.1394	"trn"	
"pur_LDI"	46.077	76.83	0.0413	"puL"	
"pur_MDI"	0.000	76.83	0.0517	"puM"	
"pur_HDI"	0.063	76.83	0.0350	"puH"	
"imp_LDI"	0.314	91.24	0.0000	"iuL"	
"imp_MDI"	0.000	98.00	0.0000	"iuM"	
"imp_HDI"	0.251	98.00	0.0000	"iuH"	

Back Creek (BCK) Transport Input File Parameters

	vahup95 col. B	vahup95 line no.	StrBnk2 line no.	HRU beg line no.	HRU end line no.
Watershed / Sub-Watershed Code =	BCK	2	5	2	18
No. of Rural Land Uses =	14				
No. of Urban Land Uses =	3				
ETadjust =	0.0	ignore!			
WATERSHED COEFFICIENTS					
Recession coefficient (day-1) =	0.0655				
Seepage coefficient (day-1) =	0.0000		0.0000		
Leakage coefficient (day-1) =	0.0000		0.0000		
Initial unsaturated storage (cm) =	10				
Initial saturated storage (cm) =	0				
Initial snow (cm) =	0				
Sediment delivery ratio =	0.1370				
Unsaturated Available Water Capacity (AWC) =	0.0000				
Antecedent Rainfall for each of 5 previous days (cm) =	0	0	0	0	0
Climatic Records (No. of Years, Beg. Year, End Year):					
No. of Years =	21		21 is the Maximum Allowable		
Beg. Year =	1990		No. of Years!!		
End Year =	2010				
ETflag =	0	ignore!			
CHANNEL EROSION COEFFICIENTS					
aFactor =	0.0001210				
Total Stream Length (m) =	20710.53				
mean channel depth =	1.0456				
SEASONAL COEFFICIENTS			*GROWING*	*EROS.*	
MONTH	*ET_CV*	*DAY HRS*	*SEASON*	*COEFF.*	
"APR"	0.982	12.96	0	0.14	
"MAY"	0.989	13.91	1	0.35	
"JUN"	0.992	14.41	1	0.35	
"JUL"	0.984	14.21	1	0.35	
"AUG"	0.968	13.36	1	0.35	
"SEP"	0.945	12.20	1	0.35	
"OCT"	0.921	11.04	0	0.14	
"NOV"	0.874	10.04	0	0.14	
"DEC"	0.851	9.49	0	0.14	
"JAN"	0.835	9.79	0	0.14	
"FEB"	0.913	10.64	0	0.14	
"MAR"	0.967	11.80	0	0.14	
LAND USE COEFFICIENTS					
LAND_USE	*AREA(ha)*	*Curve NO*	*KLSCP*	*Tag*	17
"HIGH_TILL"	0.671	79.98	0.3281	"hit"	
"LOW_TILL"	248.081	79.23	0.0797	"lot"	
"pasture1"	216.993	68.28	0.0299	"pag"	
"pasture2"	1518.951	74.61	0.1196	"pa2"	
"pasture3"	433.986	82.91	0.2123	"pa3"	
"riparian_pas"	73.540	82.91	1.8221	"trp"	
"afo"	0.460	91.00	0.0000	"afo"	
"hay"	826.810	74.09	0.0694	"hay"	
"forest"	1982.279	67.27	0.0081	"for"	
"harvested_for"	20.023	72.20	0.0814	"hvf"	
"barren"	1.645	88.84	2.8745	"trn"	
"pur_LDI"	153.738	74.61	0.0302	"puL"	
"pur_MDI"	1.531	74.61	0.0242	"puM"	
"pur_HDI"	0.118	74.61	0.0025	"puH"	
"imp_LDI"	5.418	90.65	0.0000	"iuL"	
"imp_MDI"	1.531	98.00	0.0000	"iuM"	
"imp_HDI"	0.473	98.00	0.0000	"iuH"	

Cripple Creek (CPL) Transport Input File Parameters

	vahup95 col. B	vahup95 line no.	StrBnk2 line no.	HRU beg line no.	HRU end line no.
Watershed / Sub-Watershed Code =	CPL1x	10	13	138	154
No. of Rural Land Uses =	14				
No. of Urban Land Uses =	3				
ETadjust =	0.0	ignore!			
WATERSHED COEFFICIENTS					
Recession coefficient (day-1) =	0.0493				
Seepage coefficient (day-1) =	0.0000		0.0000		
Leakage coefficient (day-1) =	0.0000		0.0000		
Initial unsaturated storage (cm) =	10				
Initial saturated storage (cm) =	0				
Initial snow (cm) =	0				
Sediment delivery ratio =	0.0862				
Unsaturated Available Water Capacity (AWC) =	0.0000				
Antecedent Rainfall for each of 5 previous days (cm) =	0	0	0	0	0
Climatic Records (No. of Years, Beg. Year, End Year):					
No. of Years =	21		21 is the Maximum Allowable		
Beg. Year =	1990		No. of Years!!		
End Year =	2010				
ETflag =	0	ignore!			
CHANNEL EROSION COEFFICIENTS					
aFactor =	0.0001262				
Total Stream Length (m) =	269217.50				
mean channel depth =	1.6094				
SEASONAL COEFFICIENTS			*GROWING*	*EROS.*	
MONTH	*ET_CV*	*DAY HRS*	*SEASON*	*COEFF.*	
"APR"	0.985	12.96	0	0.13	
"MAY"	0.992	13.91	1	0.26	
"JUN"	0.995	14.41	1	0.26	
"JUL"	0.987	14.21	1	0.26	
"AUG"	0.970	13.36	1	0.26	
"SEP"	0.946	12.20	1	0.26	
"OCT"	0.921	11.04	0	0.13	
"NOV"	0.871	10.04	0	0.13	
"DEC"	0.847	9.49	0	0.13	
"JAN"	0.830	9.79	0	0.13	
"FEB"	0.913	10.64	0	0.13	
"MAR"	0.969	11.80	0	0.13	
LAND USE COEFFICIENTS					
LAND_USE	*AREA(ha)*	*Curve NO*	*KLSCP*	*Tag*	17
"HIGH_TILL"	65.120	80.33	0.3565	"hit"	
"LOW_TILL"	191.553	79.57	0.0866	"lot"	
"pasture1"	612.252	68.82	0.0496	"pag"	
"pasture2"	4285.764	75.03	0.1985	"pa2"	
"pasture3"	1224.504	83.19	0.3524	"pa3"	
"riparian_pas"	227.678	83.19	2.9607	"trp"	
"afo"	4.615	91.00	0.0000	"afo"	
"hay"	2082.001	74.47	0.1158	"hay"	
"forest"	16196.523	67.81	0.0099	"for"	
"harvested_for"	180.536	72.67	0.0992	"hvf"	
"barren"	9.251	89.05	1.6968	"trn"	
"pur_LDI"	906.624	75.03	0.0399	"puL"	
"pur_MDI"	1.098	75.03	0.0121	"puM"	
"pur_HDI"	0.000	75.03	0.0648	"puH"	
"imp_LDI"	7.060	90.78	0.0000	"iuL"	
"imp_MDI"	1.098	98.00	0.0000	"iuM"	
"imp_HDI"	0.000	98.00	0.0000	"iuH"	

Kimberling Creek (KBL) Transport Input File Parameters

	vahup95 col. B	vahup95 line no.	StrBnk2 line no.	HRU beg line no.	HRU end line no.
Watershed / Sub-Watershed Code =	KBL1x	18	21	274	290
No. of Rural Land Uses =	14				
No. of Urban Land Uses =	3				
ETadjust =	0.0	ignore!			
WATERSHED COEFFICIENTS					
Recession coefficient (day-1) =	0.0514				
Seepage coefficient (day-1) =	0.0000		0.0000		
Leakage coefficient (day-1) =	0.0000		0.0000		
Initial unsaturated storage (cm) =	10				
Initial saturated storage (cm) =	0				
Initial snow (cm) =	0				
Sediment delivery ratio =	0.0965				
Unsaturated Available Water Capacity (AWC) =	0.0000				
Antecedent Rainfall for each of 5 previous days (cm) =	0	0	0	0	0
Climatic Records (No. of Years, Beg. Year, End Year):					
No. of Years =	21		21 is the Maximum Allowable		
Beg. Year =	1990		No. of Years!!		
End Year =	2010				
ETflag =	0	ignore!			
CHANNEL EROSION COEFFICIENTS					
aFactor =	0.0000663				
Total Stream Length (m) =	115983.71				
mean channel depth =	1.4477				
SEASONAL COEFFICIENTS			*GROWING*	*EROS.*	
MONTH	*ET_CV*	*DAY HRS*	*SEASON*	*COEFF.*	
"APR"	0.987	12.96	0	0.15	
"MAY"	0.996	13.91	1	0.23	
"JUN"	0.998	14.41	1	0.23	
"JUL"	0.989	14.21	1	0.23	
"AUG"	0.970	13.36	1	0.23	
"SEP"	0.942	12.20	1	0.23	
"OCT"	0.914	11.04	0	0.15	
"NOV"	0.858	10.04	0	0.15	
"DEC"	0.830	9.49	0	0.15	
"JAN"	0.811	9.79	0	0.15	
"FEB"	0.905	10.64	0	0.15	
"MAR"	0.968	11.80	0	0.15	
LAND USE COEFFICIENTS					
LAND_USE	*AREA(ha)*	*Curve NO*	*KLSCP*	*Tag*	17
"HIGH_TILL"	13.803	81.26	0.2666	"hit"	
"LOW_TILL"	123.546	80.49	0.0648	"lot"	
"pasture1"	129.717	70.24	0.0289	"pag"	
"pasture2"	908.018	76.13	0.1156	"pa2"	
"pasture3"	259.434	83.94	0.2051	"pa3"	
"riparian_pas"	15.816	83.94	1.7478	"trp"	
"afo"	18.953	91.00	0.0000	"afo"	
"hay"	353.808	75.57	0.0679	"hay"	
"forest"	15389.306	69.20	0.0079	"for"	
"harvested_for"	162.033	73.94	0.0794	"hvf"	
"barren"	3.693	89.67	2.2989	"trn"	
"pur_LDI"	358.531	76.13	0.0461	"puL"	
"pur_MDI"	2.116	76.13	0.0617	"puM"	
"pur_HDI"	0.063	76.13	0.0422	"puH"	
"imp_LDI"	2.560	91.05	0.0000	"iuL"	
"imp_MDI"	2.116	98.00	0.0000	"iuM"	
"imp_HDI"	0.251	98.00	0.0000	"iuH"	

Stony Creek (SNC) Transport Input File Parameters

	vahup95 col. B	vahup95 line no.	StrBnk2 line no.	HRU beg line no.	HRU end line no.
Watershed / Sub-Watershed Code =	SNC	20	23	308	324
No. of Rural Land Uses =	14				
No. of Urban Land Uses =	3				
ETadjust =	0.0	ignore!			
WATERSHED COEFFICIENTS					
Recession coefficient (day-1) =	0.0573				
Seepage coefficient (day-1) =	0.0000		0.0000		
Leakage coefficient (day-1) =	0.0000		0.0000		
Initial unsaturated storage (cm) =	10				
Initial saturated storage (cm) =	0				
Initial snow (cm) =	0				
Sediment delivery ratio =	0.1175				
Unsaturated Available Water Capacity (AWC) =	0.0000				
Antecedent Rainfall for each of 5 previous days (cm) =	0	0	0	0	0
Climatic Records (No. of Years, Beg. Year, End Year):					
No. of Years =	21		21 is the Maximum Allowable		
Beg. Year =	1990		No. of Years!!		
End Year =	2010				
ETflag =	0	ignore!			
CHANNEL EROSION COEFFICIENTS					
aFactor =	0.0000538				
Total Stream Length (m) =	25796.86				
mean channel depth =	1.2059				

SEASONAL COEFFICIENTS

MONTH	*ET_CV*	*DAY HRS*	*GROWING SEASON*	*EROS. COEFF.*
"APR"	0.988	12.96	0	0.08
"MAY"	0.997	13.91	1	0.20
"JUN"	1.000	14.41	1	0.20
"JUL"	0.990	14.21	1	0.20
"AUG"	0.970	13.36	1	0.20
"SEP"	0.941	12.20	1	0.20
"OCT"	0.911	11.04	0	0.08
"NOV"	0.852	10.04	0	0.08
"DEC"	0.823	9.49	0	0.08
"JAN"	0.803	9.79	0	0.08
"FEB"	0.901	10.64	0	0.08
"MAR"	0.968	11.80	0	0.08

LAND USE COEFFICIENTS

LAND_USE	*AREA(ha)*	*Curve NO*	*KLSCP*	*Tag*	17
"HIGH_TILL"	0.037	79.10	0.1975	"hit"	
"LOW_TILL"	0.276	78.34	0.0480	"lot"	
"pasture1"	1.689	66.89	0.0139	"pag"	
"pasture2"	11.824	73.58	0.0555	"pa2"	
"pasture3"	3.378	82.15	0.0984	"pa3"	
"riparian_pas"	0.637	82.15	0.8428	"trp"	
"afo"	0.081	91.00	0.0000	"afo"	
"hay"	4.324	73.17	0.0235	"hay"	
"forest"	8938.668	65.89	0.0082	"for"	
"harvested_for"	90.290	71.09	0.0822	"hvf"	
"barren"	1.277	88.34	2.7831	"trn"	
"pur_LDI"	126.326	73.58	0.0270	"puL"	
"pur_MDI"	0.000	73.58	0.0546	"puM"	
"pur_HDI"	0.000	73.58	0.0546	"puH"	
"imp_LDI"	0.063	90.32	0.0000	"iuL"	
"imp_MDI"	0.000	98.00	0.0000	"iuM"	
"imp_HDI"	0.000	98.00	0.0000	"iuH"	

Walker Creek (WLK) Transport Input File Parameters

	vahup95 col. B	vahup95 line no.	StrBnk2 line no.	HRU beg line no.	HRU end line no.
Watershed / Sub-Watershed Code =	WLKx	26	29	410	426
No. of Rural Land Uses =	14				
No. of Urban Land Uses =	3				
ETadjust =	0.0	ignore!			
WATERSHED COEFFICIENTS					
Recession coefficient (day-1) =	0.0534				
Seepage coefficient (day-1) =	0.0000		0.0000		
Leakage coefficient (day-1) =	0.0000		0.0000		
Initial unsaturated storage (cm) =	10				
Initial saturated storage (cm) =	0				
Initial snow (cm) =	0				
Sediment delivery ratio =	0.1050				
Unsaturated Available Water Capacity (AWC) =	0.0000				
Antecedent Rainfall for each of 5 previous days (cm) =	0	0	0	0	0
Climatic Records (No. of Years, Beg. Year, End Year):					
No. of Years =	21		21 is the Maximum Allowable		
Beg. Year =	1990		No. of Years!!		
End Year =	2010				
ETflag =	0	ignore!			
CHANNEL EROSION COEFFICIENTS					
aFactor =	0.0001413				
Total Stream Length (m) =	83012.00				
mean channel depth =	1.3390				
SEASONAL COEFFICIENTS					
MONTH	*ET_CV*	*DAY HRS*	*GROWING SEASON*	*EROS. COEFF.*	
"APR"	0.982	12.96	0	0.15	
"MAY"	0.989	13.91	1	0.25	
"JUN"	0.991	14.41	1	0.25	
"JUL"	0.984	14.21	1	0.25	
"AUG"	0.968	13.36	1	0.25	
"SEP"	0.946	12.20	1	0.25	
"OCT"	0.923	11.04	0	0.15	
"NOV"	0.877	10.04	0	0.15	
"DEC"	0.855	9.49	0	0.15	
"JAN"	0.839	9.79	0	0.15	
"FEB"	0.915	10.64	0	0.15	
"MAR"	0.967	11.80	0	0.15	
LAND USE COEFFICIENTS					
LAND_USE	*AREA(ha)*	*Curve NO*	*KLSCP*	*Tag*	17
"HIGH_TILL"	3.485	78.10	0.6639	"hit"	
"LOW_TILL"	32.327	77.35	0.1613	"lot"	
"pasture1"	361.137	65.35	0.0410	"pag"	
"pasture2"	2527.957	72.35	0.1642	"pa2"	
"pasture3"	722.273	81.33	0.2915	"pa3"	
"riparian_pas"	147.955	81.33	2.4635	"trp"	
"afo"	0.837	91.00	0.0000	"afo"	
"hay"	1002.058	72.06	0.1001	"hay"	
"forest"	7810.024	64.34	0.0095	"for"	
"harvested_for"	122.166	69.72	0.0949	"hvf"	
"barren"	6.589	87.71	1.4273	"trn"	
"pur_LDI"	596.745	72.35	0.0445	"puL"	
"pur_MDI"	16.749	72.35	0.0474	"puM"	
"pur_HDI"	0.502	72.35	0.0209	"puH"	
"imp_LDI"	19.531	89.98	0.0000	"iuL"	
"imp_MDI"	16.749	98.00	0.0000	"iuM"	
"imp_HDI"	2.007	98.00	0.0000	"iuH"	

APPENDIX D: TI DISTRIBUTION STATISTICAL RESULTS

Table D-1. Pairwise Wilcoxon Rank Sum test for JR1 watersheds

	WDS	DCK	DDY	RGR
DCK	< 2e-16	-	-	-
DDY	0.00019	< 8.2e-14	-	-
RGR	< 2e-16	< 2e-16	7.1e-09	-
STV	< 2e-16	< 2e-16	0.02549	1.4e-06

Table D-2. Pairwise Wilcoxon Rank Sum test for JR2 watersheds

	CAT	BLD	JKS	MIW
BLD	< 2e-16	-	-	-
JKS	< 2e-16	8.2e-14	-	-
MIW	< 2e-16	< 2e-16	< 2e-16	-
WLN	< 2e-16	< 2e-16	< 2e-16	< 2e-16

Table D-3. Pairwise Wilcoxon Rank Sum test for NR1 watersheds

	XEH	LFK	NBS	RDC
LFK	< 2e-16	-	-	-
NBS	< 2e-16	1.2e-06	-	-
RDC	3.3e-13	< 2e-16	< 2e-16	-
WNS	< 2e-16	< 2e-16	< 2e-16	< 2e-16

Table D-4. Pairwise Wilcoxon Rank Sum test for NR2 watersheds

	BCK	CPL	KBL	SNC
CPL	< 2e-16	-	-	-
KBL	< 2e-16	< 2e-16	-	-
SNC	3.7e-16	< 2e-16	< 2e-16	-
WLK	< 2e-16	< 2e-16	< 2e-16	< 2e-16