Benthic TMDL Development for Bailey Creek, Nuttree Branch, Oldtown Creek, Proctors Creek, Rohoic Creek, and Swift Creek Watersheds Located in Chesterfield, Dinwiddie, and Prince George Counties and Cities of Hopewell, Colonial Heights, and Petersburg

Prepared by:
Wetland Studies and Solutions, Inc.
and
James Madison University

Prepared for:
Virginia Department of Environmental Quality
January 2023

Acknowledgements

Project Personnel

Wetland Studies and Solutions, Inc.

Katie Shoemaker, PE, CFM, Environmental Engineer
Jeremy Bradley, CFM, GIS Specialist
Thomas Schubert, EIT, Project Engineer

James Madison University

Dr. Robert Brent, Associate Professor
Nicholas Saraceno, Undergraduate Research Assistant
Madison Hagen, Undergraduate Research Assistant

Virginia Department of Environmental Quality (VADEQ)

Kelley West, Environmental Planner
Jennifer Palmore, Water Planning Team Leader
Denise Moyer, TMDL Coordinator

Technical Advisory Committee

Laura Barry, Scott Bookwalter, Weedon Cloe, Scott Flanigan, Rebecca Stewart - Chesterfield County
Alan Lederman - Chesterfield County School Board
Arnold "Chip" Kramer - John Tyler Community College
Tracey Harmon - VDOT
Ashley Hall - Stantec representing VDOT
Erin Reilly - James River Association
Kelly Hengler - CE&H Heritage Civic League
David Sirois - Addison Evans Water Production and Lab Facility
Ryan Shore - Aleris
Laura Nicklin - Ashland Special Ingredients G.P.
Julian Lipscomb - Branscome Incorporated
Jennifer Rogers, Liz McKercher, Oula Shehab-Dandan - Dominion Energy
Randall Breeden - International Paper
Ryan Smith - LaBella Associates
Mitchell Scott - Martin Marietta Materials, Inc.
Emily Guillaume, Andrea Wortzel - Troutman Pepper representing VA Manufacturers Assn.

For additional information, please contact:

Virginia Department of Environmental Quality

Piedmont Regional Office, Glen Allen: Kelley West (804-432-7946)

Table of Contents

Figures

Figures in Appendices

Tables

Tables in Appendices

Acronyms

AllForX	All-Forest Load Multiplier
CADDIS	Causal Analysis Diagnosis Decision Information System
CBP	Chesapeake Bay Program
CREP	Conservation Reserve Enhancement Program
CV	Coefficient of Variation
EQIP	Environmental Quality Incentive Program
GWLF	Generalized Watershed Loading Function
HSG	Hydrologic Soil Group
ISW	Industrial Stormwater
JMU	James Madison University
LA	Load Allocation
LTA	Long-Term Average
MDL	Maximum Daily Load
MOS	Margin of Safety
MS4	Municipal Separate Storm Sewer Systems
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resource Conservation Service
POC	Pollutant(s) of Concern
SCS-CN	Soil Conservation Service Curve Number
SSURGO	Soil Survey Geographic database
SWCB	State Water Control Board
SWCD	Soil and Water Conservation District
TAC	Technical Advisory Committee
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
TSS	Total Suspended Sediment
USEPA	United States Environmental Protection Agency
USLE	Universal Soil Loss Equation
VADEQ	Virginia Department of Environmental Quality
VDOT	Virginia Department of Transportation
VGIN	Virginia Geographic Information Network
VPDES	Virginia Pollutant Discharge Elimination System
VSCI	Virginia Stream Condition Index
VSMP	Virginia Stormwater Management Program
WIP	Watershed Implementation Plan
WLA	Wasteload Allocation
WQMIRA	Water Quality Monitoring, Information and Restoration Act

1.0 EXECUTIVE SUMMARY

1.1. Background

This TMDL study spans six watersheds near Richmond and Petersburg, Virginia. These watersheds include Bailey Creek in Hopewell City and Prince George County, Nuttree Branch in Chesterfield County, Oldtown Creek in Chesterfield County and the City of Colonial Heights, Proctors Creek in Chesterfield County, Rohoic Creek in Dinwiddie County and City of Petersburg, and Swift Creek in Chesterfield and Powhatan Counties. All streams drain either directly or indirectly to the James River or Appomattox River (which itself is a tributary of the James).

> Definition:
>
> Watershed – All of the land area that drains to a particular point or body of water.

Bailey Creek, Nuttree Branch, Oldtown Creek, Proctors Creek, Rohoic Creek, and Swift Creek (herein collectively referred to as the "James River Tributaries") are listed as impaired on Virginia's 2020 Section 305(b)/303(d) Water Quality Assessment Integrated Report (IR) due to water quality violations of the general aquatic life (benthic) standard. The impaired segments addressed in this document are listed in **Table 1-1**. The watersheds of the impaired streams are shown in **Figure 1-1**.

Table 1-1. 2020 IR impaired segments addressed in this TMDL study.

TMDL Watershed	305(b) Segment ID	Cause Group Code 303(d) Impairment ID	Listing Station	Year Initially Listed
Bailey Creek	VAP-G03R_BLY02A08 (1.35 mi)	G03R-02-BEN	2-BLY005.73	2014
	VAP-G03R_BLY01A98 (5.12 mi)			2014
Nuttree Branch	VAP-J17R_NUT01A06 (5.58 mi)	J17R-06-BEN	2-NUT000.62	2012
Oldtown Creek	VAP-J15R_OTC01A00 (4.22 mi)	J15R-02-BEN	2-OTC001.54	2010
	VAP-J15R_OTC01B08 (6.22 mi)	J15R-08-BEN	2-OTC005.38	2018
Proctors Creek	VAP-G01R_PCT01A06 (8.26 mi)	G01R-15-BEN	2-PCT002.46	2010
Rohoic Creek	VAP-J15R_RHC01A06 (13.45 mi)	J15R-05-BEN	2-RHC000.58	2012
Swift Creek	VAP-J17R_SFT01B98 (7.25 mi)	J17R-01-BEN	2-SFT019.02	2010
	VAP-J17R_SFT02A00 (2.88 mi)	J17R-09-BEN	2-SFT025.32	2010

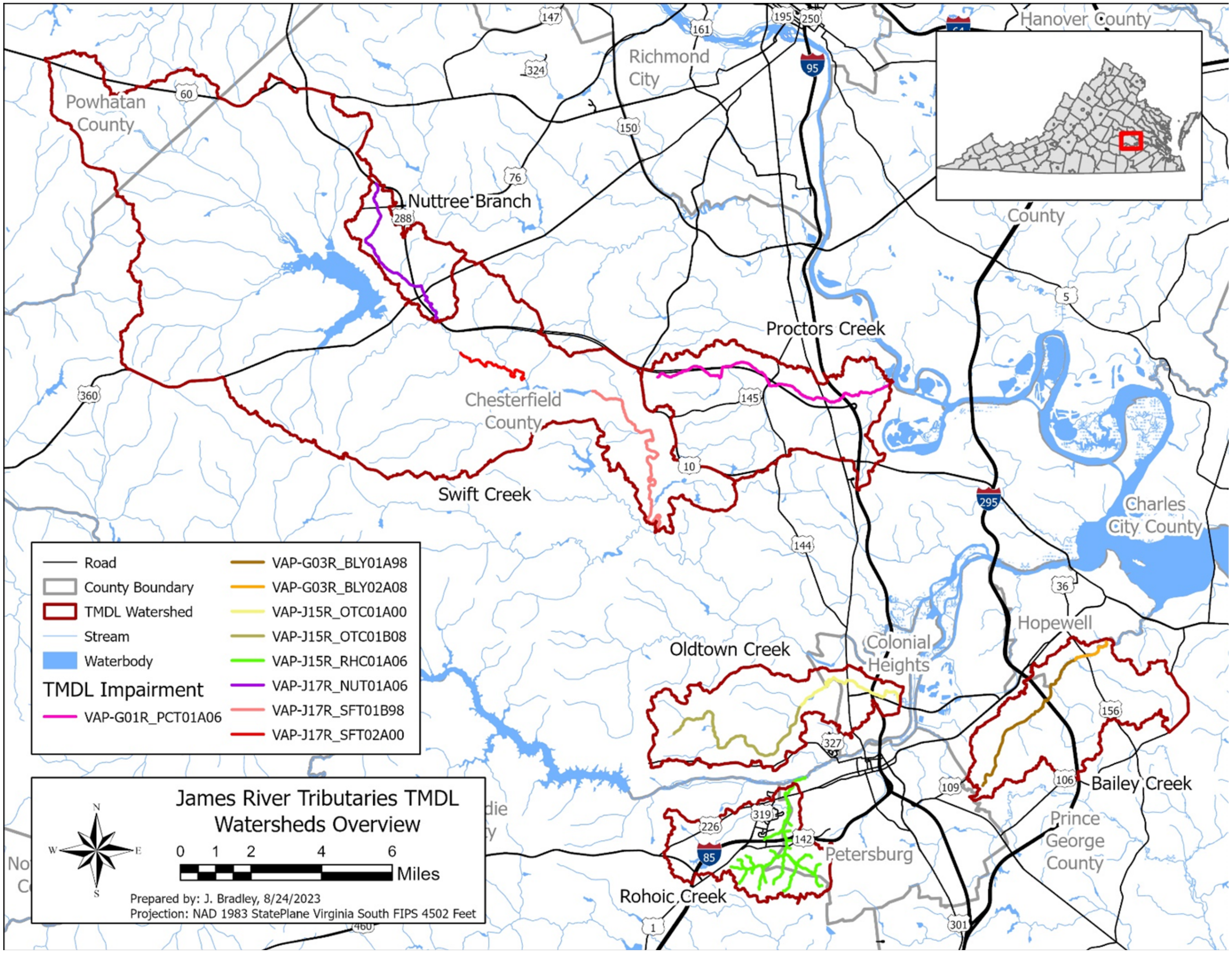


Figure 1-1. Location of the 2020 IR James River tributaries water impairments.

1.2. The Problem

1.2.1. Impaired Aquatic Life

The Commonwealth of Virginia sets standards for all the waters in the state. One of those standards is the expectation that every stream will support a healthy and diverse community of macroinvertebrates and fish (the aquatic life designated use). The Virginia Department of Environmental Quality (VADEQ) determines whether this standard is met by monitoring the benthic macroinvertebrate community (bugs that live on the bottom of the stream) in our waterways. The health and diversity of these bugs are assessed using the Virginia Stream Condition Index (VSCI). The VSCI is a multi-metric index used to derive stream health scores ranging from 0 to 100. Scores below 60 are categorized as impaired. **Figure 1-2** shows the various monitoring stations throughout the watershed, color-coded by the average score at each site. Red and yellow symbols indicate that the streams do not support a healthy and diverse community of macroinvertebrates and fish. This shows that the various impaired streams in this study fail the aquatic life use standard, and pollutants within the watershed need to be identified and reduced to help clean up the waterway.

A benthic stressor analysis study was conducted in 2021 to determine the reason for the benthic impairments in Bailey Creek, Nuttree Branch, Oldtown Creek, Proctors Creek, Rohoic Creek, and Swift Creek (**8.0Appendix E**) (herein collectively referred to as the "James River Tributaries"). The study found that excess sediment was a cause of impairment across all watersheds, and excess phosphorus was determined to be an additional cause of impairment in Oldtown Creek, Rohoic Creek, and Swift Creek.

1.2.2. Too Much Sediment

Excess sediment was identified as a primary stressor in all study watersheds. When it rains, sediment is washed from the land surface into nearby creeks and rivers. The amount of soil that is washed off depends on how much it rains and the characteristics of the surrounding watershed. Rain falling on a construction site without sediment barriers or highly tilled cropland without a cover crop may carry a large amount of sediment to a stream. Other land types, like forests and well-maintained pasture, contribute much less sediment to waterways during rainfall events. When excess soil gets into nearby streams, it can fill in and destroy valuable habitat for aquatic macroinvertebrates that live underneath and between rocks on the bottom of the stream. Without this valuable habitat, the diversity of aquatic life in a stream may be severely limited.

1.2.3. Too Much Phosphorus

In addition to having too much sediment, Oldtown Creek, Rohoic Creek, and Swift Creek have too much phosphorus. Phosphorus is a nutrient that helps plants grow. Phosphorus can be found attached to the sediment that is washed into streams and can also be found in fertilizer and manure. Just as dirt can wash off of the land surface into nearby creeks, phosphorus contained in fertilizer and manure can wash off into streams. Phosphorus can also enter streams from point or piped sources, such as effluent from wastewater treatment plants and other permitted sources. Too much phosphorus can cause excess algae to grow in a stream. When that algae dies and begins to decompose it can cause the oxygen supply in the water to dramatically decrease and limit the diversity of bugs and fish which need oxygen to survive.

1.3. The Study

To study the problem of excess sediment and phosphorus (where applicable) in the James River Tributaries TMDL, a combination of monitoring and computer modeling was utilized. Monitoring was used to tell how much sediment and phosphorus is in the streams at any given time and how aquatic life conditions have changed over time. The computer model was used to estimate where the sediment and phosphorus are coming from and make predictions about how stream conditions would change if those sources were reduced.

For this purpose, a computer numerical model called the Generalized Watershed Loading Function model (or GWLF) was used. This model considers slope, soils, land cover, erodibility, and runoff to estimate the amount of soil and associated phosphorus eroded in the watershed and deposited in the stream. The model was calibrated against real-world flow measurements taken from a nearby stream to ensure that it was producing accurate results. The tested model was then used to estimate the sediment and phosphorus reductions that would be needed to completely restore a healthy aquatic benthic community to the impaired streams in the watershed.

Frequently Asked Question:

Why use a computer model?
Sampling and testing tell you a lot about the present and the past, but nothing about the future. A computer model is a tool that can help you make predictions about the future. This is necessary to figure out how much effort is needed to clean up a stream.

This report summarizes the study and sets goals for a clean-up plan. The study is called a Total Maximum Daily Load (TMDL) study because it determines the maximum amount of a pollutant that can enter a waterbody without harming the stream or the organisms living in it.

Definition:

TMDL – Total Maximum Daily Load. This is the amount of a pollutant that a stream can receive and still meet water quality standards. The term TMDL is also used more generally to describe the state's formal process for cleaning up polluted streams.

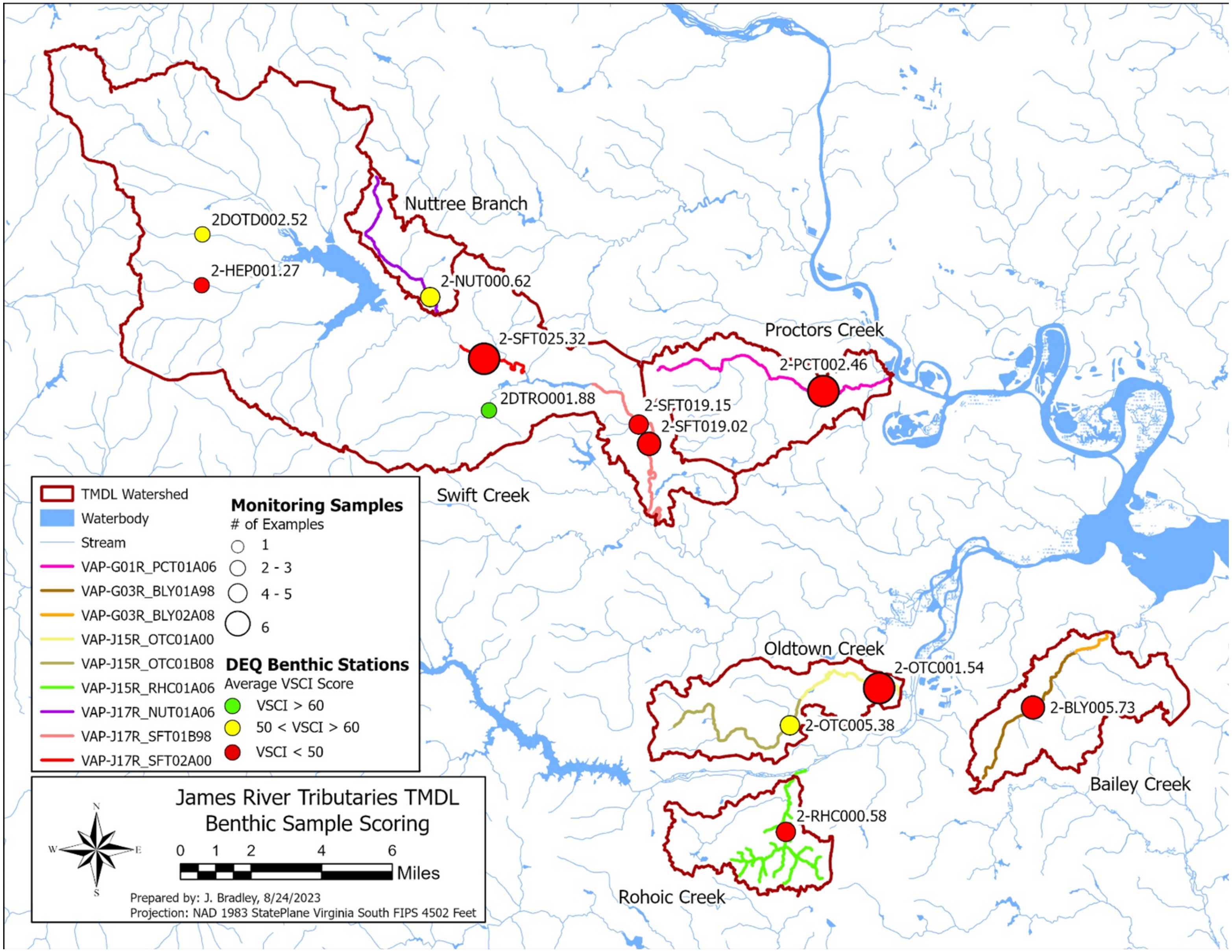


Figure 1-2. Stream health score summaries in the James River Tributaries watersheds.

1.4. Current Conditions

The Virginia Geographic Information Network (VGIN) 2016 Virginia Land Cover Dataset (VLCD) was used to determine current land use within the watersheds, with minor modifications (discussed in **Section 3.3**). The primary land cover in each watershed in this study is forest, followed by turfgrass and urban/suburban development. Agriculture (cropland and pasture/hay) is only a small percent of the land cover in each watershed. The land cover distribution for each impaired watershed is shown in **Figure 1-3** through **Figure 1-8.**

> Definition:
>
> Point Source – pollution that comes out of a pipe (like at a sewage treatment plant).
> Non-point Source – pollution that does not come out of a pipe but comes generally from the landscape (usually as runoff).

This land cover dataset combined with an accounting of the permitted discharges, represent the major pollutant sources in the watershed. The GWLF model was used to determine the relative contribution of sources of sediment and phosphorus in the impaired watersheds. **Figure 1-3** through **Figure 1-8** show the distribution of sediment and phosphorus (where applicable) contributions from various sources in the watersheds. Permitted sources include eight (8) Municipal Separate Storm Sewer System (MS4) entities: City of Colonial Heights, City of Hopewell, City of Petersburg, Central State Hospital, Chesterfield County, Fort Lee, John Tyler Community College, and Virginia Department of Transportation (VDOT). Additionally, the watersheds include Virginia Pollutant Discharge Elimination System (VPDES) individual permits, industrial stormwater permits, concrete general permits, domestic sewage permits, construction general permits, vehicle wash permits, and non-metallic mineral mining permits (NMMM). The sediment and phosphorus loads from permitted sources were calculated based on the permit language, reported discharge data, and land cover type and area (permits are detailed in **Section 4.3.2**). Due to the largely urban/suburban nature of the study watersheds, relatively little sediment or phosphorus is sourced from agricultural land and instead pollutant loads are driven by developed land uses, streambank erosion, and permitted discharges.

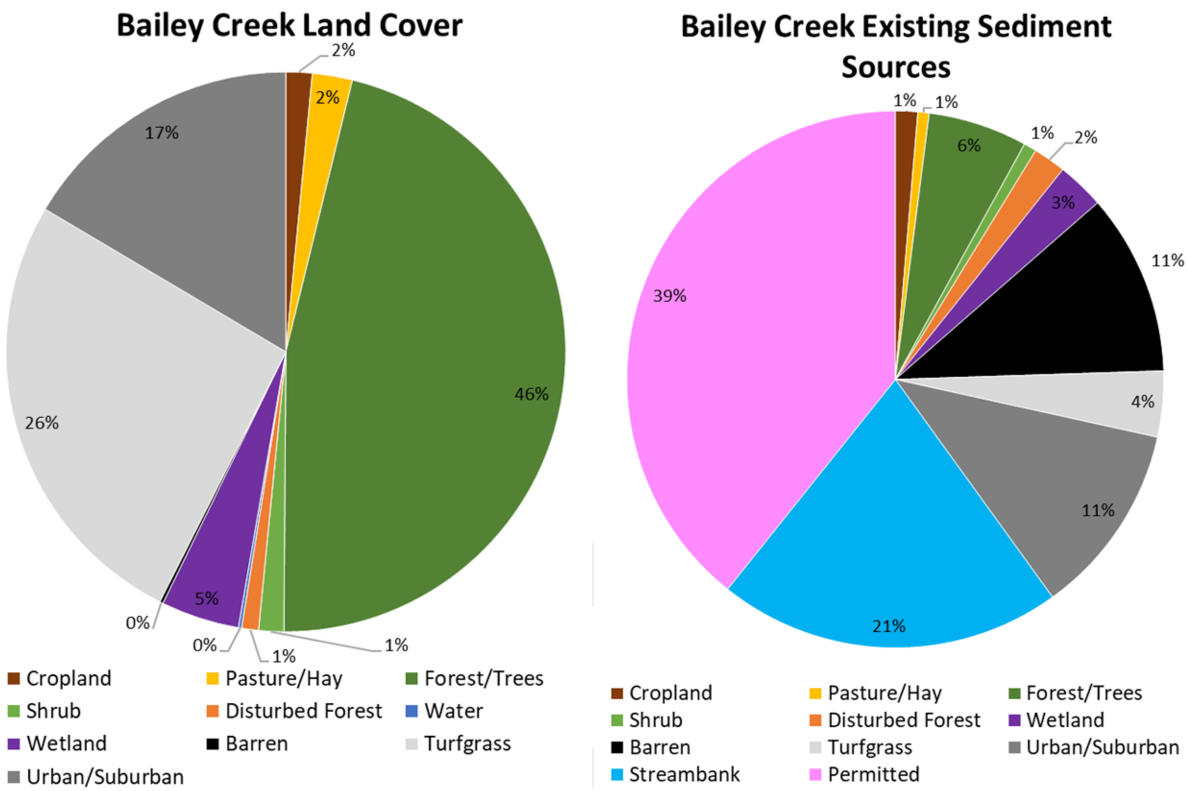


Figure 1-3. Land cover and existing source load distributions in the Bailey Creek watershed.

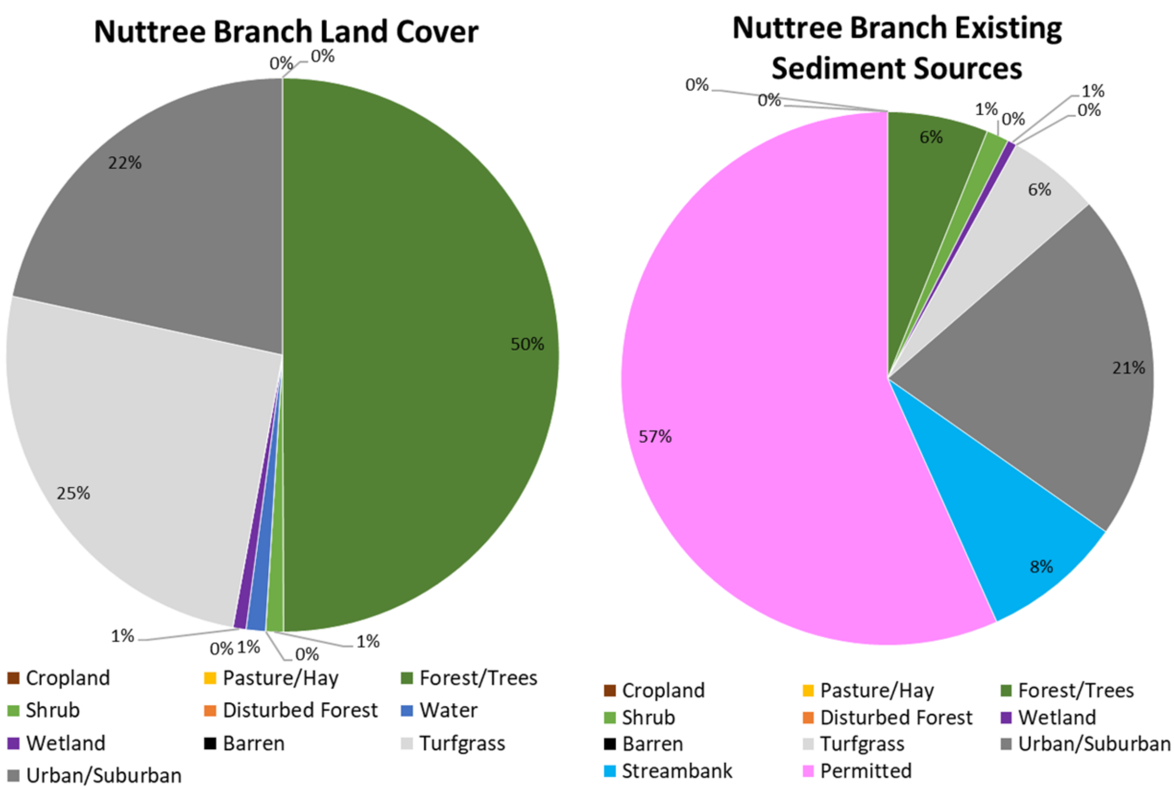


Figure 1-4. Land cover and existing source load distributions in the Nuttree Branch watershed.

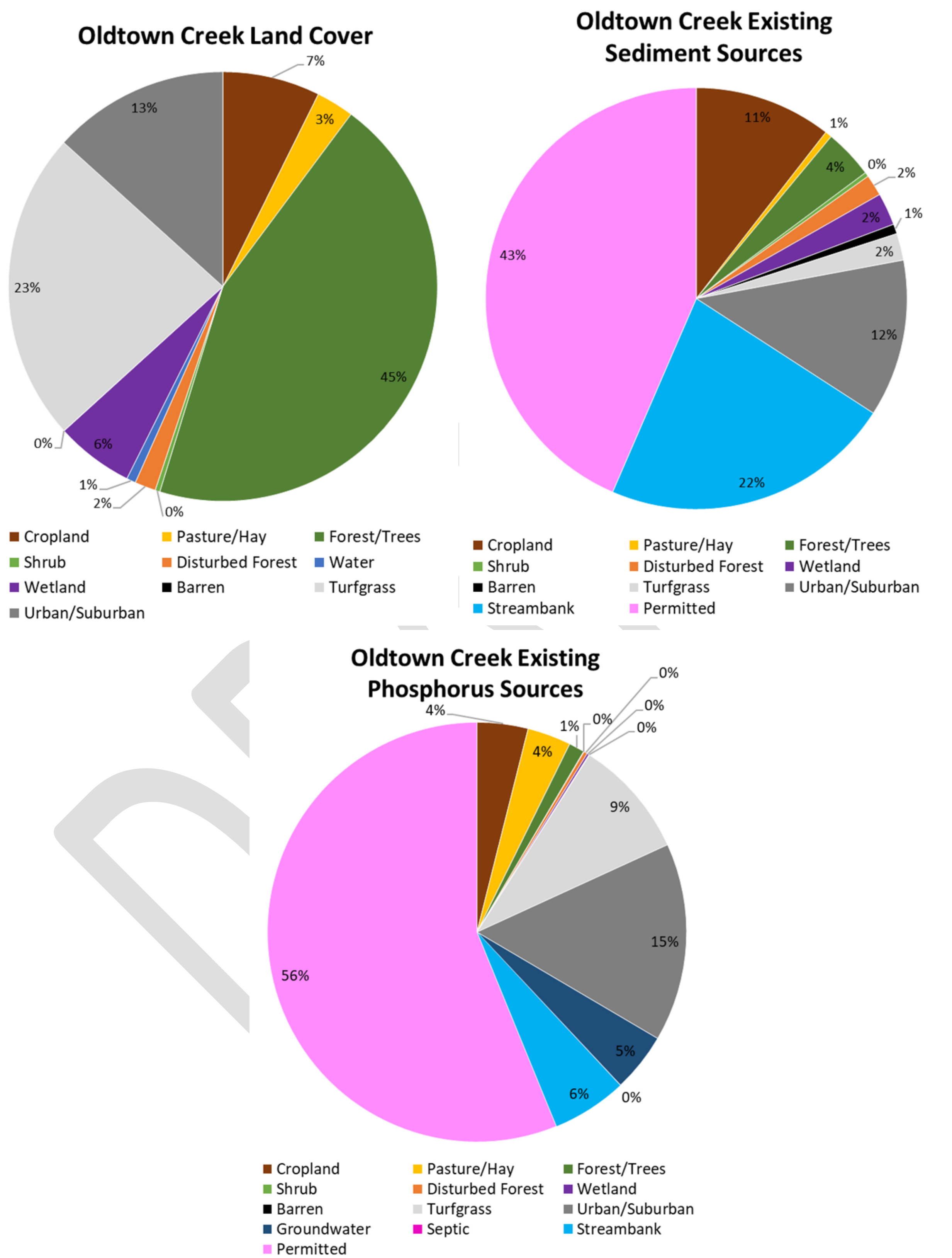


Figure 1-5. Land cover and existing source load distributions in the Oldtown Creek watershed.

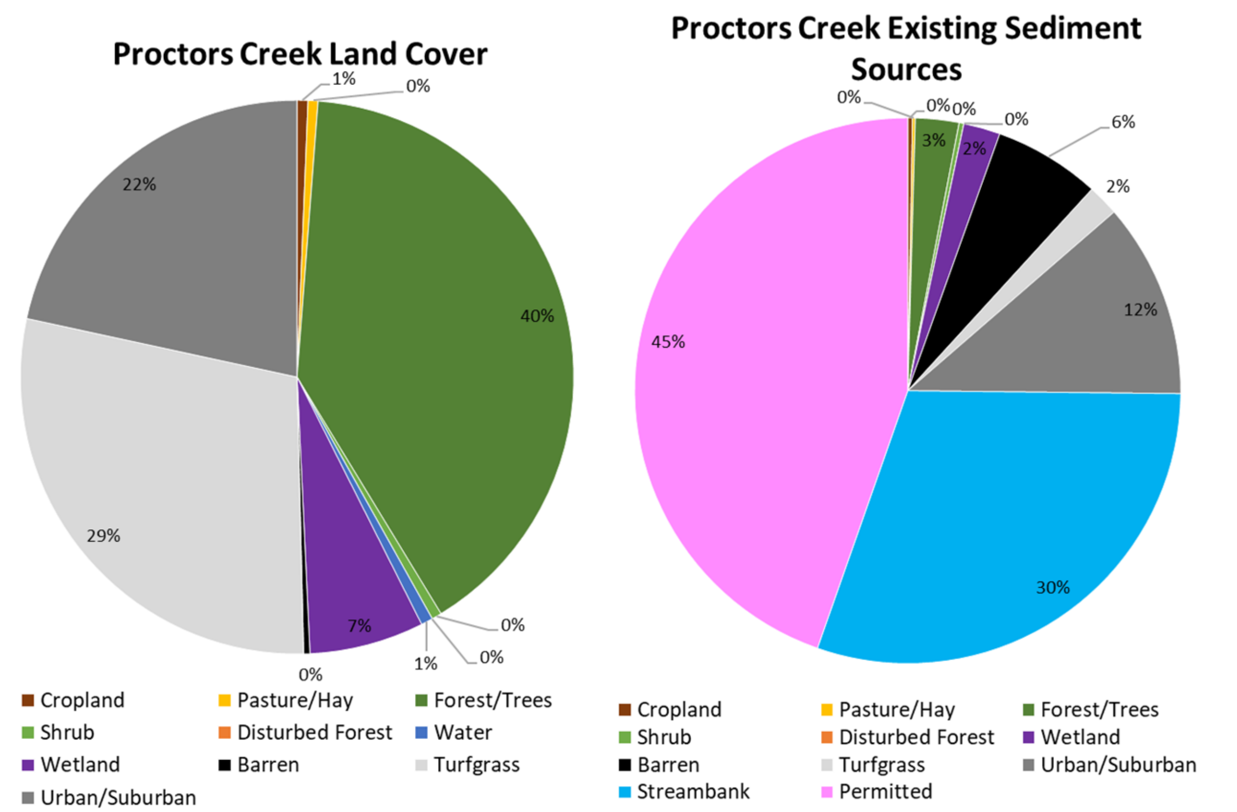


Figure 1-6. Land cover and existing source load distributions in the Proctors Creek watershed.

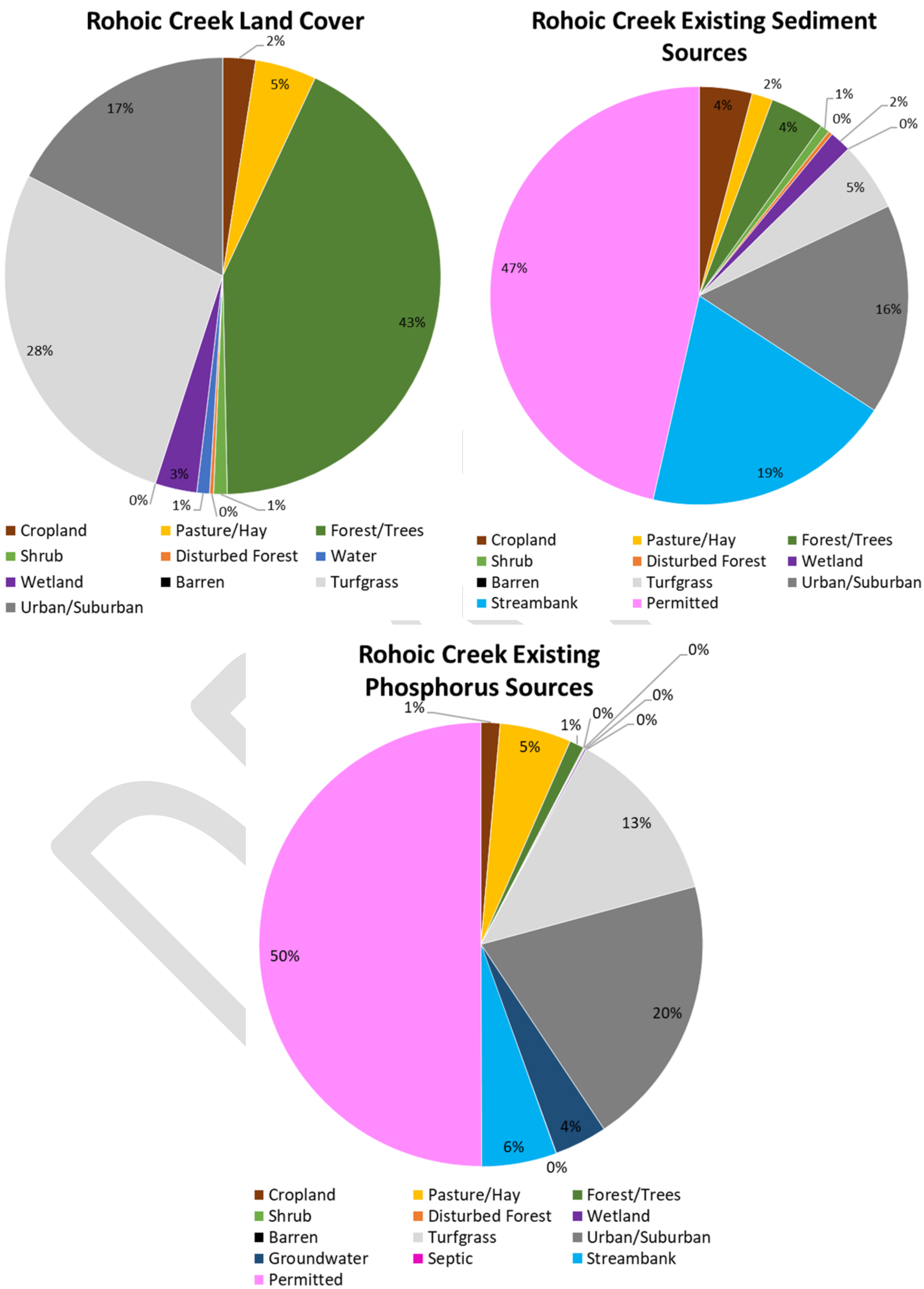
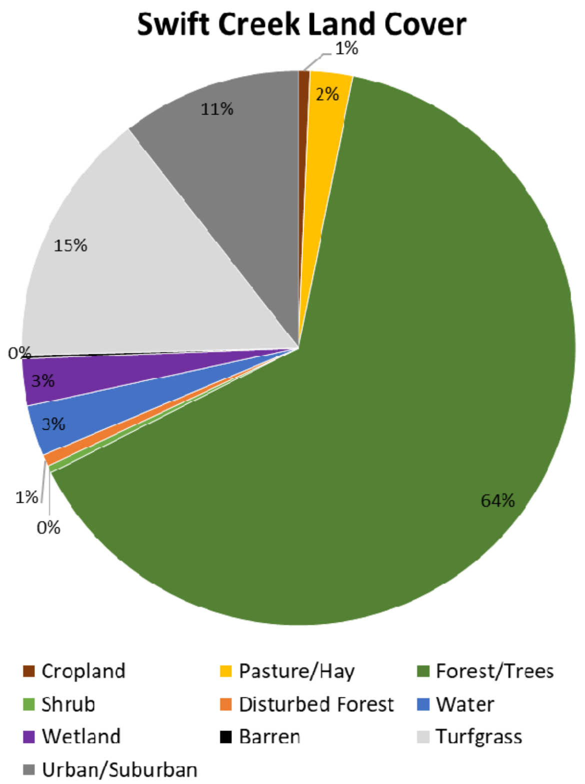
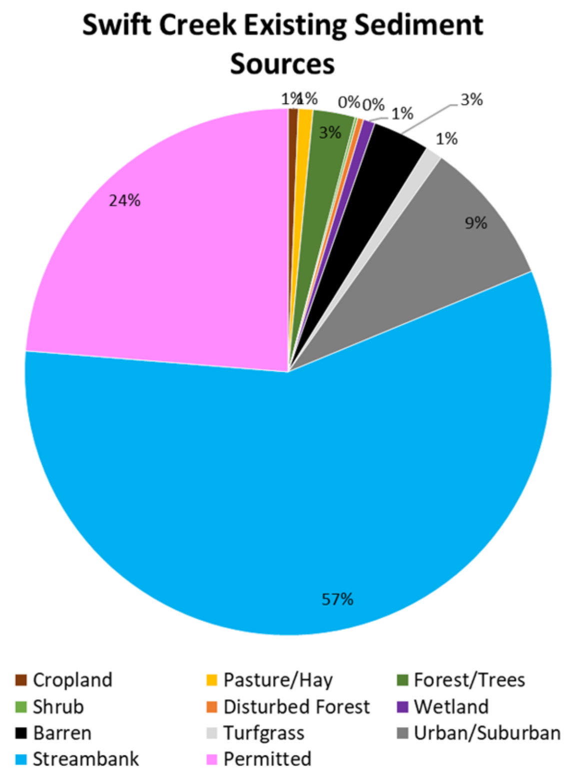


Figure 1-7. Land cover and existing source load distributions in the Rohoic Creek watershed.





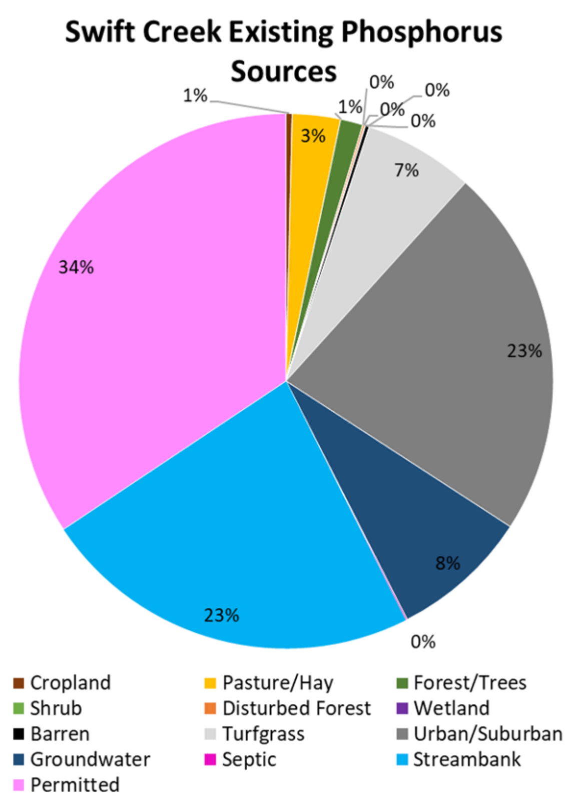


Figure 1-8. Land cover and existing source load distributions in the Swift Creek watershed.

1.5. Future Goals (the TMDL)

After determining existing sediment and phosphorus sources, a computer model was utilized to determine necessary load reductions needed to return the stream to a healthy condition. The goal for the impaired stream segments is to establish sediment and phosphorus levels that allow for diverse and abundant aquatic life without causing an undue burden on existing entities. The reductions in sediment and phosphorus needed to meet these goals are shown in **Table 1-2** and **Table 1-3.**

Table 1-2. Reductions in sediment needed to restore a healthy benthic community.

Watershed	Crop, Pasture, Hay	Forest, Trees, Shrubs, Wetland	Developed Pervious and Impervious Areas, Turfgrass*	Streambank Erosion	Permitted Sources**
Bailey Creek	54.5%	0.0%	54.5%	54.5%	0.0%
Nuttree Branch	N/A	0.0%	59.9%	59.9%	0.0%
Oldtown Creek	72.3%	0.0%	72.3%	72.3%	0.0%
Proctors Creek	88.4%	0.0%	88.4%	88.4%	0.0%
Rohoic Creek	79.8%	0.0%	79.8%	79.8%	50.0%
Swift Creek	57.0%	0.0%	57.0%	57.0%	0.0%

*Including MS4 permitted areas.
**Only industrial stormwater (ISW) permit loads are reduced in Rohoic Creek.

Table 1-3. Reductions in phosphorus needed to restore a healthy benthic community.

Watershed	Crop, Pasture, Hay	Forest, Trees, Shrubs, Wetland	Developed Pervious and Impervious Areas, Turfgrass*	Streambank Erosion	Permitted Sources**
Oldtown Creek	76.7%	0.0%	76.7%	76.7%	0.0%
Rohoic Creek	98.8%	0.0%	98.8%	98.8%	50%
Swift Creek	73.2%	0.0%	73.2%	73.2%	0.0%

*Including MS4 permitted areas.
**Only industrial stormwater (ISW) permit loads are reduced in Rohoic Creek.

To obtain healthy sediment levels in the impaired streams, significant reductions are needed from sediment and phosphorus sources. After the recommended reductions are made, the total amount of sediment and phosphorus per year that would be entering each of these streams represent the total maximum daily load of the pollutant for each stream. **Table 1-4** to **Table 1-9** present the annual average sediment TMDLs for sediment. **Table 1-10** to **Table 1-12** present the annual average TMDLs for phosphorus. Model results are rounded to 4 significant figures and calculated totals are rounded to 3 significant figures to reflect the accuracy of model inputs and the intended accuracy of the model results. These annual loads are converted to daily maximum loads as well, as described in **Section 6.3** (**Table 1-13** to **Table 1-21**). If sediment and phosphorus loads are reduced to these amounts, healthy aquatic life should be restored in these streams.

Table 1-4. Annual average sediment TMDL components for Bailey Creek.*

Impairment	Allocated Point Sources (WLA) (lb/yr TSS)	Allocated Nonpoint Sources (LA) (lb/yr TSS)	Margin of Safety (MOS) (lb/yr TSS)	Total Maximum Daily Load (TMDL) (lb/yr TSS)	Existing Load (lb/yr TSS)	Overall Reduction (%)
Bailey Creek (VAP-G03R_BLY02A08, VAP-G03R_BLY01A98)	**424,000**	**656,400**	**119,600**	**1,200,000**	2,130,000	43.7%
VA0059161	*5,245*					
Concrete Facility Permits	*1,945*					
ISW Permits	*43,060*					
MS4 Permits	*316,500*					
Construction Permits	*33,500*					
Future Growth (2% of TMDL)	*23,930*					

Table 1-5. Annual average sediment TMDL components for Nuttree Branch.*

Impairment	Allocated Point Sources (WLA) (lb/yr TSS)	Allocated Nonpoint Sources (LA) (lb/yr TSS)	Margin of Safety (MOS) (lb/yr TSS)	Total Maximum Daily Load (TMDL) (lb/yr TSS)	Existing Load (lb/yr TSS)	Overall Reduction (%)
Nuttree Branch (VAP-J17R_NUT01A06)	**303,000**	**177,000**	**53,280**	**532,000**	861,000	38.2%
NMMM Permits	*45,700*					
Concrete Facility Permits	*326*					
ISW Permits	*8,888*					
MS4 Permits	*107,300*					
Construction Permits	*129,600*					
Future Growth (2% of TMDL)	*10,700*					

* Any apparent differences in calculated values are due to rounding. Model results were rounded to 4 significant figures and calculated totals of those results were rounded to 3 significant figures.

Table 1-6. Annual average sediment TMDL components for Oldtown Creek.[*]

Impairment	Allocated Point Sources (WLA) (lb/yr TSS)	Allocated Nonpoint Sources (LA) (lb/yr TSS)	Margin of Safety (MOS) (lb/yr TSS)	Total Maximum Daily Load (TMDL) (lb/yr TSS)	Existing Load (lb/yr TSS)	Overall Reduction (%)
Oldtown Creek (VAP-J15R_OTC01A00 VAP-J15R_OTC01B08)	**253,000**	**308,500**	**62,520**	**624,000**	1,590,000	60.8%
MS4 Permits	*159,700*					
Construction Permits	*80,810*					
Future Growth (2% of TMDL)	*12,500*					

Table 1-7. Annual average sediment TMDL components for Proctors Creek. [*]

Impairment	Allocated Point Sources (WLA) (lb/yr TSS)	Allocated Nonpoint Sources (LA) (lb/yr TSS)	Margin of Safety (MOS) (lb/yr TSS)	Total Maximum Daily Load (TMDL) (lb/yr TSS)	Existing Load (lb/yr TSS)	Overall Reduction (%)
Proctors Creek (VAP-G01R_PCT01A06)	**573,000**	**345,000**	**102,100**	**1,020,000**	3,290,000	69.0%
Concrete Facility Permits	*1,188*					
ISW Permits	*64,760*					
Vehicle Wash Permits	*55*					
MS4 Permits	*112,900*					
Construction Permits	*373,600*					
Future Growth (2% of TMDL)	*20,420*					

[*] Any apparent differences in calculated values are due to rounding. Model results were rounded to 4 significant figures and calculated totals of those results were rounded to 3 significant figures.

Table 1-8. Annual average sediment TMDL components for Rohoic Creek. [*]

Impairment	Allocated Point Sources (WLA) (lb/yr TSS)	Allocated Nonpoint Sources (LA) (lb/yr TSS)	Margin of Safety (MOS) (lb/yr TSS)	Total Maximum Daily Load (TMDL) (lb/yr TSS)	Existing Load (lb/yr TSS)	Overall Reduction (%)
Rohoic Creek (VAP-J15R_RHC01A06)	**377,000**	**206,000**	**64,870**	**648,000**	1,360,000	52.4%
NMMM Permits	*127,900*					
Concrete Facility Permits	*4,586*					
ISW Permits	*57,800*					
MS4 Permits	*43,510*					
Construction Permits	*130,500*					
Future Growth (2% of TMDL)	*12,970*					

Table 1-9. Annual average sediment TMDL components for Swift Creek (Nuttree Branch represented within the LA). [*]

Impairment	Allocated Permitted Point Sources (WLA) (lb/yr TSS)	Allocated Nonpoint Sources (LA) (lb/yr TSS)	Margin of Safety (MOS) (lb/yr TSS)	Total Maximum Daily Load (TMDL) (lb/yr TSS)	Existing Load (lb/yr TSS)	Overall Reduction (%)
Swift Creek (VAP-J17R_SFT01B98, VAP-J17R_SFT02A00)	**2,870,000**	**7,030,000**	**1,099,000**	**11,000,000**	20,100,000	45.3%
VA0006254	*91,380*					
VA0023426	*8,910*					
NMMM Permits	*137,100*					
ISW Permits	*101,700*					
Domestic Sewage Permits	*366*					
MS4 Permits	*993,200*					
Construction Permits	*1,314,000*					
Future Growth (2% of TMDL)	*219,800*					

[*] Any apparent differences in calculated values are due to rounding. Model results were rounded to 4 significant figures and calculated totals of those results were rounded to 3 significant figures.

Table 1-10. Annual average phosphorus TMDL components for Oldtown Creek.*

Impairment	Allocated Point Sources (WLA) (lb/yr TP)	Allocated Nonpoint Sources (LA) (lb/yr TP)	Margin of Safety (MOS) (lb/yr TP)	Total Maximum Daily Load (TMDL) (lb/yr TP)	Existing Load (lb/yr TP)	Overall Reduction (%)
Oldtown Creek (VAP-J15R_OTC01A00, VAP-J15R_OTC01B08)	**404**	**409.5**	**90.5**	**904**	2,720	66.8%
MS4 Permits	*327.7*					
Construction Permits	*58.2*					
Future Growth (2% of TMDL)	*18.1*					

Table 1-11. Annual average phosphorus TMDL components for Rohoic Creek.*

Impairment	Allocated Point Sources (WLA) (lb/yr TP)	Allocated Nonpoint Sources (LA) (lb/yr TP)	Margin of Safety (MOS) (lb/yr TP)	Total Maximum Daily Load (TMDL) (lb/yr TP)	Existing Load (lb/yr TP)	Overall Reduction (%)
Rohoic Creek (VAP-J15R_RHC01A06)	**426**	**163**	**65**	**654**	2,330	71.0%
NMMM Permits	*85.3*					
Concrete Facility Permits	*31.0*					
ISW Permits	*197.0*					
MS4 Permits	*6.3*					
Construction Permits	*94.0*					
Future Growth (2% of TMDL)	*13.1*					

* Any apparent differences in calculated values are due to rounding. Model results were rounded to 4 significant figures and calculated totals of those results were rounded to 3 significant figures.

Table 1-12. Annual average phosphorus TMDL components for Swift Creek.*

Impairment	Allocated Point Sources (WLA) (lb/yr TP)	Allocated Nonpoint Sources (LA) (lb/yr TP)	Margin of Safety (MOS) (lb/yr TP)	Total Maximum Daily Load (TMDL) (lb/yr TP)	Existing Load (lb/yr TP)	Overall Reduction (%)
Swift Creek (VAP-J17R_SFT01B98, VAP-J17R_SFT02A00)	**3,145**	**4,700**	**873**	**8,730**	20,200	56.8%
VA0006254	*9.6*					
VA0023426	*46.0*					
NMMM Permits	*121.8*					
ISW Permits	*377.1*					
Domestic Sewage Permits	*17.2*					
MS4 Permits	*1,359*					
Construction Permits	*1,040*					
Future Growth (2% of TMDL)	*174.6*					

Table 1-13. Maximum 'daily' sediment loads and components for Bailey Creek.*

Impairment	Allocated Point Sources (WLA) (lb/day TSS)	Allocated Nonpoint Sources (LA) (lb/day TSS)	Margin of Safety (MOS) (lb/day TSS)	Maximum Daily Load (MDL) (lb/day TSS)
Bailey Creek (VAP-G03R_BLY02A08, VAP-G03R_BLY01A98)	**1,161**	**3,038**	**467**	**4,665**
VA0059161	*14.4*			
Concrete Facility Permits	*5.3*			
ISW Permits	*117.9*			
MS4 Permits	*866.6*			
Construction Permits	*91.7*			
Future Growth (2% of TMDL)	*65.5*			

* Any apparent differences in calculated values are due to rounding. Model results were rounded to 4 significant figures and calculated totals of those results were rounded to 3 significant figures.

Table 1-14. Maximum 'daily' sediment loads and components for Nuttree Branch.*

Impairment	Allocated Point Sources (WLA) (lb/day TSS)	Allocated Nonpoint Sources (LA) (lb/day TSS)	Margin of Safety (MOS) (lb/day TSS)	Maximum Daily Load (MDL) (lb/day TSS)
Nuttree Branch (VAP-J17R_NUT01A06)	**830**	**1,097**	**214**	**2,141**
NMMM Permits	*125.1*			
Concrete Facility Permits	*0.9*			
ISW Permits	*24.3*			
MS4 Permits	*293.8*			
Construction Permits	*355*			
Future Growth (2% of TMDL)	*29*			

Table 1-15. Maximum 'daily' sediment loads and components for Oldtown Creek.*

Impairment	Allocated Point Sources (WLA) (lb/day TSS)	Allocated Nonpoint Sources (LA) (lb/day TSS)	Margin of Safety (MOS) (lb/day TSS)	Maximum Daily Load (MDL) (lb/day TSS)
Oldtown Creek (VAP-J15R_OTC01A00 VAP-J15R_OTC01B08)	**693**	**1,491**	**243**	**2,426**
MS4 Permits	*437.2*			
Construction Permits	*221.3*			
Future Growth (2% of TMDL)	*34.2*			

Table 1-16. Maximum 'daily' sediment loads and components for Proctors Creek.*

Impairment	Allocated Point Sources (WLA) (lb/day TSS)	Allocated Nonpoint Sources (LA) (lb/day TSS)	Margin of Safety (MOS) (lb/day TSS)	Maximum Daily Load (MDL) (lb/day TSS)
Proctors Creek (VAP-G01R_PCT01A06)	**1,569**	**2,025**	**399**	**3,994**
Concrete Facility Permits	*3.3*			
ISW Permits	*177.3*			
Vehicle Wash Permits	*0.2*			
MS4 Permits	*309.1*			
Construction Permits	*1,023*			
Future Growth (2% of TMDL)	*56*			

* Any apparent differences in calculated values are due to rounding. Model results were rounded to 4 significant figures and calculated totals of those results were rounded to 3 significant figures.

Table 1-17. Maximum 'daily' sediment loads and components for Rohoic Creek.*

Impairment	Allocated Point Sources (WLA) (lb/day TSS)	Allocated Nonpoint Sources (LA) (lb/day TSS)	Margin of Safety (MOS) (lb/day TSS)	Maximum Daily Load (MDL) (lb/day TSS)
Rohoic Creek (VAP-J15R_RHC01A06)	**1,032**	**1,235**	**252**	**2,519**
NMMM Permits	*350.2*			
Concrete Facility Permits	*12.6*			
ISW Permits	*158.3*			
MS4 Permits	*119.1*			
Construction Permits	*357*			
Future Growth (2% of TMDL)	*36*			

Table 1-18. Maximum 'daily' sediment loads and components for Swift Creek. *

Impairment	Allocated Point Sources (WLA) (lb/day TSS)	Allocated Nonpoint Sources (LA) (lb/day TSS)	Margin of Safety (MOS) (lb/day TSS)	Maximum Daily Load (MDL) (lb/day TSS)
Swift Creek (VAP-J17R_SFT01B98, VAP-J17R_SFT02A00)	**7,858**	**30,632**	**4,277**	**42,766**
VA0006254	*250.2*			
VA0023426	*24.4*			
NMMM Permits	*375.4*			
ISW Permits	*278.4*			
Domestic Sewage Permits	*1.0*			
MS4 Permits	*2,719.3*			
Construction Permits	*3,598*			
Future Growth (2% of TMDL)	*602*			

Table 1-19. Maximum 'daily' phosphorus loads and components for Oldtown Creek. *

Impairment	Allocated Point Sources (WLA) (lb/day TP)	Allocated Nonpoint Sources (LA) (lb/day TP)	Margin of Safety (MOS) (lb/day TP)	Maximum Daily Load (MDL) (lb/day TP)
Oldtown Creek (VAP-J15R_OTC01A00 VAP-J15R_OTC01B08)	**1.1**	**2.3**	**0.4**	**3.8**
MS4 Permits	*0.9*			
Construction Permits	*0.2*			
Future Growth (2% of TMDL)	*0.05*			

* Any apparent differences in calculated values are due to rounding. Model results were rounded to 4 significant figures and calculated totals of those results were rounded to 3 significant figures.

Table 1-20. Maximum 'daily' phosphorus loads and components for Rohoic Creek.*

Impairment	Allocated Point Sources (WLA) (lb/day TP)	Allocated Nonpoint Sources (LA) (lb/day TP)	Margin of Safety (MOS) (lb/day TP)	Maximum Daily Load (MDL) (lb/day TP)
Rohoic Creek (VAP-J15R_RHC01A06)	**1.2**	**1.4**	**0.3**	**2.8**
NMMM Permits	*0.2*			
Concrete Facility Permits	*0.1*			
ISW Permits	*0.5*			
MS4 Permits	*0.0*			
Construction Permits	*0.3*			
Future Growth (2% of TMDL)	*0.04*			

Table 1-21. Maximum 'daily' phosphorus loads and components for Swift Creek.*

Impairment	Allocated Point Sources (WLA) (lb/day TP)	Allocated Nonpoint Sources (LA) (lb/day TP)	Margin of Safety (MOS) (lb/day TP)	Maximum Daily Load (MDL) (lb/day TP)
Swift Creek (VAP-J17R_SFT01B98, VAP-J17R_SFT02A00)	**8.6**	**24.0**	**3.6**	**36.3**
VA0006254	*0.03*			
VA0023426	*0.1*			
NMMM Permits	*0.3*			
ISW Permits	*1.0*			
Domestic Sewage Permits	*0.05*			
MS4 Permits	*3.7*			
Construction Permits	*2.8*			
Future Growth (2% of TMDL)	*0.5*			

1.5.1. Allocation Scenarios

There are many ways to reduce pollutants to reach TMDL goals. Several versions of these reduction plans, or allocation scenarios, were developed. These were presented to the Technical Advisory Committee which determined that Scenario 1 was preferred for each watershed (see **Table 1-22** through **Table 1-30**) . Model results were rounded to four significant figures, and calculated totals of those results were rounded to three significant figures.

* Any apparent differences in calculated values are due to rounding. Model results were rounded to 4 significant figures and calculated totals of those results were rounded to 3 significant figures.

Table 1-22. Allocation scenarios for Bailey Creek sediment loads.

Bailey Creek Watershed		Scenario 1 (preferred)		Scenario 2		Scenario 3	
Source	**Existing TSS (lb/yr)**	**Reduction (%)**	**Allocation TSS (lb/yr)**	**Reduction (%)**	**Allocation TSS (lb/yr)**	**Reduction (%)**	**Allocation TSS (lb/yr)**
Cropland	26,620	54.5	12,110	40.8	15,760	77.1	6,096
Hay	6,796	54.5	3,092	40.8	4,024	77.1	1,556
Pasture	6,592	54.5	2,999	40.8	3,902	77.1	1,510
Forest	52,790	-	52,790	-	52,790	-	52,790
Trees	65,790	-	65,790	-	65,790	-	65,790
Shrub	15,240	-	15,240	-	15,240	-	15,240
Harvested	38,880	54.5	17,690	40.8	23,020	77.1	8,904
Wetland	56,730	-	56,730	-	56,730	-	56,730
Barren	216,700	54.5	98,610	60.0	86,690	45.5	118,100
Turfgrass	78,630	54.5	35,780	60.0	31,450	45.5	42,850
Developed Pervious	10,940	54.5	4,975	60.0	4,374	45.5	5,960
Developed Impervious	219,200	54.5	99,720	60.0	87,660	45.5	119,400
Streambank Erosion	410,600	54.5	186,800	40.8	243,100	77.1	94,020
VA0059161	5,245	-	5,245	-	5,245	-	5,245
Concrete Facility Permits	1,945	-	1,945	-	1,945	-	1,945
ISW Permits	43,060	-	43,060	-	43,060	-	43,060
MS4	695,700	54.5	316,500	60.0	278,300	45.5	379,100
Construction Permits	33,500	-	33,500	-	33,500	-	33,500
Future Growth (2%)	23,930	-	23,930	-	23,930	-	23,930
MOS (10%)	119,600	-	119,600	-	119,600	-	119,600
TOTAL	**2,130,000**	**43.7**	**1,200,000**	**43.7**	**1,200,000**	**43.7**	**1,200,000**

Table 1-23. Allocation scenarios for Nuttree Branch sediment loads.

Nuttree Branch Watershed		Scenario 1 (preferred)		Scenario 2		Scenario 3	
Source	**Existing TSS (lb/yr)**	**Reduction (%)**	**Allocation TSS (lb/yr)**	**Reduction (%)**	**Allocation TSS (lb/yr)**	**Reduction (%)**	**Allocation TSS (lb/yr)**
Cropland	-	-	-	-	-	-	-
Hay	-	-	-	-	-	-	-
Pasture	-	-	-	-	-	-	-
Forest	16,410	-	16,410	-	16,410	-	16,410
Trees	32,270	-	32,270	-	32,270	-	32,270
Shrub	10,830	-	10,830	-	10,830	-	10,830
Harvested	-	-	-	-	-	-	-
Wetland	4,520	-	4,520	-	4,520	-	4,520
Barren	-	-	-	-	-	-	-
Turfgrass	44,640	59.9	17,900	68.4	14,110	62.7	16,650
Developed Pervious	3,547	59.9	1,422	68.4	1,121	62.7	1,323
Developed Impervious	164,700	59.9	66,040	68.4	52,040	62.7	61,430
Streambank Erosion	68,130	59.9	27,320	-	68,130	40.0	40,880
NMMM Permits	45,690	-	45,690	-	45,690	-	45,690
Concrete Facility Permits	326	-	326	-	326	-	326
ISW Permits	8,888	-	8,888	-	8,888	-	8,888
MS4	267,500	59.9	107,300	68.4	84,550	62.7	99,800
Construction Permits	129,600	-	129,600	-	129,600	-	129,600
Future Growth (2%)	10,660	-	10,660	-	10,660	-	10,660
MOS (10%)	53,280	-	53,280	-	53,280	-	53,280
TOTAL	**861,000**	**38.2**	**532,000**	**38.2**	**532,000**	**38.1**	**533,000**

Table 1-24. Allocation scenarios for Oldtown Creek sediment loads.

Oldtown Creek Watershed		Scenario 1 (preferred)		Scenario 2		Scenario 3	
Source	**Existing TSS (lb/yr)**	**Reduction (%)**	**Allocation TSS (lb/yr)**	**Reduction (%)**	**Allocation TSS (lb/yr)**	**Reduction (%)**	**Allocation TSS (lb/yr)**
Cropland	159,200	72.3	44,090	40.0	95,510	81.5	29,450
Hay	6,105	72.3	1,691	40.0	3,663	81.5	1,129
Pasture	1,690	72.3	468	40.0	1,014	81.5	313
Forest	37,250	-	37,250	-	37,250	-	37,250
Trees	19,720	-	19,720	-	19,720	-	19,720
Shrub	5,024	-	5,024	-	5,024	-	5,024
Harvested	24,670	72.3	6,834	40.0	14,800	81.5	4,564
Wetland	37,550	-	37,550	-	37,550	-	37,550
Barren	11,290	72.3	3,127	77.7	2,517	81.5	2,088
Turfgrass	31,170	72.3	8,635	77.7	6,952	81.5	5,767
Developed Pervious	3,218	72.3	891	77.7	718	81.5	595
Developed Impervious	179,100	72.3	49,620	77.7	39,940	81.5	33,140
Streambank Erosion	337,800	72.3	93,580	77.7	75,340	45.0	185,800
MS4	576,600	72.3	159,700	77.7	128,600	81.5	106,700
Construction Permits	80,810	-	80,810	-	80,810	-	80,810
Future Growth (2%)	12,500	-	12,500	-	12,500	-	12,500
MOS (10%)	62,520	-	62,520	-	62,520	-	62,520
TOTAL	**1,590,000**	**60.8**	**624,000**	**60.8**	**624,000**	**60.7**	**625,000**

Table 1-25. Allocation scenarios for Proctors Creek sediment loads.

Proctors Creek Watershed		Scenario 1 (preferred)		Scenario 2		Scenario 3	
Source	**Existing TSS (lb/yr)**	**Reduction (%)**	**Allocation TSS (lb/yr)**	**Reduction (%)**	**Allocation TSS (lb/yr)**	**Reduction (%)**	**Allocation TSS (lb/yr)**
Cropland	8,824	88.4	1,024	-	8,824	50.0	4,412
Hay	2,111	88.4	245	-	2,111	50.0	1,055
Pasture	3,043	88.4	353	-	3,043	50.0	1,521
Forest	36,460	-	36,460	-	36,460	-	36,460
Trees	45,160	-	45,160	-	45,160	-	45,160
Shrub	8,735	-	8,735	-	8,735	-	8,735
Harvested	-	-	-	-	-	-	-
Wetland	68,880	-	68,880	-	68,880	-	68,880
Barren	199,600	88.4	23,160	88.9	22,160	88.6	22,760
Turfgrass	58,680	88.4	6,807	88.9	6,514	88.6	6,690
Developed Pervious	4,151	88.4	482	88.9	461	88.6	473
Developed Impervious	361,100	88.4	41,880	88.9	40,080	88.6	41,160
Streambank Erosion	955,900	88.4	110,900	88.9	106,100	88.6	109,000
Concrete Facility Permits	1,188	-	1,188	-	1,188	-	1,188
Vehicle Wash Permits	55	-	55	-	55	-	55
ISW Permits	64,760	-	64,760	-	64,760	-	64,760
MS4	973,100	88.4	112,900	88.9	108,000	88.6	110,900
Construction Permits	373,600	-	373,600	-	373,600	-	373,600
Future Growth (2%)	20,420	-	20,420	-	20,420	-	20,420
MOS (10%)	102,100	-	102,100	-	102,100	-	102,100
TOTAL	**3,290,000**	**69.0**	**1,020,000**	**69.0**	**1,020,000**	**69.0**	**1,020,000**

Table 1-26. Allocation scenarios for Rohoic Creek sediment loads.

Rohoic Creek Watershed		Scenario 1 (preferred)		Scenario 2		Scenario 3	
Source	**Existing TSS (lb/yr)**	**Reduction (%)**	**Allocation TSS (lb/yr)**	**Reduction (%)**	**Allocation TSS (lb/yr)**	**Reduction (%)**	**Allocation TSS (lb/yr)**
Cropland	52,140	79.8	10,530	77.3	11,840	80.0	10,430
Hay	16,410	79.8	3,314	77.3	3,724	80.0	3,281
Pasture	4,153	79.8	839	77.3	943	80.0	831
Forest	22,270	-	22,270	-	22,270	-	22,270
Trees	31,910	-	31,910	-	31,910	-	31,910
Shrub	9,145	-	9,145	-	9,145	-	9,145
Harvested	4,129	79.8	834	77.3	937	80.0	826
Wetland	21,340	-	21,340	-	21,340	-	21,340
Barren	-	-	-	-	-	-	-
Turfgrass	68,250	79.8	13,790	80.0	13,650	79.6	13,920
Developed Pervious	9,356	79.8	1,890	80.0	1,871	79.6	1,909
Developed Impervious	198,800	79.8	40,160	80.0	39,760	79.6	40,560
Streambank Erosion	247,200	79.8	49,930	80.0	49,430	80.0	49,430
NMMM Permits	127,900	-	127,900	-	127,900	-	127,900
Concrete Facility Permits	4,586	-	4,586	-	4,586	-	4,586
ISW Permits	115,600	50.0	57,800	50.0	57,800	50.0	57,800
MS4	215,400	79.8	43,510	80.0	43,080	79.6	43,950
Construction Permits	130,500	-	130,500	-	130,500	-	130,500
Future Growth (2%)	12,970	-	12,970	-	12,970	-	12,970
MOS (10%)	64,870	-	64,870	-	64,870	-	64,870
TOTAL	**1,360,000**	**52.4**	**648,000**	**52.3**	**649,000**	**52.4**	**648,000**

Table 1-27. Allocation scenarios for Swift Creek sediment loads.

Swift Creek Watershed		Scenario 1 (preferred)		Scenario 2		Scenario 3		Scenario 4	
Source	**Existing TSS (lb/yr)**	**Reduction (%)**	**Allocation TSS (lb/yr)**	**Reduction (%)**	**Allocation TSS (lb/yr)**	**Reduction (%)**	**Allocation TSS (lb/yr)**	**Reduction (%)**	**Allocation TSS (lb/yr)**
Cropland	119,500	57.0	51,390	39.6	72,180	83.2	20,080	-	119,500
Hay	26,210	57.0	11,270	39.6	15,830	83.2	4,404	-	26,210
Pasture	144,700	57.0	62,210	39.6	87,380	83.2	24,310	-	144,700
Forest	305,700	-	305,700	-	305,700	-	305,700	-	305,700
Trees	142,300	-	142,300	-	142,300	-	142,300	-	142,300
Shrub	19,860	-	19,860	-	19,860	-	19,860	-	19,860
Harvested	70,200	57.0	30,190	39.6	42,400	83.2	11,790	-	70,200
Wetland	134,300	-	134,300	-	134,300	-	134,300	-	134,300
Barren	668,000	57.0	287,200	39.6	403,500	83.2	112,200	58.4	277,900
Turfgrass	155,500	57.0	66,860	39.6	93,910	83.2	26,120	58.4	64,680
Developed Pervious	20,960	57.0	9,015	39.6	12,660	83.2	3,522	58.4	8,721
Developed Impervious	1,517,000	57.0	652,100	39.6	916,000	83.2	254,800	58.4	630,900
Streambank Erosion	10,970,000	57.0	4,717,000	65.0	3,839,000	45.0	6,033,000	58.4	4,563,000
VA0006254	91,380	-	91,380	-	91,380	-	91,380	-	91,380
VA0023426	8,910	-	8,910	-	8,910	-	8,910	-	8,910
NMMM Permits	137,072	-	137,072	-	137,072	-	137,072	-	137,072
Domestic Sewage Permits	366	-	366	-	366	-	366	-	366
ISW Permits	101,700	-	101,700	-	101,700	-	101,700	-	101,700
MS4	2,310,000	57.0	993,200	39.6	1,395,000	83.2	388,000	58.4	960,900
Construction Permits	1,314,000	-	1,314,000	-	1,314,000	-	1,314,000	-	1,314,000
Future Growth (2%)	219,800	-	219,800	-	219,800	-	219,800	-	219,800
Nuttree Branch TMDL Target	533,000	-	533,000	-	533,000	-	533,000	-	533,000
MOS (10%)	1,099,000	-	1,099,000	-	1,099,000	-	1,099,000	-	1,099,000
TOTAL	**20,100,000**	**45.3**	**11,000,000**	**45.3**	**11,000,000**	**45.3**	**11,000,000**	**45.3**	**11,000,000**

Table 1-28. Allocation scenarios for Oldtown Creek phosphorus loads.

Oldtown Creek Watershed		Scenario 1 (preferred)		Scenario 2		Scenario 3	
Source	**Existing TP (lb/yr)**	**Reduction (%)**	**Allocation TP (lb/yr)**	**Reduction (%)**	**Allocation TP (lb/yr)**	**Reduction (%)**	**Allocation TP (lb/yr)**
Cropland	102.4	76.7	23.9	50.0	51.2	78.7	21.8
Hay	84.8	76.7	19.8	50.0	42.4	78.7	18.1
Pasture	3.1	76.7	0.7	50.0	1.5	78.7	0.6
Forest	18.0	-	18.0	-	18.0	-	18.0
Trees	13.4	-	13.4	-	13.4	-	13.4
Shrub	0.9	-	0.9	-	0.9	-	0.9
Harvested	7.1	76.7	1.7	50.0	3.6	78.7	1.5
Wetland	4.1	-	4.1	-	4.1	-	4.1
Barren	1.3	76.7	0.3	79.2	0.3	78.7	0.3
Turfgrass	238.6	76.7	55.6	79.2	49.6	78.7	50.8
Developed Pervious	4.7	76.7	1.1	79.2	1.0	78.7	1.0
Developed Impervious	394.1	76.7	91.8	79.2	82.0	78.7	83.9
Streambank Erosion	118.2	76.7	27.6	79.2	24.6	40.0	71.0
Septic	0.9	76.7	0.2	79.2	0.2	78.7	0.2
Groundwater	150.9	-	150.9	-	150.9	-	150.9
MS4	1,406.0	76.7	327.7	79.2	292.5	78.7	299.6
Construction Permits	58.2	-	58.2	-	58.2	-	58.2
Future Growth (2%)	18.1	-	18.1	-	18.1	-	18.1
MOS (10%)	90.5	-	90.5	-	90.5	-	90.5
TOTAL	**2,720.0**	**66.8**	**904.0**	**66.8**	**903.0**	**66.8**	**903.0**

Table 1-29. Allocation scenarios for Rohoic Creek phosphorus loads. Scenario 2 does not meet target reductions. Scenario 2 total is highlighted in red as it does not meet the target water quality goal.

Rohoic Creek Watershed		Scenario 1 (preferred)		Scenario 2	
Source	Existing TP (lb/yr)	Reduction (%)	Allocation TP (lb/yr)	Reduction (%)	Allocation TP (lb/yr)
Cropland	31.3	98.8	0.4	100.0	-
Hay	113.1	98.8	1.4	100.0	-
Pasture	4.1	98.8	0.0	100.0	-
Forest	9.7	-	9.7	-	9.7
Trees	14.3	-	14.3	-	14.3
Shrub	1.5	-	1.5	-	1.5
Harvested	1.2	98.8	0.0	100.0	-
Wetland	2.6	-	2.6	-	2.6
Barren	-	-	-	-	-
Turfgrass	290.9	98.8	3.5	100.0	-
Developed Pervious	9.7	98.8	0.1	100.0	-
Developed Impervious	437.4	98.8	5.2	100.0	-
Streambank Erosion	86.5	98.8	1.0	100.0	-
Septic	0.9	98.8	0.0	100.0	-
Groundwater	122.3	-	122.3	-	122.3
NMMM Permits	85.3	-	85.3	-	85.3
Concrete Facility Permits	31.0	-	31.0	-	31.0
ISW Permits	394.1	50.0	197.0	-	394.1
MS4	523.4	98.8	6.3	100.0	-
Construction Permits	94.0	-	94.0	-	94.0
Future Growth (2%)	13.1	-	13.1	-	13.1
MOS (10%)	65.4	-	65.4	-	65.4
TOTAL	**2,330.0**	**71.9**	**654.0**	**64.2**	**833.0**

Table 1-30. Allocation scenarios for Swift Creek phosphorus loads (inclusive of Nuttree Branch).

Swift Creek Watershed		Scenario 1 (preferred)		Scenario 2		Scenario 3	
Source	**Existing TP (lb/yr)**	**Reduction (%)**	**Allocation TP (lb/yr)**	**Reduction (%)**	**Allocation TP (lb/yr)**	**Reduction (%)**	**Allocation TP (lb/yr)**
Cropland	70.9	73.2	19.0	25.0	53.2	82.2	12.6
Hay	362.6	73.2	97.2	25.0	271.9	82.2	64.5
Pasture	190.9	73.2	51.2	25.0	143.2	82.2	34.0
Forest	143.3	-	143.3	-	143.3	-	143.3
Trees	115.1	-	115.1	-	115.1	-	115.1
Shrub	2.5	-	2.5	-	2.5	-	2.5
Harvested	22.6	73.2	6.1	25.0	16.9	82.2	4.0
Wetland	7.9	-	7.9	-	7.9	-	7.9
Barren	43.7	73.2	11.7	75.3	10.8	82.2	7.8
Turfgrass	1,267.0	73.2	339.5	75.3	312.9	82.2	225.5
Developed Pervious	35.3	73.2	9.5	75.3	8.7	82.2	6.3
Developed Impervious	4,237.0	73.2	1,135.0	75.3	1,046.0	82.2	754.1
Streambank Erosion	4,383.0	73.2	1,175.0	75.3	1,083.0	50.0	2,191.0
Septic	17.4	73.2	4.7	75.3	4.3	82.2	3.1
Groundwater	1,588.0	-	1,588.0	-	1,588.0	-	1,588.0
VA0006254	9.6	-	9.6	-	9.6	-	9.6
VA0023426	46.0	-	46.0	-	46.0	-	46.0
NMMM Permits	121.8	-	121.8	-	121.8	-	121.8
Domestic Sewage Permits	17.2	-	17.2	-	17.2	-	17.2
ISW Permits	377.1	-	377.1	-	377.1	-	377.1
MS4	5,071.0	73.2	1,359.0	75.3	1,253.0	82.2	902.7
Construction Permits	1,040.0	-	1,040.0	-	1,040.0	-	1,040.0
Future Growth (2%)	174.6	-	174.6	-	174.6	-	174.6
MOS (10%)	873.0	-	873.0	-	873.0	-	873.0
TOTAL	**20,200.0**	**56.8**	**8,730.0**	**56.8**	**8,720.0**	**56.8**	**8,720.0**

1.6. Public Participation

Throughout this study, VADEQ asked for help from local residents and knowledgeable stakeholders – those who have a particular interest in or may be affected by the outcome of the project. Public participation keeps stakeholders informed, and it allows for stakeholder input to ensure information in the study is accurate. While the project was progressing, VADEQ held two public meetings and three Technical Advisory Committee (TAC) meetings. The final public meeting was held on February 15, 2023 to present the draft TMDL document and begin the official public comment period. Received comments and responses are documented in **8.0Appendix D**.

1.7. Reasonable Assurance

Public participation in the development of the TMDL and any subsequent implementation plans, follow-up monitoring, permit action plans developed and implemented by MS4 permit holders, other permit compliance, and current implementation progress within the watersheds all combine to provide reasonable assurance that these TMDLs will be implemented and water quality will be restored in the impaired watersheds.

1.8. What Happens Next

VADEQ will receive public comment on this report and then submit it to the U.S. Environmental Protection Agency (USEPA) for approval. This report sets the clean-up goals (or TMDL) for the James River tributaries, but the next step is a clean-up plan (or Implementation Plan) that lays out how those goals will be reached. Clean-up plans set intermediate goals and describe actions that should be taken to improve water quality in the impaired streams. Examples of the potential actions that could be included in an implementation plan for the James River tributaries are listed below:

- Conduct stream bank restoration projects in areas where banks are actively eroding
- Leave a band of 35 – 100 ft along the stream natural so that it buffers or filters out sediment from farm or residential land (a riparian buffer)
- Expanded street sweeping programs in urban areas
- Reduce runoff by increasing green spaces and reducing hardened spaces (asphalt or concrete)

> Frequently Asked Question:
>
> *<u>How will the TMDL be implemented?</u>* For point sources, TMDL reductions will be implemented through discharge permits. For nonpoint sources, TMDL reductions will be implemented through best management practices (BMPs). Landowners will be asked to voluntarily participate in state and federal programs that help defer the cost of BMP installation.

These and other actions that could be included in a clean-up plan are identified in the planning process along with associated costs and the extent of each action needed. The clean-up plan also identifies potential sources of money to help with the clean-up efforts. Most of the money utilized to implement actions in the watersheds to date has been in the form of cost-share programs, which share the cost of improvements with the landowner. Additional funds for urban stormwater practices have been made available through various grants, including an annual funding opportunity through the National Fish and Wildlife Foundation's Chesapeake Bay Stewardship Fund program. Please be aware that the state or federal government will not fix the problems with the impaired streams. It is primarily the responsibility of individual landowners and local governments to take the actions necessary to improve these streams. The role of state agencies is to help with developing the plan and find money to support implementation, but actually making the improvements is up to those that live in the watershed. By increasing education and awareness of the problem, and by working together to each do our part, we can make the changes necessary to improve the streams.

VADEQ will continue to sample aquatic life in these streams and monitor the progress of the clean-up. This sampling will let us know when the clean-up has reached certain milestones listed in the plan. To begin moving towards these clean-up goals, VADEQ recommends that concerned citizens come together and begin working with local governments, civic groups, soil and water conservation districts, and local health districts to increase education and awareness of the problem and promote those activities and programs that improve stream health.

2.0 INTRODUCTION

2.1. Watershed Location and Description

The Bailey Creek watershed is approximately 9,100 acres and lies in the City of Hopewell and Prince George County. Nuttree Branch's watershed is approximately 3,851 acres, entirely within Chesterfield County. Oldtown Creek's watershed is approximately 8,535 acres, within Chesterfield County and the City of Colonial Heights. Proctors Creek's watershed is approximately 12,050 acres, entirely within Chesterfield County. Rohoic Creek's watershed is approximately 6,100 acres, within Dinwiddie County and the City of Petersburg. Swift Creek's watershed is approximately 69,650 acres and lies within Chesterfield and Powhatan Counties.

The study watersheds include VAHU6 watersheds JA41, JA42, and portions of JA40, JL03, and JL07. Bailey Creek and Proctors Creek are direct tributaries of the James River. Oldtown Creek, Rohoic Creek, and Swift Creek are direct tributaries of the Appomattox River, and therefore indirect tributaries of the James River. Nuttree Branch is a tributary of Swift Creek, and indirectly the Appomattox River and James River. All study watersheds are tributaries of the Chesapeake Bay.

2.2. Designated Uses and Applicable Water Quality Standards

Virginia's Water Quality Standards (9VAC25-260) consist of designated uses established for water bodies in the Commonwealth, and water quality criteria set to protect those uses. Virginia's Water Quality Standards protect the public and environmental health of the Commonwealth and serve the purposes of the State Water Control Law (§62.1-44.2 et seq. of the Code of Virginia) and the federal Clean Water Act (33 USC §1251 et seq.).

2.2.1. Designation of Uses (9 VAC 25-260-10)

> "A. 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" (SWCB, 2011).

Bailey Creek, Nuttree Branch, Oldtown Creek, Proctors Creek, Rohoic Creek, and Swift Creek currently do not support the aquatic life designated use based on biological monitoring of the benthic macroinvertebrate community.

2.2.2. General Standard (9VAC 25-260-20)

The following general standard protects the aquatic life use:

> "A. 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.
>
> Specific substances to be controlled include, but are not limited to: floating debris, oil scum, and other floating materials; toxic substances (including those which bioaccumulate); substances that produce color, tastes, turbidity, odors, or settle to form sludge deposits; and substances which nourish undesirable or nuisance aquatic plant life. Effluents which tend to raise the temperature of the receiving water will also be controlled" (SWCB, 2011).

VADEQ's biological monitoring program is used to evaluate compliance with the above standard. This program monitors the assemblage of benthic (bottom-dwelling) macro (large enough to see) invertebrates (insects, mollusks, crustaceans, and annelid worms) in streams to determine the biological health of the stream. Benthic macroinvertebrates are sensitive to water quality conditions, important links in aquatic food chains, major contributors to energy and nutrient cycling in aquatic habitats, relatively immobile, and easy to collect. These characteristics make them excellent indicators of aquatic health. Changes in water quality are reflected in changes in the structure and diversity of the benthic macroinvertebrate community. Currently, VADEQ assesses the health of the benthic macroinvertebrate community using the Virginia Stream Condition Index (VSCI). This index was first developed by Tetra Tech (2003) and later validated by VADEQ (2006). The VSCI is a multimetric index based on 8 biomonitoring metrics. The index provides a score from 0-100, and scores from individual streams are compared to a statistically derived cutoff value based on the scores of regional reference sites.

2.3. 305(b)/303(d) Water Quality Assessment

Under Section 305(b) of the Federal Clean Water Act, states are required to assess the quality of their water bodies in comparison to the applicable water quality standards. States are also required, under Section 303(d) of the Act, to prepare a list of water bodies that do not meet one or more water quality standards. This list is often called the "Impaired Waters List", the "303(d) List", the "TMDL List", or even the "Dirty Waters List". The Commonwealth of Virginia accomplishes both requirements through the publishing of an Integrated 305(b)/303(d) Water Quality Assessment Report every two years. Each report assesses water quality by evaluating monitoring data from a six-year window. The assessment window for the 2020 305(b)/303(d) Water Quality Assessment Integrated Report (IR) was from January 1, 2013 through December 31, 2018. According to VADEQ's current Water Quality Assessment Guidance (VADEQ, 2019), streams with a calculated VSCI score ≥60 are assessed as "fully supporting" the aquatic life designated use.

Streams with VSCI scores <60 are assessed as "impaired" or "not supporting" the aquatic life designated use.

2.3.1. Impairment Listings

According to Virginia's 2020 305(b)/303(d) Integrated Report (VADEQ, 2020), Bailey Creek, Nuttree Branch, Oldtown Creek, Proctors Creek, Rohoic Creek, and Swift Creek are impaired (**Table 1-1**, **Figure 1-1**). Data collected to evaluate streams in the watersheds are collected by VADEQ and other government officials.

All study streams are impaired for failure to support the aquatic life use (i.e., a benthic impairment). These streams were initially listed as impaired on Virginia's 303(d) between 2010 and 2018 (**see Table 1-1** for stream specific listing year and station(s)). Average VSCI scores that led to each stream's listing are displayed in **Table 2-1**.

Table 2-1. Average VSCI scores used to assess stream health for all study streams

Stream	Monitoring Station	Years Sampled	Samples Collected	VSCI Average
Bailey Creek	2-BLY005.73	2010-2019	4	32
Nuttree Branch	2-NUT000.62	2010-2019	3	51.4
Oldtown Creek	2-OTC001.54	2007-2019	6	49.7
	2-OTC005.38	2015-2019	3	50.8
Proctors Creek	2-PCT002.46	2007-2019	6	51
Rohoic Creek	2-RHC000.58	2010-2019	3	48.8
Swift Creek	2-SFT019.02	2008-2009	4	48
	2-SFT019.15	2010-2019	3	43
	2-SFT025.32	2008-2019	5	44.7

2.4. TMDL Development

Section 303(d) of the Federal Clean Water Act and the U.S. Environmental Protection Agency's (USEPA) Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for waterbodies that fail to meet designated water quality standards and are placed on the state's Impaired Waters List. A TMDL reflects the total pollutant loading that a water body can receive and still meet water quality standards. A TMDL establishes the maximum allowable pollutant loading from both point and nonpoint sources for a waterbody, allocates the load among the pollutant contributors, and provides a framework for taking actions to restore water quality.

2.4.1. Pollutants of Concern

A TMDL's target pollutants, or pollutants of concern (POC), are the physical or chemical substances that will be controlled and allocated in the TMDL to restore aquatic life (measured by benthic macroinvertebrate health). POCs must be pollutants that are controllable through source reductions, such as sediment, phosphorus, nitrogen, or other substances. Physical factors or environmental conditions, such as flow regimes, hydrologic modifications, or physical structures (like dams) cannot be TMDL POCs.

In 2021, a stressor identification analysis study was conducted to determine the POC(s) contributing to the benthic impairments in the James River Tributaries watersheds. This study is included in **8.0Appendix E**. The stressor analysis study used a formal causal analysis approach developed by USEPA, known as CADDIS (Causal Analysis Diagnosis Decision Information System). The CADDIS approach evaluates 14 lines of evidence that support or refute each candidate stressor as the cause of impairment. In each stream, each candidate stressor was scored from -3 to +3 based on each line of evidence. Total scores across all lines of evidence were then summed to produce a stressor score that reflects the likelihood of that stressor being responsible for the impairment. The study found that sediment (measured as total suspended solids or TSS) was a probable stressor in all of the impaired tributaries. In three of the tributaries, Oldtown Creek, Rohoic Creek, and Swift Creek, an additional probable stressor of total phosphorus (TP) was identified.

3.0 WATERSHED CHARACTERIZATION

3.1. Ecoregion

Bailey Creek, Oldtown Creek, Proctors Creek, and Rohoic Creek lie entirely within the Rolling Coastal Plain USEPA ecoregion (**Figure 3-1**). Nuttree Branch lies within the Northern Outer Piedmont and Triassic Basins USEPA ecoregions. Swift Creek crosses the Northern Outer Piedmont, Rolling Coastal Plain, and Triassic Basins USEPA ecoregions. The Northern Outer Piedmont is characterized by low hills, rounded hills, and shallow ravines and is underlain by heavily weathered metamorphic rock (Woods et al., 1999). The Rolling Coastal Plain is underlain by unconsolidated tertiary sand, silt, clay, and gravels and is characterized by notably hillier terrain than adjacent coastal plain regions but is significantly flatter than the adjacent Northern Outer Piedmont ecoregion. The Triassic Basin is characterized by low rounded hills, gentle ridges, and shallow valleys and is underlain by unmetamorphosed Mesozoic rocks downfaulted into older metamorphic and igneous materials. The natural vegetation in all ecoregions would have originally consisted of a mixed oak-hickory-pine forest. Agricultural and urban and suburban development have impacted the extent of the native forest cover previously described in each ecoregion.

3.2. Soils

The soil related parameters for the watershed were derived from the Soil Survey Geographic (SSURGO) dataset (NRCS, accessed 2021). The predominant factor analyzed was the hydrologic soil group (HSG). Hydrologic soil groups are an index of the rate at which water infiltrates through the soil with group A having the greatest rate of infiltration and D having the lowest rate of infiltration. The dual groups (A/D, B/D, and C/D) indicate a naturally slow infiltration rate due to high water table, rather than a lack of infiltration capacity. When rainfall amounts exceed the capacity of the soil to infiltrate water, the excess water runs off and contributes to erosion.

Nuttree Branch, and Swift Creek watersheds are dominated by HSG B with significant contribution of group D. Bailey Creek watershed is also dominated by group B with significant inclusion of dual group B/D. Rohoic Creek is highly dominated by group C soils. Oldtown and Proctors Creek watersheds are dominated by group D and dual group soils, all indicating slow infiltration. The spatial distribution of soil groups can be seen in **Figure 3-2**.

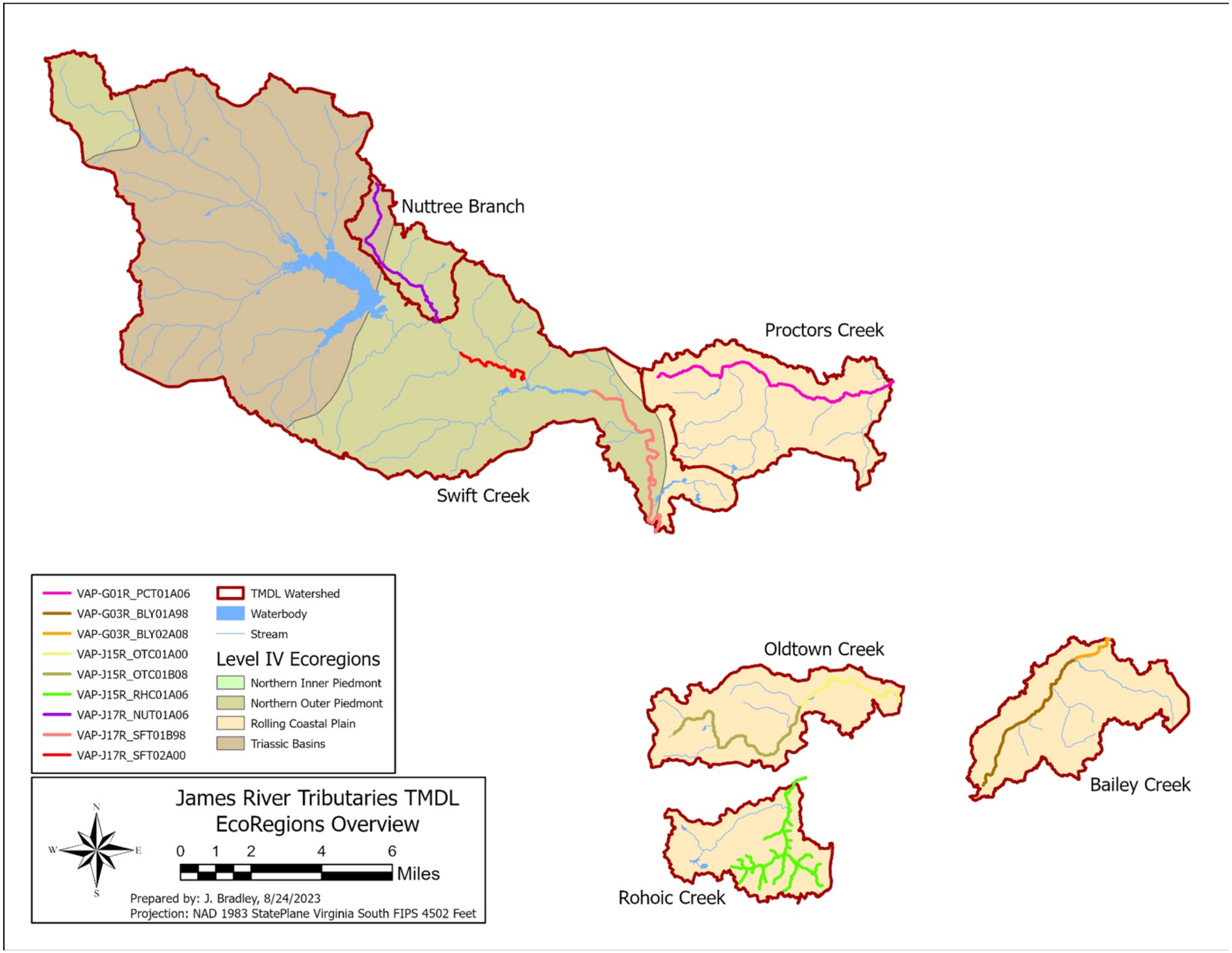


Figure 3-1. USEPA ecoregions included in the James River tributaries TMDL watersheds.

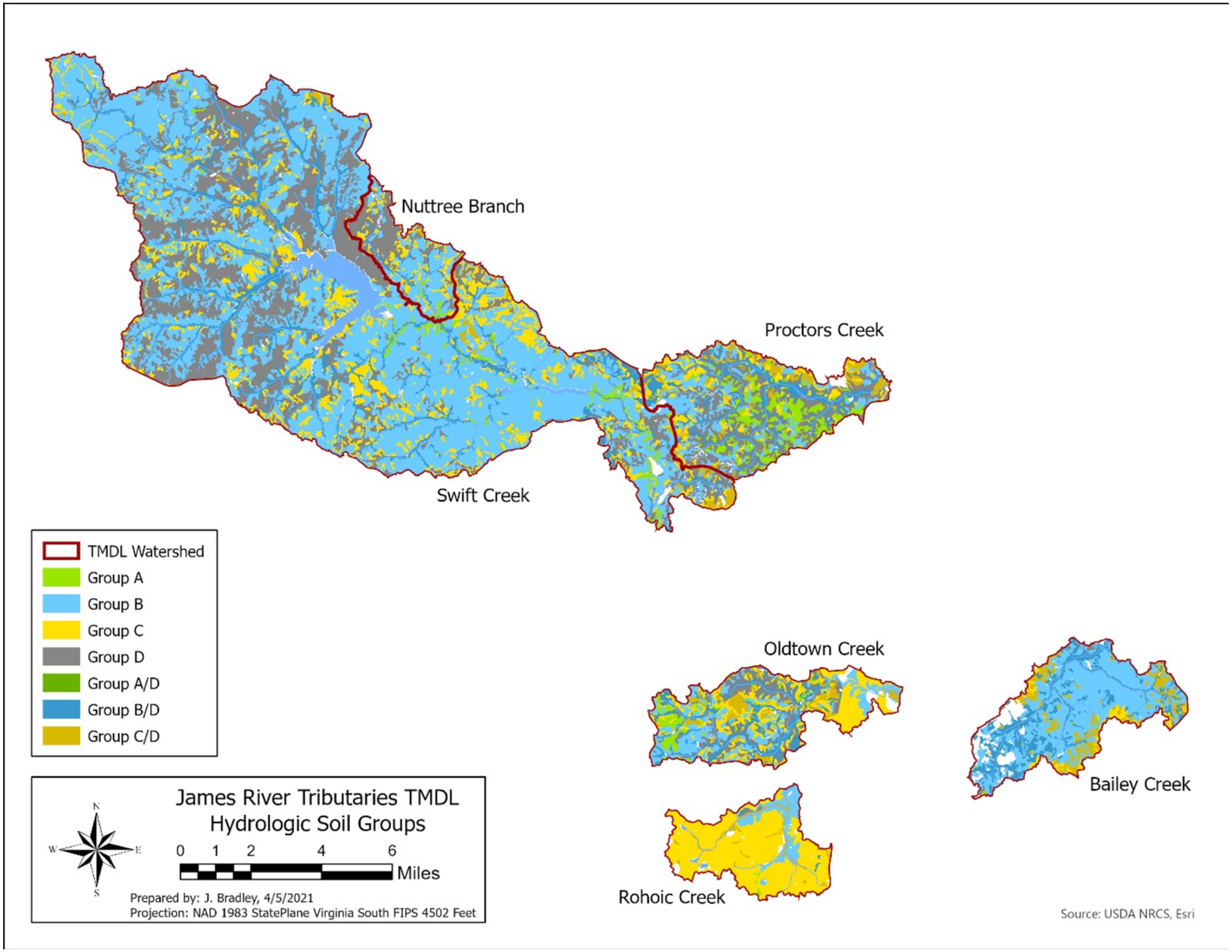


Figure 3-2. SSURGO hydrologic soil groups throughout the James River tributaries watersheds.

3.3. Climate

Daily rainfall and temperature data for the watershed was obtained from Oregon State's spatially distributed PRISM model (Parameter-Elevation Regressions on Independent Slopes Model), which interpolates available datasets from a range of monitoring networks and is used as the official spatial climate data sets of the USDA. PRISM was utilized to obtain a more exact estimate of historical weather within the watershed, rather than relying on a nearby gauge outside of the watershed (PRISM, 2021). See Daly et al. 2008 for more information on the PRISM model. Local annual average precipitation generated from the PRISM model for years 2000 to 2021 was 47.0 inches, and the average modelled daily temperature during this time range was 57.2° F.

3.4. Land Cover/Land Use

The 2016 VGIN land cover dataset was used to determine the land cover distribution throughout the watershed (**Figure 3-3**). **Table 3-1** through **Table 3-6** summarize the land cover distributions for each of the impaired watersheds.

The VGIN dataset contains two different types of impervious land cover: extracted and local datasets. The local dataset's impervious land cover is based on locally developed datasets covering specifically building footprints, roads, and other known impervious areas. This land cover type is included in the computer model as entirely impervious. VGIN's extracted impervious land cover layer was developed using computer algorithms to extract additional areas that are likely impervious, beyond those areas identified in local datasets. When compared with aerial imagery, the extracted land cover set includes some areas that are not impervious. Based on visual comparisons, the extracted impervious land cover layer from VGIN was treated in the model as 80% developed impervious and 20% developed pervious. The 'NWI/other' land cover type in the VGIN dataset is based on the combined National Wetlands Inventory and Tidal Marsh Inventory datasets and represents all identified wetland areas in those datasets. The VGIN dataset contains categories for cropland and pasture, which were subdivided for modeling purposes using the 2020 Nonpoint Source (NPS) Assessment Land Use/Land Cover database maintained by the Virginia Department of Conservation and Recreation (VADCR) (VADCR, 2020). The VADCR NPS land use database includes acreage estimates by county and by VAHU6 watersheds for acres of land in conventional and conservation tillage as well as hay and three quality-based categories of pasture. The ratio of conventional to conservation tillage for each modelled subwatershed was used to divide the VGIN cropland acres for that subwatershed into acreages of high till and low till, which were simulated using appropriately different parameters within the model, such as curve number, cover management (C) factor, and practice (P) factor. The VGIN pasture acres for each subwatershed were divided into four categories based on the NPS database: hay, pasture-good, pasture-fair, and pasture-poor. These categories were simulated with appropriately different curve number and C-factor values.

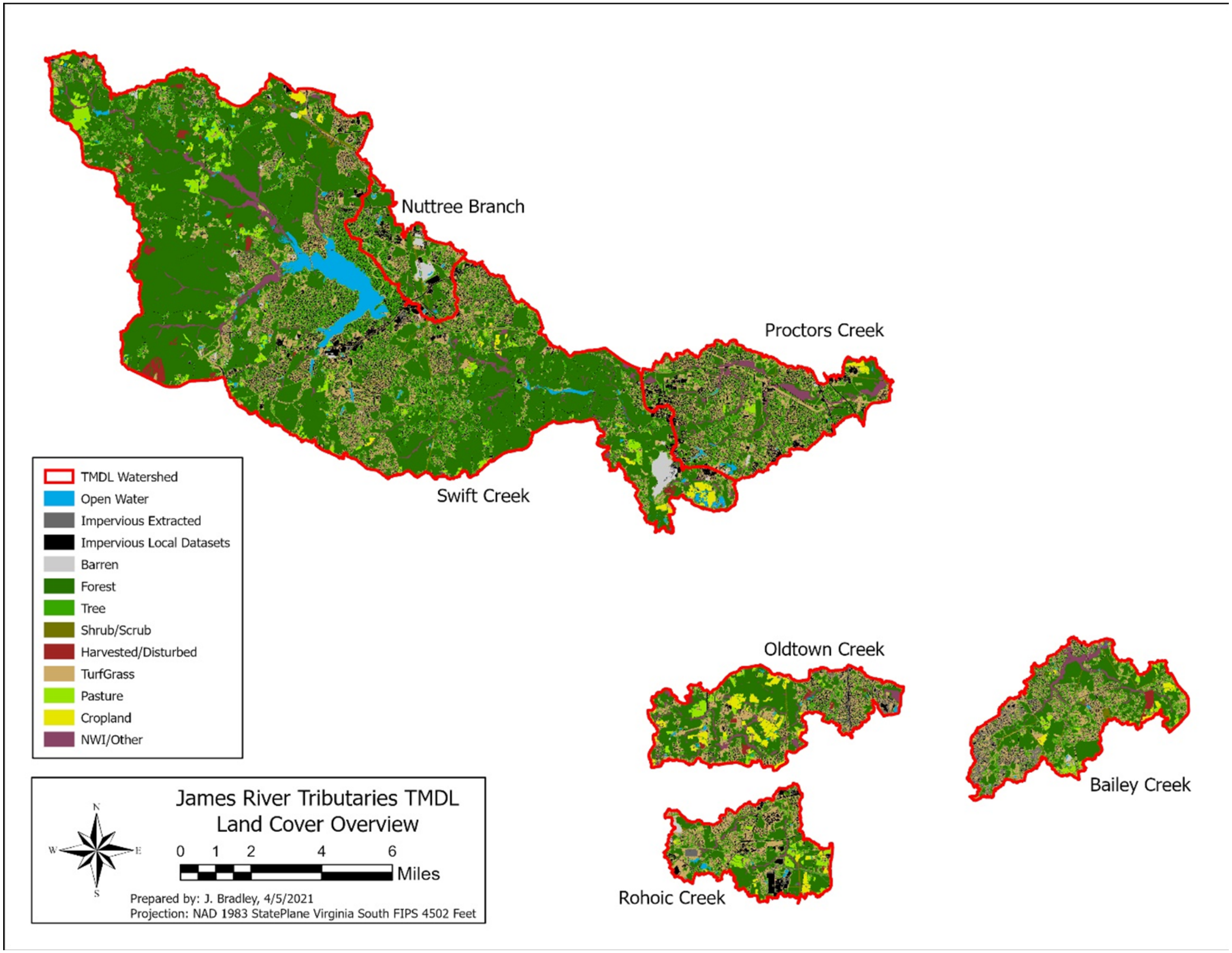


Figure 3-3. Land cover distribution used in the James River tributary watershed models.

Table 3-1. Land cover distribution in the Bailey Creek watershed.

Bailey Creek Watershed		
Land Cover Category	**Acres**	**Percentage**
Cropland	138	1.5
Hay	200	2.2
Pasture	12	0.1
Forest	2719	29.8
Trees	1502	16.5
Shrub	132	1.4
Harvested/ Disturbed	89	1.0
Water	17	0.2
Wetland	412	4.5
Barren	18	0.2
Turfgrass	2378	26.1
Developed, pervious	199	2.2
Developed, impervious	1304	14.3
Total	*9,118*	*100*

Table 3-2. Land cover distribution in the Nuttree Branch watershed.*

Nuttree Branch Watershed		
Land Cover Category	**Acres**	**Percentage**
Cropland	-	0.0
Hay	-	0.0
Pasture	-	0.0
Forest	1033	27.7
Trees	829	22.2
Shrub	39	1.0
Harvested/ Disturbed	-	0.0
Water	42	1.1
Wetland	29	0.8
Barren*	-	0.0
Turfgrass	952	25.5
Developed, pervious	32	0.9
Developed, impervious	773	20.7
Total	*3,728*	*100*

*Quarry area removed from barren land cover as it doesn't drain to stream and is accounted for in permits, total watershed area varies slightly from previously reported values for this reason.

Table 3-3. Land cover distribution in the Oldtown Creek watershed.

Oldtown Creek Watershed		
Land Cover Category	**Acres**	**Percentage**
Cropland	627	7.3
Hay	2410	2.8
Pasture	2	0.0
Forest	2,805	32.9
Trees	998	11.7
Shrub	31	0.4
Harvested/ Disturbed	135	1.6
Water	59	0.7
Wetland	502	5.9
Barren	2	0.0
Turfgrass	1,998	23.4
Developed, pervious	100	1.2
Developed, impervious	1,036	12.1
Total	*8,535*	*100*

Table 3-4. Land cover distribution in the Proctors Creek watershed.

Proctors Creek Watershed		
Land Cover Category	**Acres**	**Percentage**
Cropland	76	0.6
Hay	63	0.5
Pasture	7	0.1
Forest	2,419	20.1
Trees	2,410	20.0
Shrub	71	0.6
Harvested/ Disturbed	-	0.0
Water	83	0.7
Wetland	806	6.7
Barren	44	0.4
Turfgrass	3,467	28.8
Developed, pervious	90	0.7
Developed, impervious	2,513	20.9
Total	*12,050*	*100*

Table 3-5. Land cover distribution in the Rohoic Creek watershed.*

Rohoic Creek Watershed		
Land Cover Category	**Acres**	**Percentage**
Cropland	60	2.4
Hay	110	4.5
Pasture	1	0.0
Forest	703	28.8
Trees	341	13.9
Shrub	24	1.0
Harvested/ Disturbed	7	0.3
Water	23	0.9
Wetland	76	3.1
Barren*	-	0.0
Turfgrass	673	27.5
Developed, pervious	28	1.2
Developed, impervious	398	16.3
Total	*2,444*	*100*

Table 3-6. Land cover distribution in the Swift Creek watershed.*

Swift Creek Watershed		
Land Cover Category	**Acres**	**Percentage**
Cropland	460	0.7
Hay	1,212	1.7
Pasture	519	0.7
Forest	34,859	50.2
Trees	9,855	14.2
Shrub	296	0.4
Harvested/ Disturbed	476	0.7
Water	2,051	3.0
Wetland	1,901	2.7
Barren*	152	0.2
Turfgrass	10,326	14.9
Developed, pervious	435	0.6
Developed, impervious	6,879	9.9
Total	*69,424*	*100*

*Quarry area removed from barren land cover as it doesn't drain to stream and is accounted for in permits, total watershed area varies slightly from previously reported values for this reason.

3.5. Water Quality and Biological Monitoring Data

Biological, physical, and chemical data from 48 monitoring stations within the TMDL watersheds were used in developing the stressor analysis study. All monitoring stations provided water quality data, and 14 stations provided benthic data (the 14 benthic stations were co-located with water quality stations). The data from these monitoring stations are explored in the attached stressor identification analysis study (**8.0Appendix E**) and benthic stations are summarized in **Table 3-7**. The various benthic monitoring stations are shown in **Figure 3-4.**

Table 3-7. Summary of benthic data collected in the study watersheds.

TMDL Watershed	Benthic Station ID	Location	Year(s) Sampled
Bailey Creek	2-BLY005.73	Downstream of Rt. 630	2010-2019
Nuttree Branch	2-NUT000.62	500m downstream of Rt 630	2010-2019
Oldtown Creek	2-OTC001.54	Just upstream of Conduit Rd	2007-2019
Oldtown Creek	2-OTC005.38	Upstream of Rt 628	2015-2019
Proctors Creek	2-PCT002.46	Rt 1 bridge	2007-2019
Rohoic Creek	2-RHC000.58	50m downstream of Rt 460	2010-2019
Swift Creek	2-SFT012.84	Rt. 631 bridge, just upstream from Bradley Bridge gauging station 02042000	2014
Swift Creek	2-SFT019.02	1 mile downstream of Rt 655	2008-2009
Swift Creek	2-SFT019.15	Upstream of SR 655	2010-2019
Swift Creek	2-SFT025.32	Just upstream of Rt 653 bridge	2008-2019
Swift Creek	2-HEP001.27	Horsepen Creek above Rt 667	2002
Swift Creek	2-LIA000.50	Licking Creek at Rt 5186 below Second Br	2008
Swift Creek	2DOTD002.52	Otterdale Branch 100 m upstream of Clover Hill Athletic Complex Road	2011
Swift Creek	2DTRO001.88	Third Branch 600m downstream of Rt 654	2011

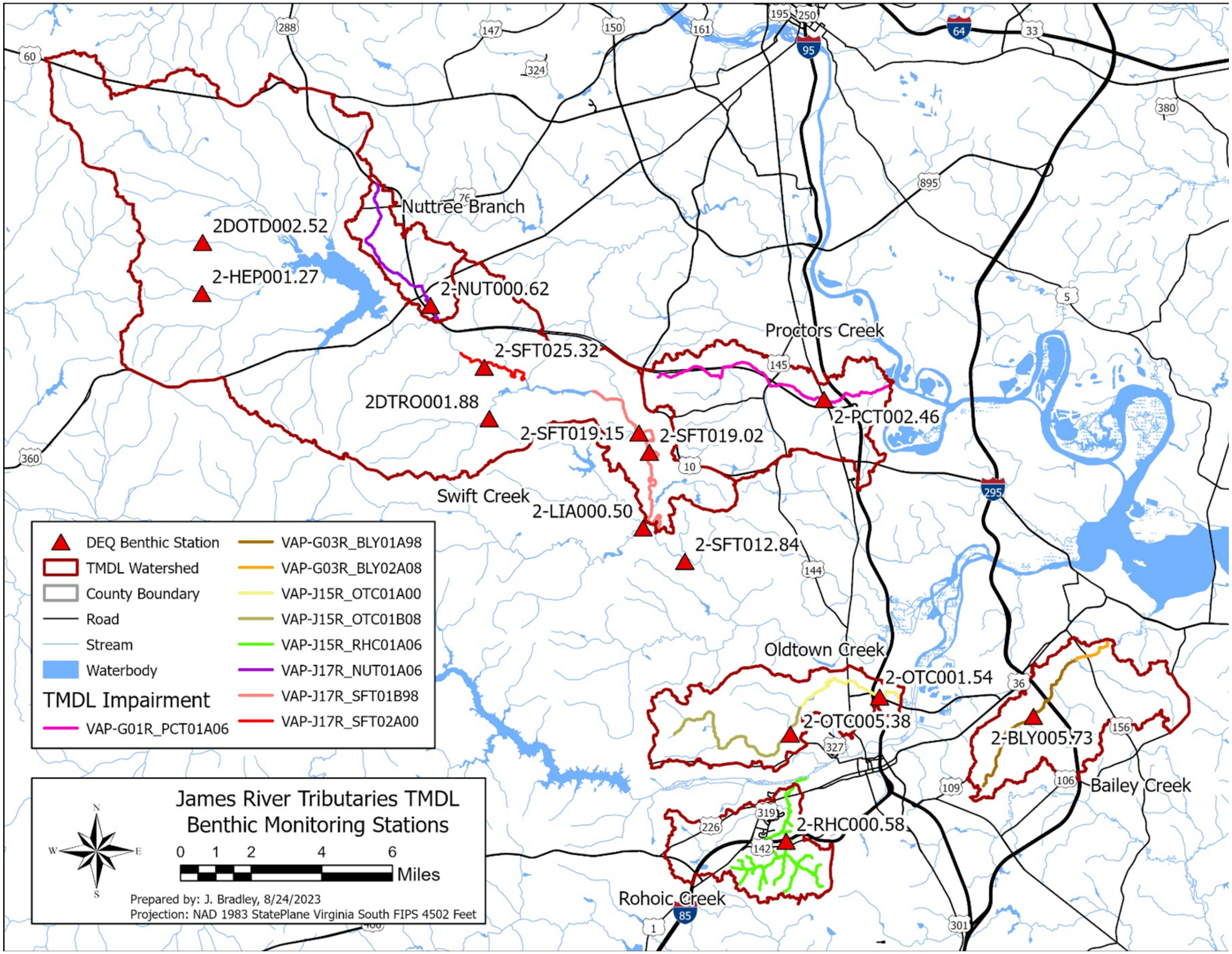


Figure 3-4. Locations of VADEQ benthic monitoring stations in the James River tributaries watersheds.

4.0 MODELING PROCESS

A computer numerical model was used in this study to simulate the relationship between pollutant loadings and in-stream water quality conditions.

4.1. Model Selection and Description

The model selected for development of the sediment and phosphorus TMDLs in the James River Tributaries TMDL was the Generalized Watershed Loading Functions (GWLF) model, developed by Haith et al. (1992), with modifications by Evans et al. (2001), Yagow et al. (2002), and Yagow and Hession (2007). GWLF is based on loading functions, which are a compromise between the empiricism of export coefficients and the complexity and data-intensive nature of process-based simulations (Haith et al., 1992). GWLF operates in metric units, but outputs were converted to English units for this report.

GWLF is a continuous simulation model that operates on a daily timestep for water balance calculations and outputs monthly runoff, sediment, and nutrient yields for the watershed. The model allows for multiple land cover categories to be incorporated, but spatially it is lumped because it does not account for the spatial distribution of sources and has no method of spatially routing sources within the watershed.

Observed daily precipitation and temperature data is input, along with land cover distribution and a range of land cover parameters, which the model uses to estimate runoff and sediment loads in addition to dissolved and attached nitrogen and phosphorus loads. Surface runoff is calculated using the Soil Conservation Service Curve Number (SCS-CN) approach. Curve numbers are a function of soils and land use type. Erosion is calculated in GWLF based on the Universal Soil Loss Equation (USLE). USLE incorporates the erosivity of rainfall in the watershed area, inherent erodibility of the soils, length and steepness of slopes, as well as factors for cover and conservation practices that affect the impact of rainfall and runoff on the landscape. Impervious or urban sediment inputs are calculated in GWLF with exponential accumulation and washoff functions. GWLF incorporates a delivery ratio into the overall sediment supply to estimate sediment deposition before runoff carries it to a stream segment. GWLF's sediment transport algorithm takes into consideration the transport capacity of the runoff based on calculated runoff volume.

Stream bank and channel erosion is calculated using an algorithm by Evans et al. (2003) as incorporated in the AVGWLF (GWLF with an ArcView interface) version (Evans et al., 2001) of the GWLF model and corrected for a flow accumulation coding error (VADEQ, 2005). This algorithm incorporates the stream flow, fraction of developed land (i.e. impervious cover) in the watershed, and livestock density in the watershed with the area-weighted curve number and soil erodibility factors and the mean slope of the watershed.

Groundwater discharge to the stream is calculated using a lumped parameter for unsaturated and shallow saturated water zones throughout the watershed. Infiltration to the unsaturated zone occurs when precipitation exceeds surface runoff and evapotranspiration. Percolation from the unsaturated zone to the shallow saturated zone occurs when the unsaturated zone capacity is exceeded. The shallow saturated zone contributes groundwater discharge to the stream based on a recession coefficient, and groundwater loss to a deep saturated zone can be modeled using a seepage coefficient.

Surface nutrient losses are determined by applying dissolved nitrogen and phosphorus coefficients to surface runoff and a nutrient content coefficient to the sediment yield for pervious source areas. Impervious or urban nutrient inputs are calculated with exponential accumulation and washoff functions. GWLF also includes functionality for manure applications and septic systems.

4.2. Model Setup

Watershed data needed to run GWLF were generated using spatial data, water quality monitoring data, streamflow data, local weather data, literature values, stakeholder input, and best professional judgement. In general, the GWLF manual (Haith et al., 1992) served as the primary source of guidance in developing input parameters where newer published methods were not available. Values for the various GWLF input parameters for each model are detailed in **Appendix A**. A sensitivity analysis of the model to select parameters is presented in **Appendix B**.

Local weather data (spanning from April 1, 2000 to March 31, 2021), including daily rainfall totals and average daily temperature, was obtained from the PRISM climate model (PRISM, 2021). The PRISM model incorporates climate observations from a variety of sources, applies quality control measures, and develops spatial climate datasets incorporating digital elevation models to improve model accuracy. Daily weather was modelled at Fine Creek Mills (37.5838, -77.8907), near USGS gage #02036500, which was used for model calibration (see **Section 4.5**).

The model allows for multiple land cover categories to be incorporated, but spatially it is lumped, meaning that it does not account for the spatial distribution of sources within the watershed. The standard practice is to sub-divide larger watersheds into smaller subwatersheds that can be simulated individually to get a more granular assessment of the pollutant loads. The TMDL study area was divided into 26 subwatersheds. The Swift Creek study area was divided into subwatersheds one through sixteen, with subwatershed nine being the Nuttree Branch study. The Proctors Creek and Bailey Creek watersheds were each divided into three subwatersheds, while the Oldtown Creek and Rohoic Creek watersheds were each divided into two subwatersheds (**Figure 4-1**). Locations of monitoring stations were used to guide subwatershed development to take advantage of available data. Junctions of streams were also used as breaking points to reduce subwatershed size, allowing large tributaries to be modeled independently.

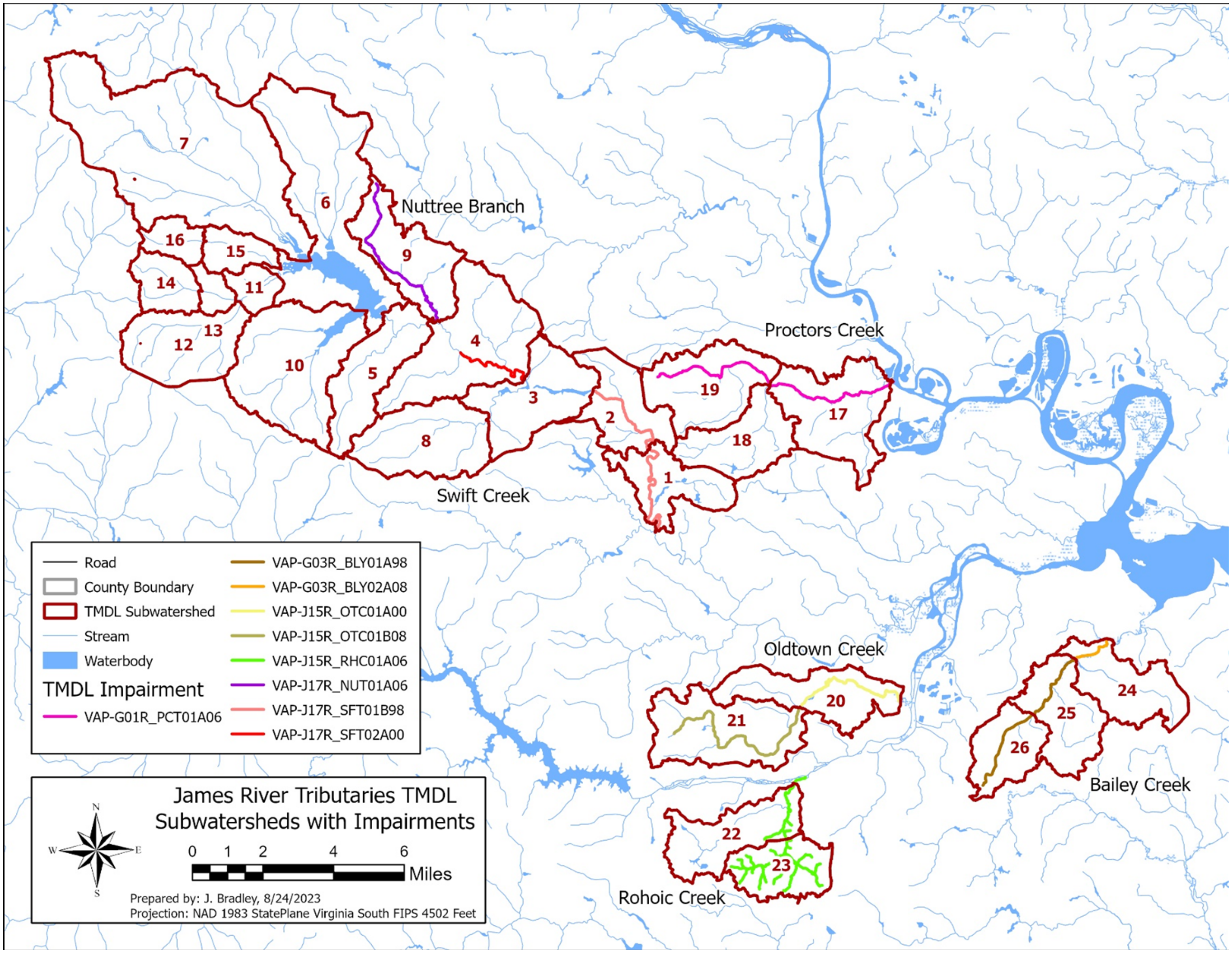


Figure 4-1. James River tributaries TMDL model subwatersheds.

4.3. Source Assessment

Sediment and phosphorus can be delivered to streams by either point or non-point sources. Point sources include permitted sources such as water treatment facilities. Non-point sources encompass all of the other sources in the watersheds, including natural background contributions. Non-point sediment and phosphorus is primarily from surface runoff (that is not captured and converted to point sources) and erosion happening within and on the banks of streams. Phosphorus in particular can be either bound to and transported with eroded sediment or dissolved in water directly.

4.3.1. Non-Point Sources

4.3.1.1. Surface Runoff

Sediment and attached phosphorus can be transported from both pervious and impervious surfaces during runoff events. Between rainfall events, sediment accumulates on impervious surfaces and can then be washed off during runoff events. On pervious surfaces, soil particles are detached by rainfall impact and shear stress from overland flow and then transported with the runoff water to nearby streams. Various factors including rainfall intensity, storm duration, surface cover, topography, tillage practices, soil erosivity, soil permeability, and other factors all impact these processes. Surface applications of manure and other fertilizers are also subject to suspension and transport via runoff. In addition to the phosphorus attached to mobilized sediment particles, phosphorus can also be dissolved in water. Surface runoff can 'pick up' soluble phosphorus and then contribute directly to dissolved phosphorus in streams.

The VGIN 2016 land cover dataset was used to determine the distribution of different land cover types in the watersheds (with the modifications noted in **Section 3.3**). Values for various parameters affecting sediment and phosphorus loads were gleaned from literature guidance (CBP, 1998; Haith et al., 1992; Hession et al., 1997, CTBMPEP, 2016, SSDCEP, 2015).

4.3.1.2. Streambank Erosion

Sediment is transported in stream systems as part of their natural processes. However, changes to the landscape can alter these processes, in turn changing the balance of sediment mobilization and deposition within the stream system. Phosphorus in the soil binds tightly with sediment and is transported in the stream along with the associated sediment, altering the loading and transportation of phosphorus within the watershed.

Increases in impervious areas can increase the amount and rate of flow in streams following rainfall events, which provides more erosive power to the streams and increases the channel erosion potential. This is often the cause of the entrenchment, or downcutting, of urban streams – disconnecting higher flow events from the surrounding floodplain. The higher flows are then increasingly confined to the channel, thus mobilizing more sediment, both as total suspended sediment (TSS) in the water column and bedload (the movement of larger particles along the bottom of the channel). Erosion of entrenched streams continues as steep banks are more susceptible to erosion and eventually mass wasting as chunks of undercut banks are dislodged into the stream. Sediment deposition between storm events and the highly mobile bed material during erosive storm flows negatively impact aquatic life.

Additionally, impacts to riparian (streambank) vegetation from livestock access and other management practices weaken the stability of the streambanks themselves as root system matrices break down. Weakened streambanks are more easily eroded by storm flows and can lead to excessive channel migration and eventual channel over-widening. Increasing channel width decreases stream depth which can lead to increased sediment deposition and increased water temperatures, which both negatively impact aquatic life.

Stream bank and channel erosion is calculated in GWLF using an algorithm by Evans et al. (2003) as incorporated in the AVGWLF version (Evans et al., 2001) of the GWLF model and corrected for a flow accumulation coding error (VADEQ, 2005). This algorithm estimates average annual streambank erosion as a function of cumulative stream flow, fraction of developed land (i.e. impervious cover) in the watershed, and livestock density in the watershed with the area-weighted curve number and soil erodibility factors and the mean slope of the watershed.

4.3.1.3. Groundwater

Shallow surface groundwater interacts with phosphorus both dissolved in percolating runoff and attached to the soil itself. The higher the concentration of soil-bound phosphorus and dissolved phosphorus in runoff water, the higher the levels of phosphorus in shallow groundwater. Groundwater can contribute directly to streamflow through upwelling, taking its dissolved phosphorus with it and adding to the overall total phosphorus (TP) load in the streams.

4.3.1.4. Residential Septic Systems

Residential septic systems are designed so that their drainfields dissipate effluent over a broad area. The organic phosphorus in the effluent is adsorbed to soil particles and used by plants and microorganisms. When systems are failing, they can discharge nutrient-rich waste to the surface instead, where it is easily transported to surface waters during runoff events, or directly to surface waters if nearby.

The number and distribution of dwellings with septic systems throughout the watersheds was determined using a dataset provided by Virginia Department of Health dated March 2021 (**Table 4-1**). Residences with failing (ponded) septic systems were estimated based on a failure rate of 3.3% (except 0.51% in Chesterfield County, failure rate provided by county), derived from the assumption that each septic system fails, on average, once during an expected lifetime of 30 years. Without reliable estimates or stakeholder input stating otherwise, it was assumed that there were no direct sewage discharges to streams (straight pipes). Census data (US Census Bureau, 2020) for the localities was used as the reference for number of persons per household, which was applied to the number of residences on septic systems to obtain a population distribution to be input to GWLF.

Table 4-1. Estimated numbers of residences with septic systems.

TMDL Watershed	Sub-watershed	Percent Failure Rate	Functioning Septic Systems	Ponded Septic Systems
Swift Creek	1	0.51	294	2
	2	0.51	79	0
	3	0.51	15	0
	4	0.51	130	1
	5	0.51	21	0
	6	0.51	40	0
	7	0.51	199	1
	8	0.51	507	3
Nuttree Branch (within Swift Creek)	9	0.51	15	0
Swift Creek	10	0.51	31	0
	11	0.51	4	0
	12	0.51	11	0
	13	0.51	5	0
	14	0.51	2	0
	15	0.51	12	0
	16	0.51	8	0
Proctors Creek	17	0.51	66	0
	18	0.51	109	1
	19	0.51	50	0
Oldtown Creek	20	0.51	21	0
	21	0.51	55	0
Rohoic Creek	22	3.30	2	0
	23	3.30	6	0
Bailey Creek	24	3.30	17	0
	25	3.30	16	0
	26	3.30	3	0

4.3.2. Point Sources

Various point sources of sediment and phosphorus exist within the James River tributaries watersheds. These point sources are permitted under the Virginia Pollutant Discharge Elimination System (VPDES) program and include the following categories of permits: individual permits, non-metallic mineral mining (NMMM) general permits, concrete facility general permits, industrial stormwater (ISW) general permits, vehicle wash / laundry facility general permits, domestic sewage general permits, municipal separate storm sewer system (MS4) permits, and construction stormwater general permits. The approach for determining pollutant loads from each of these permit types is described below. Typically, wasteload allocations for VPDES general permits in a TMDL are aggregated by permit type (if multiple of the same permit type). As permits are issued in the watershed in the future, the associated loads will be aggregated within the relevant TMDL wasteload allocation.

4.3.2.1. VPDES Individual Permit

There are three VPDES individual permits within the study area, associated with a correctional center, Fort Lee, and a water treatment facility. The existing condition's sediment and phosphorus loads from the facilities were calculated from discharge monitoring report data. The existing conditions load for the Addison Evans Water facility was set to zero, as there has been no record of discharge in the last thirty years, though the permit is still valid. The permitted loads, which are included in the wasteload allocation of the TMDL, were calculated based on the permitted discharge and concentration for each facility (**Table 4-2**).

Table 4-2. Sediment and phosphorus loads associated with VPDES individual permits.

Permit Number (Facility Name)	Receiving Stream	Permitted Discharge (MGD)	Permit Conc. (mg/L TSS)	Allocated Load (lb/yr TSS)	Permit Conc. (mg/L TP)	Allocated Load (lb/yr TP)
VA0023426 (DOC Central Virginia Correctional Center for Women)	Swift Creek	0.065	45	8,910	0.23	46
VA0059161 (US Army Garrison Fort Lee, outfall #002)	Bailey Creek	0.046	30	4,204	n/a*	n/a*
VA0006254 (Addison Evans Water Production Laboratory)	Swift Creek	0.5	60	91,382	0.23	9.6

*Bailey Creek not subject to phosphorus TMDL

4.3.2.2. Nonmetallic Mineral Mining General Permit

There are three nonmetallic mineral mining (NMMM) general permits in the watershed (**Table 4-3**). These facilities are permitted sources of sediment at an average concentration of 30 mg/L TSS. Discharge rates were calculated based on provided DMR data. There is currently no permitted loading rate for phosphorus in the NMMM general permit. As such, VADEQ developed a methodology to estimate the loads from these permits using the Chesapeake Bay TMDL Phase III Watershed Implementation Plan (WIP) Input Deck Process Water Assumptions based on various categories of VPDES general permits. For VAG84 – Nonmetallic Mineral Mining permits an average TP concentration of 0.02 mg/L TP is listed in the Input Deck Assumptions. This concentration was applied to the discharge rate for each permit.

Table 4-3. Nonmetallic mineral mining general permits in the study area.

Permit Number	Facility Name	Stream	Allocated Discharge (MGD)	Allocated Load (lb/ yr TSS)	Allocated Load (lb/ yr TP)
VAG840079	Midlothian Quarry	Nuttree/ Swift	0.50	45,690.6	30.5
VAG840114	Vulcan Construction Materials LLC – Dale Quarry	Swift	1.50	137,071.8	91.4
VAG840126	Vulcan Construction Materials LLC – Jack Quarry	Rohoic	1.40	127,933.7	85.3

4.3.2.3. Concrete Products Facility General Permit

There are five concrete products facilities general permits in the study area (**Table 4-4**). These facilities are a permitted source of sediment and phosphorus in the watershed and contribute pollutants primarily from stormwater runoff. For process water (where applicable), pollutant loads from each facility were calculated using the average flow rate and permitted loading rate of 30 mg/L TSS. However, there is not currently a permitted loading rate for phosphorus in the concrete facilities general permit. As such, VADEQ developed a methodology to estimate the loads from these permits using the Chesapeake Bay TMDL Phase III Watershed Implementation Plan (WIP) Input Deck Process Water Assumptions based on various categories of VPDES general permits. For VAG11 – Concrete Products permits, an average TP concentration of 0.71 mg/L TP is listed in the Input Deck Assumptions. This concentration was applied to the average discharge rate for process water, where applicable.

Concrete facility permitted outfalls associated with only stormwater loads were handled in the same way as Industrial Stormwater Permits (**Section 0**) by using a weight per unit area loading rate to calculate loads (440 lb/ac/yr and 1.5 lb/ac/yr for sediment and phosphorus, respectively).

Table 4-4. Concrete products facility general permits in the study area.

Permit Number	Facility Name	Receiving Stream	Load Type	Allocated Load (lb/yr TSS)	Allocated Load (lb/yr TP)
VAG110157	Smyrna Ready Mix	Proctors Creek	Stormwater	1188.0	4.1
VAG110158	Mechanicsville Concrete LLC – Petersburg Ready Mix	Rohoic Creek	Stormwater	1166.0	4.0
VAG110159	Chesterfield Ready Mix Concrete Plant	Nuttree Branch	Stormwater	325.6	1.1
VAG110171	Vulcan Construction Materials LLC – Dinwiddie	Rohoic Creek	Stormwater	1592.8	5.4
			Process Water (0.01 MGD)	1827.6	21.6
VAG110231	Greenrock Materials LLC – Prince George Plant	Bailey Creek	Stormwater	1944.8	6.6

4.3.2.4. Industrial Stormwater (ISW) General Permit

There are 19 industrial stormwater (ISW) general permits in the study area (**Table 4-5**). Sediment and phosphorus loads from industrial stormwater permits are included in this study. There is currently no permitted loading rate for either sediment or phosphorus for industrial stormwater sources in the general permit. However, the Chesapeake Bay TMDL now requires permittees to assess their nutrient and sediment loadings. As such, VADEQ developed a methodology to estimate the loads from ISW permitted areas. To develop existing loads, the regulated acreages for the permits were separated from the accounting of total acreages for the watershed. Under existing conditions, the regulated industrial acres for each permit were included in the model at the same loading rate as other developed, impervious acres. In the TMDL allocation scenario, the allocated loads were calculated using the same methodology, but utilizing the loading rates of 440 lb/ac/yr TSS and 1.5 lb/ac/yr TP, as noted in the general permit. These values are cited in the permit (9VAC25-151-70) as those used to estimate the loading from industrial stormwater facilities in Chesapeake Bay TMDL documentation.

Table 4-5. Industrial stormwater general permits in the study area.

Permit Number	Facility Name	Receiving Stream
VAR050549	Kaiser Aluminum Fabricated Products LLC	Proctors Creek
VAR050583	South Side Auto Recycling Inc.	Nuttree Branch
VAR050594	US Army Garrison and Fort Lee	Bailey Creek
VAR050614	Harrells Used Auto Parts	Bailey Creek
VAR050619	Chaparral Virginia Inc.	Rohoic Creek
VAR050625	Reynolds Consumer Products LLC	Proctors Creek
VAR050666	Branscome Richmond – Chesterfield Plant	Nuttree Branch
VAR050672	Adams Construction Co. - Jack Plant	Rohoic Creek
VAR051023	Dominion Energy – Chesterfield Power Station	Proctors Creek
VAR051168	Aleris Rolled Products Inc.	Proctors Creek
VAR051218	International Paper – Petersburg	Rohoic Creek
VAR051683	Lee Hy Paving Corp – Chester	Swift Creek
VAR051684	Shoosmith Sanitary Landfill	Swift Creek
VAR051893	Atlantic Iron and Metal	Rohoic Creek
VAR052059	Hillcrest Transportation Inc.	Rohoic Creek
VAR052185	TFC Recycling – Chester Facility	Proctors Creek
VAR052263	Hill Phoenix – Battery Brooke Pkwy	Proctors Creek
VAR052314	Pierce Mechanical Inc	Proctors Creek
VAR052351	County Waste MRF	Swift Creek

4.3.2.5. Vehicle Wash Facility General Permit

There is one vehicle wash facility general permit in the watershed (**Table 4-6**). The discharge rate was based on provided permit data. Allocated sediment loads were calculated using the average discharge rate and the TSS concentration of 60 mg/L listed in the general permit. There is currently no permitted loading rate for phosphorus in the vehicle wash general permit. As such, VADEQ developed a methodology to estimate the loads from these permits using the Chesapeake Bay TMDL Phase III Watershed Implementation Plan (WIP) Input Deck Process Water Assumptions based on various categories of VPDES general permits. For VAG75 – Vehicle Wash and Laundry permits, an average TP concentration of 0.77 mg/L TP is listed in the Input Deck Assumptions. This concentration was applied to the discharge rate for each permit.

Table 4-6. Vehicle wash facility general permits in the study area.

Permit Number	Facility Name	Stream	Allocated Discharge (MGD)	Allocated Load (lb/yr TSS)	Allocated Load (lb/yr TP)
VAG750205	Chesterfield County DPR Maintenance Rinse Station	Proctors Creek	0.0003	54.8	0.7

4.3.2.6. Domestic Sewage General Permit

There are four domestic sewage general permits in the study area (**Table 4-7**). The domestic sewage general permit specifies a maximum flow rate of 1000 gallons per day at a sediment concentration of 30 mg/L. These permit limits were used to calculate a wasteload allocation of 91.44 lb/yr TSS for the domestic sewage permits in the TMDL. Using the Chesapeake Bay TMDL Phase III Watershed Implementation Plan (WIP) Input Deck Process Water Assumptions, for VAG40 – Domestic Sewage permits are listed at an average TP concentration of 7.05 mg/L TP and a flow rate of 0.0002 MGD in the Input Deck Assumptions. These values lead to a wasteload allocation of 4.30 lb/yr TP for each permit.

Table 4-7. Domestic sewage general permit in the study area.

Permit Number	Receiving Stream
VAG404275	Swift Creek
VAG404286	Swift Creek
VAG404357	Swift Creek
VAG404358	Swift Creek

4.3.2.7. Municipal Separate Storm Sewer System (MS4) Permits

There are eight MS4 permits within the TMDL watersheds (**Table 4-8**). These areas are potential sources of sediment and phosphorus to the study watersheds and were assigned wasteload allocations in this TMDL report. The existing loads were based on the extent and type of land cover within the boundaries of the permitted areas and the existing modeled loading rates associated. For the allocated loads, the same reductions by land cover were applied to the MS4 areas as recommended throughout the watershed. Due to the localized extent and interconnected nature of the permitted areas, the loads associated with the MS4 permits were aggregated and presented as one combined wasteload allocation in the final TMDL scenarios to provide some degree of flexibility to permit holders to determine their portion of the load and to address the needed reductions.

Table 4-8. MS4 permits within the watersheds.

Permit Number	Permitted Entity
VAR040006	Central State Hospital
VAR040007	Fort Lee
VAR040009	City of Colonial Heights
VAR040013	City of Petersburg
VAR040015	City of Hopewell
VAR040110	John Tyler Community College
VA0088609	Chesterfield County
VA0092975	VDOT

4.3.2.8. Construction Stormwater General Permit

There were 175 active Virginia Stormwater Management Program (VSMP) permits for construction within the watersheds at the time of TMDL development (**Table 4-9**). These permits are a potential source of sediment and phosphorus to the James River tributaries watersheds and were assigned wasteload allocations in the TMDL. Each permit contains an estimate of the permitted disturbed area, however, this area is generally not disturbed for the entire length of the permit's active status. To account for this discrepancy, the acreage estimated to be disturbed for each permit was divided over the length of the permit's active status (no less than one year). Any active permits in process of termination were excluded because at that stage in the permitting cycle all areas are stabilized.

Table 4-9. Disturbed acreage associated with active construction general permits within the watersheds.

Receiving Stream	Estimated Potential Disturbed Area (ac)
Bailey Creek	16.7
Nuttree Branch	64.4
Oldtown Creek	40.2
Proctors Creek	185.6
Rohoic Creek	64.9
Swift Creek	717.4

Disturbed acreage associated with construction permits was modeled as barren land cover, and the acres allocated to construction permits subtracted proportionally from all land cover values in the watershed so that areas were not double counted when developing the existing load estimates. Appropriate erosion and sediment control measures were assumed to be utilized on all construction projects, and for developing final WLAs for the allocation scenarios, loads were simulated with an 85% sediment removal efficacy based on Chesapeake Bay Expert Panel Guidance (ESCEP, 2014). These reductions were applied only to sediment loads, as the guidance does not indicate an effectiveness for nutrient removal by the assumed erosion control measures.

4.4. Best Management Practices

Many entities and private citizens have installed best management practices (BMPs) throughout the watersheds. Some BMPs have associated removal efficacies defined in the literature, which can be applied to the raw pollutant accumulation loads for the land areas draining to the BMP. Other BMPs can be simulated as a change in land use over the treated acreage, such as planting a riparian buffer and turning previous pasture land into forested areas. The active BMPs installed in the study watersheds included in the model are detailed in **Table 4-10**. The Chesapeake Bay Phase 5.3 Community Model Documentation Section 6 (USEPA, 2010) was used to guide the TSS and TP removal estimates.

Table 4-10. BMPs installed in the TMDL study area.

Receiving Stream	Practice	Count	Extent Installed	Efficacy method (fraction removal, other)	TSS Removed (lb/yr)	TP Removed (lb/yr)
Swift Creek	Afforestation of Crop, Hay and Pasture Land (FR-1)	2	13 ac	Land cover change	3757	23.2
	Grazing Land Management (SL-9)	2	8 ac	0.3 TSS; 0.24 TP	716	3.4
	Stream Exclusion with Grazing Land Management (SL-6)	1	50 ac	0.4 TSS; 0.3 TP	5966	26.9

4.5. Flow Calibration

GWLF was originally developed as a planning tool for estimating nutrient and sediment loadings in ungauged watersheds and was designed to be implemented without calibration. Hydrologic calibration was still performed as a preliminary modeling step to ensure that hydrology was being simulated as accurately as feasibly possible.

Historic daily flow data was available from USGS flow gauge #02036500 – Fine Creek at Fine Creek Mills back to 1990. While not located directly on one of the TMDL streams, the gauge is located on nearby Fine Creek, which was included in the development of the AllForX regression (**Section 5.0** and **8.0Appendix C**, Fine Creek watershed contains station 2-FIN000.81 noted in **Table C-1**). Fine Creek watershed is similar in size to the Proctors Creek watershed, with similar land cover distributions to the study areas, and is very close geographically. While the cumulative Swift Creek watershed is significantly larger than Fine Creek, its various subwatersheds are similarly sized. For these reasons, it is likely that the study watersheds will have a hydrologic response very similar to that of Fine Creek. Final calibrated parameters were applied to the other modeled watersheds. Local weather data, including daily rainfall totals and average daily temperature, was obtained from the PRISM climate model (see **Section 3.3**). Leaving a 'warm-up' period for the model, the years from 2011 to 2021 were used as the calibration period, and 2001 to 2010 were used as a validation dataset. These ranges are sufficiently long that a range of both dry and wet years are encompassed in each to get a good assessment of the model's performance.

Calibration efforts focused on adjusting watershed scale parameters, such as the recession coefficient, seepage coefficient, and leakage coefficient, which cannot be calculated or estimated reliably from available guidance. The typical target ranges for GWLF calibration efforts are to achieve ±5% of the observed total flow and ±20% compared to seasonal flow totals. While calibration efforts make a best effort at meeting the target for all criteria, this is not always possible as no model is a perfect simulation of the reality it is approximating. The final GWLF calibration results are shown in **Figure 4-2** and **Figure 4-3** and summarized in **Table 4-11**. The results of the calibration were also assessed for overall correlation by calculating an R^2 value for the datasets. Generally, for GWLF, an R^2 value greater than 0.7 indicates a strong positive correlation between simulated and observed data. Following calibration, the model output was run compared to the observed 2001-2010 discharge as a validation of the model calibration. The final GWLF validation results are summarized in **Table 4-11** and shown in **Figure 4-4** and **Figure 4-5**. Both the calibration and validation runs meet all of the target criteria to be considered a good fit to the observed hydrologic data.

Table 4-11. Results of hydrology calibration of GWLF model.

Criteria	Calibration Range Percent Difference (%)	Validation Range Percent Difference (%)	Entire Modelled Range (%)
Total Cumulative Discharge	6.68	-4.07	1.34
Spring Discharge	-0.18	-18.42	-8.49
Summer Discharge	-0.23	2.23	1.14
Fall Discharge	11.43	7.29	9.34
Winter Discharge	10.59	-8.11	1.41
R^2	0.80	0.82	0.81

4.6. Consideration of Critical Conditions and Seasonal Variations

The GWLF model simulated a 20-year period (2001 through 2021) with an additional buffer period of nine months at the beginning of the run serving as a 'warm-up' period for the model to equilibrate and minimize the impact of uncertain initial conditions. Using this extended modeling period allows the results to account for both annual and seasonal variations in hydrology and sediment and phosphorus loads.

The modeled time period encompasses a range of weather conditions for the area, including 'dry', 'normal', and 'wet' years, which allows the model to represent critical conditions during both low and high flows. Critical conditions during low flows are generally associated with point source loads, while critical conditions during high flows are generally associated with nonpoint source loads.

GWLF considers seasonal variation through several mechanisms. Daily time steps are used for weather data inputs and water balance equation calculations. GWLF also incorporates parameters that vary by month, including evapotranspiration cover coefficients and average hours per day of daylight. Additionally, the values for the rainfall erosivity coefficient are dependent on whether a given month is tagged as part of the growing season or dormant season. The model is also capable of incorporating data for the land-application of manure in up to two user-set application periods.

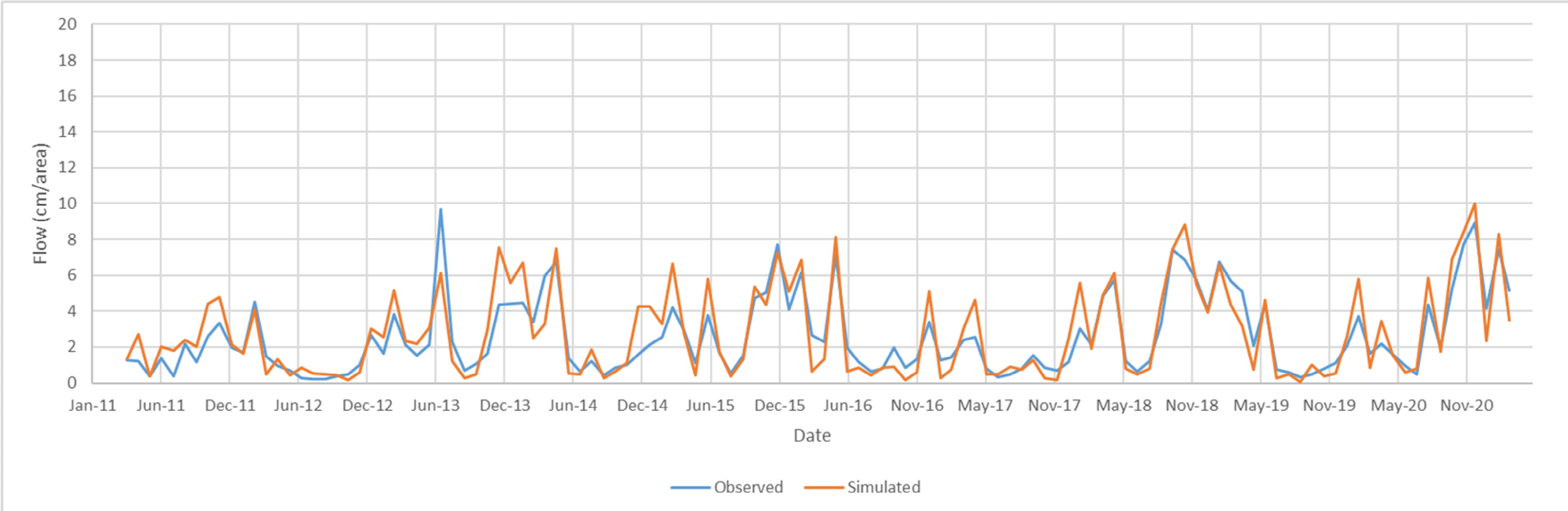


Figure 4-2. Calibration data set of simulated stream flow compared to observed flow (USGS#02036500).

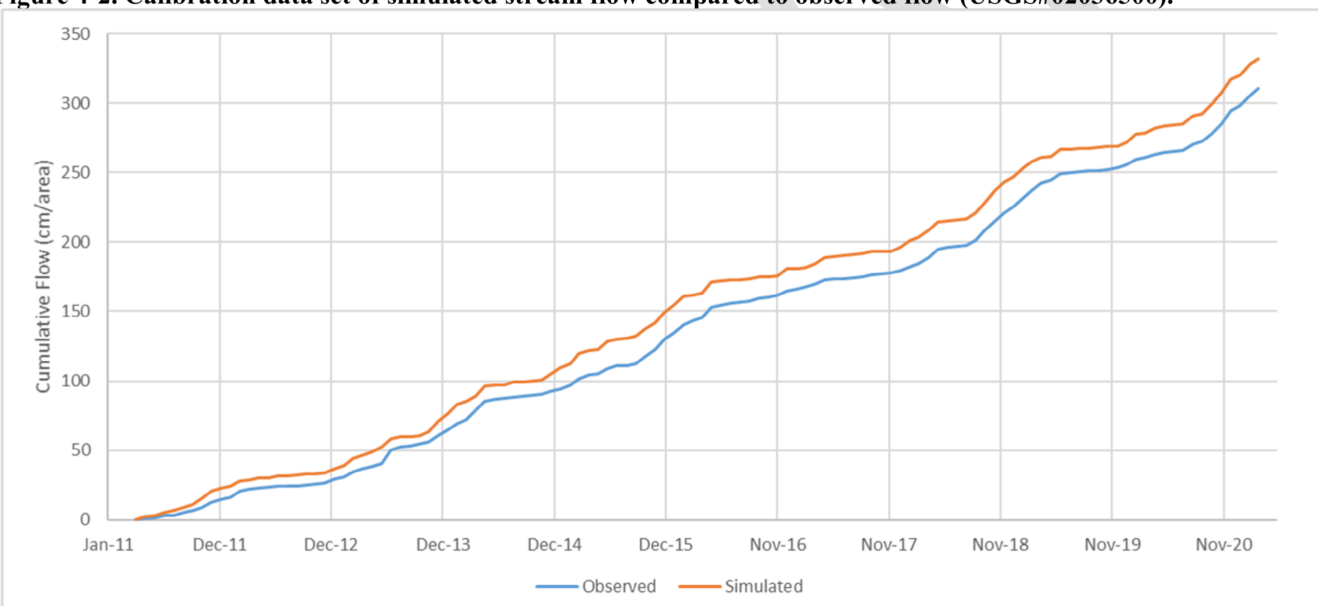


Figure 4-3. Calibration data set simulated cumulative flow from model compared to observed (USGS#02036500).

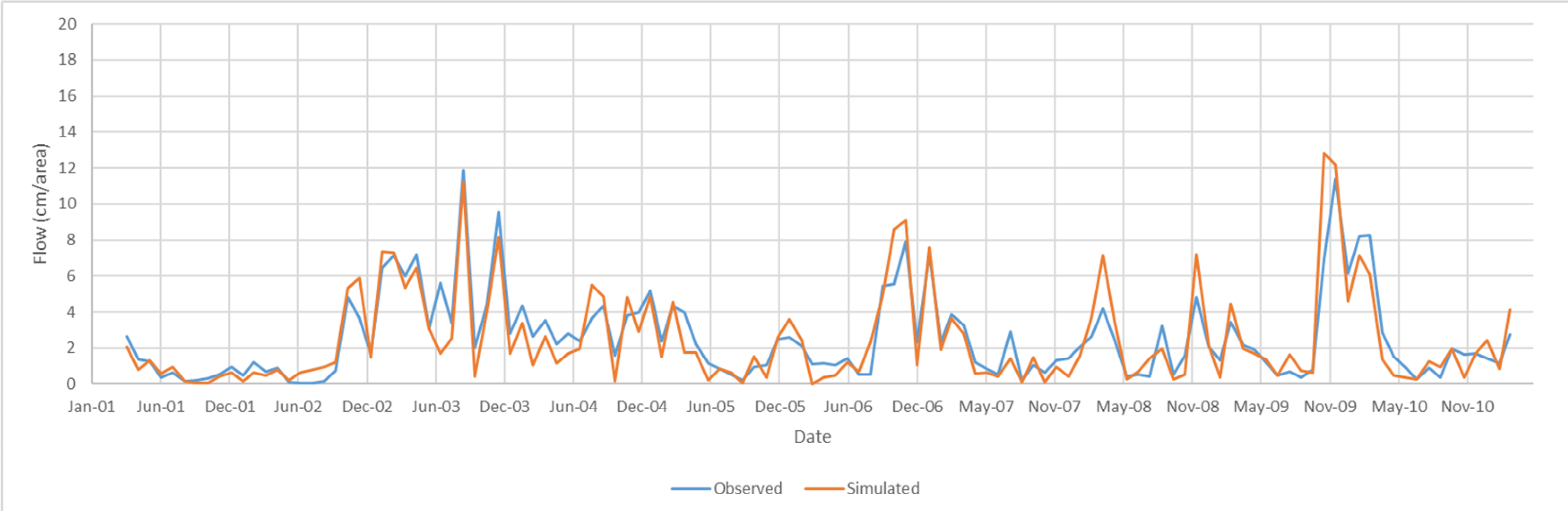


Figure 4-4. Validation data set of simulated stream flow compared to observed flow (USGS#02036500).

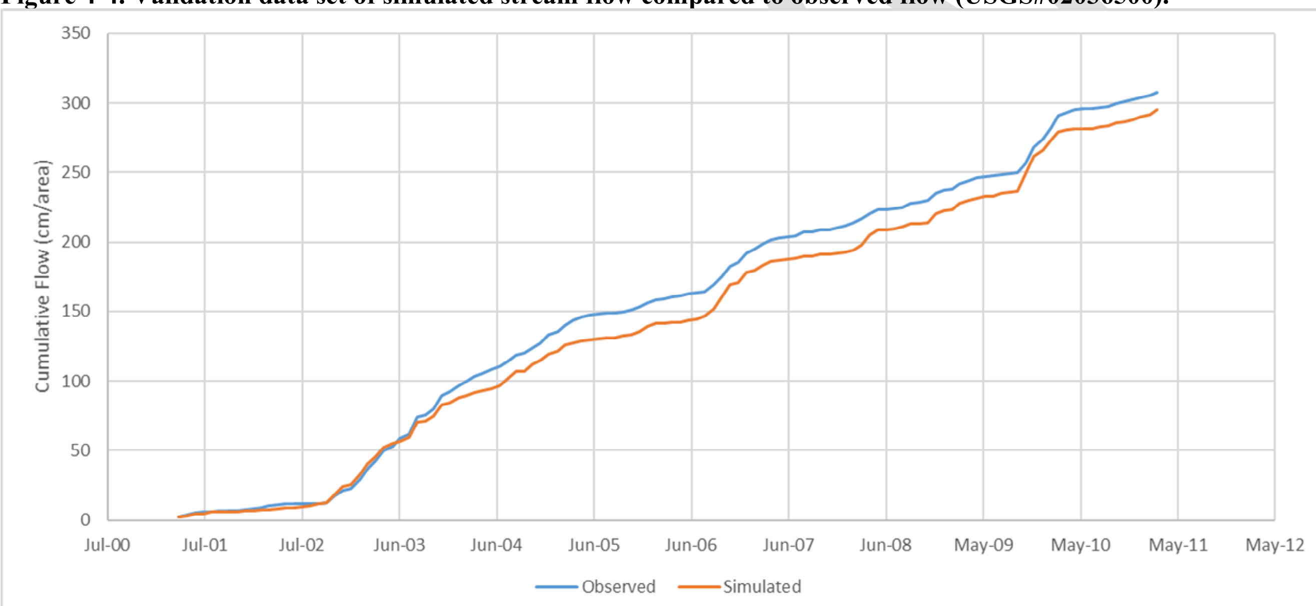


Figure 4-5. Validation data set simulated cumulative flow from model compared to observed (USGS#02036500).

4.7. Existing Conditions

Existing sediment and phosphorus loads from the impaired watersheds were simulated in GWLF as described above. **Table 4-12** through **Table 4-17** summarize the resulting loads for sediment and phosphorus, where appropriate. While the model is run using weather data from a several year period to capture the range of seasonal and annual variation, the land cover and sources within the model do not vary over time as the model runs. Instead, the land cover and pollutant sources simulate a snapshot in time representing available data and active permits. In this model, the land cover is from 2016, the BMPs reflect conditions in May 2020, and permits included are reflective of conditions in July 2020. These dates reflect the collected water quality monitoring data used to determine the necessity of developing this TMDL and to gauge the existing conditions in the model results. The monitoring window for sediment and phosphorus data analyzed for this study ran through June 2020.

Any apparent differences in calculated values are due to rounding. Model results were rounded to 4 significant figures, and calculated totals of those results were rounded to 3 significant figures.

Table 4-12. Existing sediment loads in the Bailey Creek watershed, accounting for known BMPs (not including MOS or FG detailed in Section 6.0). Phosphorus is not a stressor in Bailey Creek.

Bailey Creek Watershed		
Land Cover Category	***TSS (lb/yr)***	***Percentage***
Cropland	26,620	1.3
Hay	6,796	0.3
Pasture	6,592	0.3
Forest	52,790	2.7
Trees	65,790	3.3
Shrub	15,240	0.8
Harvested/Disturbed	38,880	2.0
Water	0	0.0
Wetland	56,730	2.9
Barren	216,700	10.9
Turfgrass	78,630	4.0
Developed, pervious	10,940	0.6
Developed, impervious	219,200	11.1
Streambank	410,600	20.7
Permitted	779,500	39.1
Total	*1,990,000*	*100*

Table 4-13. Existing sediment loads in the Nuttree Branch watershed, accounting for known BMPs (not including MOS or FG detailed in Section 4.4.). Phosphorus is not a stressor in Nuttree Branch

Nuttree Branch Watershed		
Land Cover Category	***TSS (lb/yr)***	***Percentage***
Cropland	0	0.0
Hay	0	0.0
Pasture	0	0.0
Forest	16,410	2.06
Trees	32,270	4.05
Shrub	10,830	1.36
Harvested/Disturbed	0	0.00
Water	0	0.00
Wetland	4,520	0.57
Barren	0	0.00
Turfgrass	44,640	5.60
Developed, pervious	3547	0.45
Developed, impervious	164,700	20.66
Streambank	68,130	8.55
Permitted	452,000	56.71
Total	*797,000*	*100*

Table 4-14. Existing sediment and phosphorus loads in the Oldtown Creek watershed, accounting for known BMPs (not including MOS or FG detailed in Section 4.4.).

Oldtown Creek Watershed				
Land Cover Category	***TSS (lb/yr)***	***Percentage***	***TP (lb/yr)***	***Percentage***
Cropland	159,200	10.5	102	3.9
Hay	6,105	0.4	85	3.2
Pasture	1,690	0.1	3	0.1
Forest	37,250	2.5	18	0.7
Trees	19,720	1.3	13	0.5
Shrub	5,024	0.3	1	0.0
Harvested/Disturbed	24,670	1.6	7	0.3
Water	0	0.0	0	0.0
Wetland	37,550	2.5	4	0.2
Barren	11,290	0.7	1	0.0
Turfgrass	31,170	2.1	239	9.1
Developed, pervious	3,218	0.2	5	0.2
Developed, impervious	179,100	11.9	394	15.1
Streambank	337,800	22.4	118	4.5
Groundwater	-	-	151	5.8
Septic	-	-	1	0.0
Permitted	657,400	43.5	1,465	56.1
Total	*1,510,000*	*100*	*2,610*	*100*

Table 4-15. Existing sediment loads in the Proctors Creek watershed, accounting for known BMPs (not including MOS or FG detailed in Section 4.4.). Phosphorus is not a stressor in Proctors Creek.

Proctors Creek Watershed		
Land Cover Category	***TSS (lb/yr)***	***Percentage***
Cropland	8,824	0.3
Hay	2,111	0.1
Pasture	3,043	0.1
Forest	36,460	1.2
Trees	45,160	1.4
Shrub	8,735	0.3
Harvested/Disturbed	0	0.0
Water	0	0.0
Wetland	68,880	2.2
Barren	199,600	6.3
Turfgrass	58,680	1.9
Developed, pervious	4,151	0.1
Developed, impervious	361,100	11.4
Streambank	955,900	30.2
Permitted	1,413,000	44.6
Total	*3,170,000*	*100*

Table 4-16. Existing sediment and phosphorus loads in the Rohoic Creek watershed, accounting for known BMPs (not including MOS or FG detailed in Section 4.4.).

Rohoic Creek Watershed				
Land Cover Category	***TSS (lb/yr)***	***Percentage***	***TP (lb/yr)***	***Percentage***
Cropland	52,140	4.1	31	1.4
Hay	16,410	1.3	113	5.0
Pasture	4,153	0.3	4	0.2
Forest	22,270	1.7	10	0.4
Trees	31,910	2.5	14	0.6
Shrub	9,145	0.7	2	0.1
Harvested/Disturbed	4,129	0.3	1	0.1
Water	0	0.0	0	0.0
Wetland	21,340	1.7	3	0.1
Barren	0	0.0	0	0.0
Turfgrass	68,250	5.3	291	12.9
Developed, pervious	9,356	0.7	10	0.4
Developed, impervious	198,800	15.5	437	19.4
Streambank	247,200	19.3	87	3.8
Groundwater	-	-	122	5.4
Septic	-	-	1	0.0
Permitted	594,100	46.4	1,128	50.1
Total	*1,280,000*	*100*	*2,250*	*100*

Table 4-17. Existing sediment and phosphorus loads in the Swift Creek watershed (including Nuttree Branch), accounting for known BMPs (not including MOS or FG detailed in Section 4.4.).

Swift Creek Watershed				
Land Cover Category	***TSS (lb/yr)***	***Percentage***	***TP (lb/yr)***	***Percentage***
Cropland	119,500	0.6	71	0.4
Hay	26,210	0.1	363	1.9
Pasture	144,700	0.8	191	1.0
Forest	322,110	1.7	143	0.8
Trees	174,570	0.9	115	0.6
Shrub	30,690	0.2	3	0.0
Harvested/Disturbed	70,200	0.4	23	0.1
Water	0	0.0	0	0.0
Wetland	138,820	0.7	8	0.0
Barren	668,000	3.5	44	0.2
Turfgrass	200,140	1.0	1,267	6.7
Developed, pervious	24,507	0.1	35	0.2
Developed, impervious	1,681,700	8.8	4,237	22.3
Streambank	11,038,130	57.5	4,383	23.1
Groundwater	-	-	1,588	8.4
Septic	-	-	17	0.1
Permitted	4,553,000	23.7	6,535	34.4
Total	*19,200,000*	*100*	*19,000*	*100*

5.0 SETTING TARGET SEDIMENT LOADS

TMDL development requires an endpoint or water quality goal to target for the impaired watershed(s). Many pollutants have numeric water quality criteria set in regulatory documentation, and it is assumed that compliance with these numeric criteria will lead the waterbody to achieve support of all designated uses. However, sediment and phosphorus do not have numeric criteria established, as the acceptable level is expected to vary from stream to stream based on a range of contributing factors. Therefore, an alternative method must be used to determine the water quality targets for sediment and phosphorus TMDLs.

The method used to set TMDL endpoint loads for the James River tributaries watersheds is called the "all-forest load multiplier" (AllForX) approach, which has been used in developing many sediment and nutrient TMDLs in Virginia since 2014. AllForX is the ratio of the simulated pollutant load under existing conditions to the pollutant load from an all-forest simulated condition for the same watershed. In other words, AllForX is an indication of how much higher current sediment or nutrient loads are above an undeveloped condition. These ratios were calculated for a total of 15 watersheds (both impaired and unimpaired) of similar size and within the same ecoregion as the TMDL watersheds (**Appendix C**). A regression was then developed between the Virginia Stream Condition Index (VSCI) scores at monitoring stations and the corresponding AllForX value calculated for the watershed draining to each station. This regression was used to quantify the AllForX value that corresponds to the benthic health threshold (VSCI = 60). **Figure 5-1** and **Figure 5-2** show the regressions developed for the James River Tributaries study for sediment and phosphorus, respectively. The allowable pollutant TMDL load was then calculated by applying the AllForX threshold where VSCI = 60 (AllForX TSS = 5.85, AllForX TP = 3.36) to the all-forest simulated pollutant load of the TMDL study watershed, as summarized in (**Table 5-1** and **Table 5-2**).

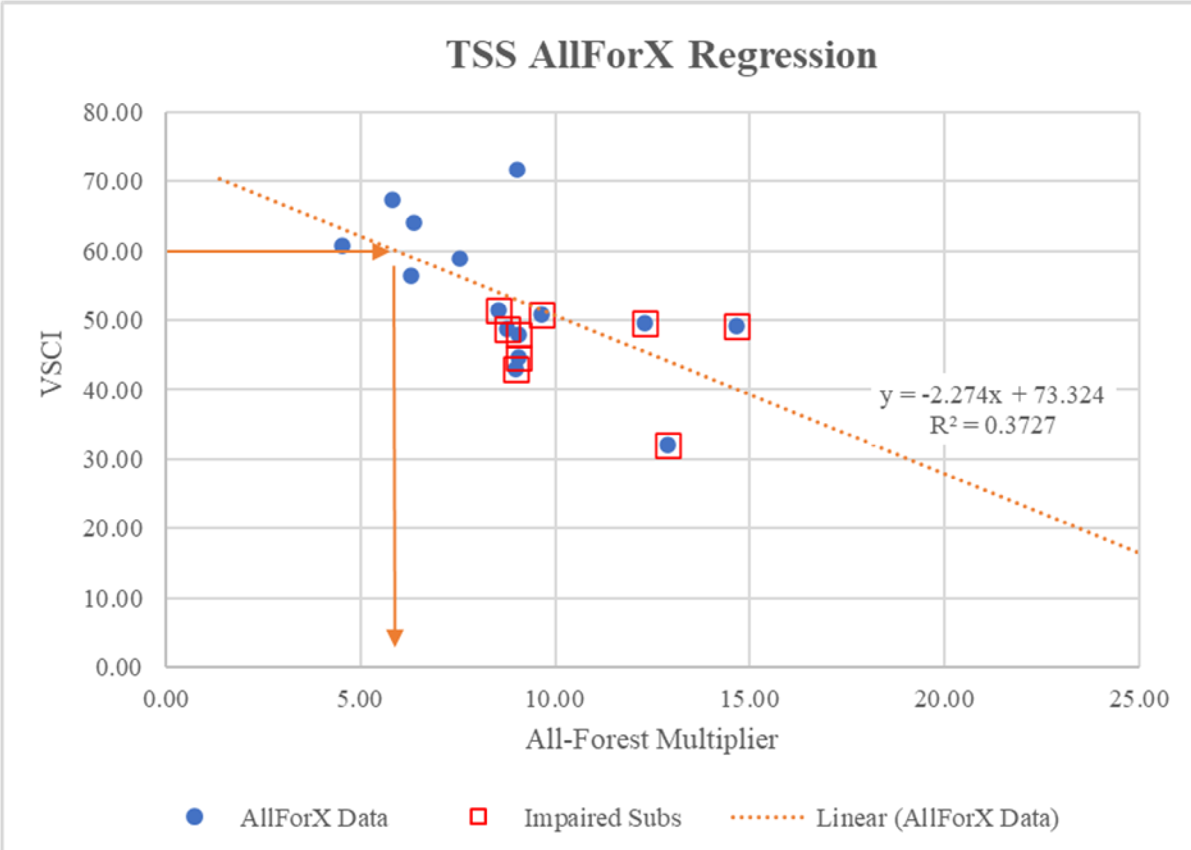


Figure 5-1. Regression between stream condition index and all-forest multiplier for sediment in the James River tributaries TMDL using VSCI scores, resulting in an AllForX target value of 5.85.

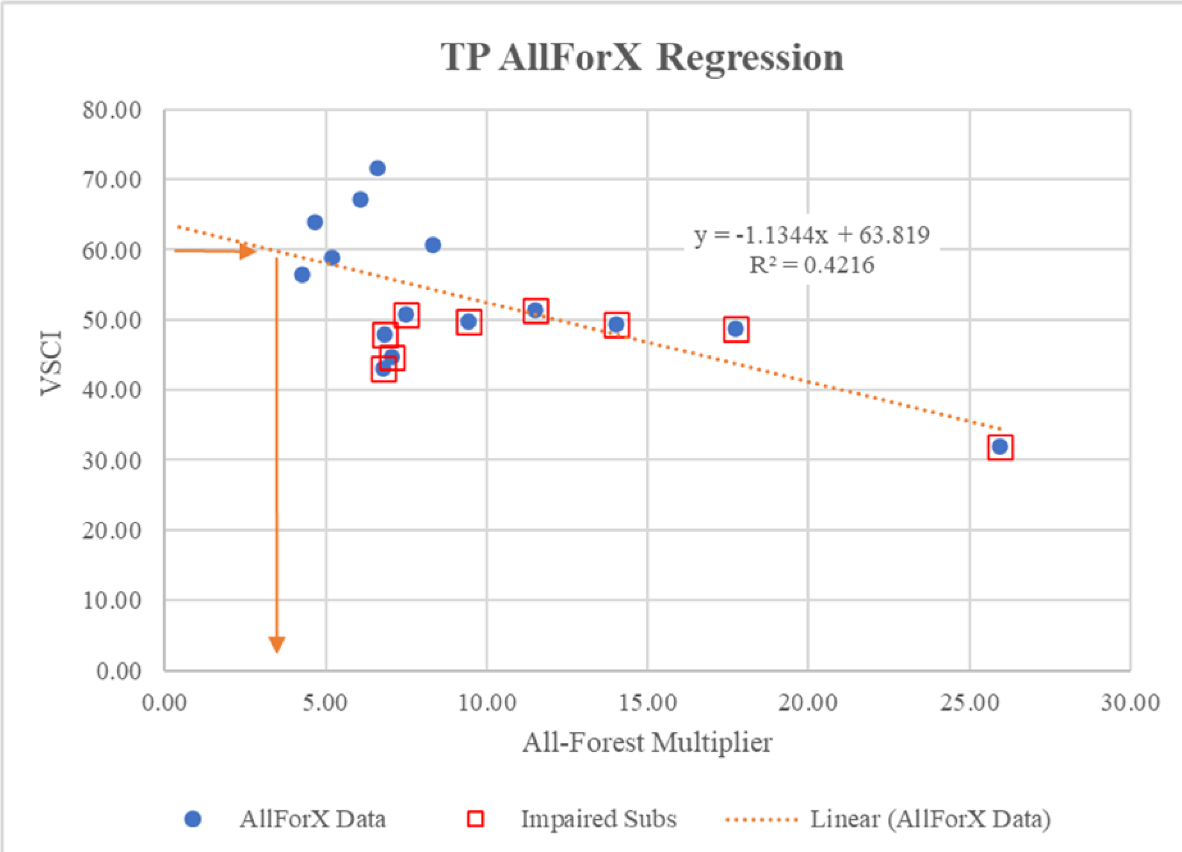


Figure 5-2 Regression between stream condition index and all-forest multiplier for phosphorus in the James River tributaries TMDL using VSCI scores, resulting in an AllForX target value of 3.36.

Table 5-1. Target sediment loading rates as determined by the AllForX regression multiplier of 5.85.

Impaired Stream	**TSS AllForest** (lb/yr)	**TSS Target** (lb/yr)
Bailey Creek	204,200	1,200,000
Nuttree Branch	90,930	533,000
Oldtown Creek	106,700	625,000
Proctors Creek	174,200	1,020,000
Rohoic Creek	110,700	649,000
Swift Creek	1,875,000	11,000,000

Table 5-2. Target phosphorus loading rates as determined by the AllForX regression multiplier of 3.36

Impaired Stream	**TP AllForest** (lb/yr)	**TP Target** (lb/yr)
Oldtown Creek	269	904
Rohoic Creek	194	654
Swift Creek	2,594	8,730

6.0 TMDL ALLOCATIONS

Total Maximum Daily Loads (TMDLs) are determined as the maximum allowable load of a pollutant. Part of developing a TMDL is allocating this load among the various sources of the pollutant of concern (POC). Each TMDL is comprised of three components, as summed up in this equation:

$$TMDL = \sum WLA + \sum LA + MOS$$

where ΣWLA is the sum of the wasteload allocations (permitted sources),
ΣLA is the sum of the load allocations (non-point sources), and
MOS is a margin of safety.

The wasteload allocation (WLA) is calculated as the sum of all the permitted sources of the POC within the watershed as if they were discharging at their permitted allowable rate. A description of the permitted sources and their permitted loads are included in **Section 4.3.2**. The margin of safety (MOS) is determined based on the characteristics of the watershed and the model used to develop the TMDL loads (see **Section 6.1**). The overall load allocation (LA) is then calculated by subtracting the total WLA and MOS from the TMDL. Various allocation scenarios are typically developed to show different breakdowns of how this LA can be divided among the various non-point and natural background sources of the POC, stakeholder input is used to determine the most favorable allocation scenario for a particular watershed.

To develop the annual existing loads and target loads using the AllForX methodology, a 20-year period was simulated (2001 through 2021) with an additional buffer period of nine months at the beginning of the run to serve as a 'warm-up' period for the model to equilibrate and minimize the impact of uncertain initial conditions. Using this extended modeling period allows the results to account for both annual and seasonal variations in hydrology and sediment/phosphorus loading.

6.1. Margin of Safety

To account for uncertainties inherent in model outputs, a margin of safety (MOS) is incorporated into the TMDL development process. The MOS can be implicit, explicit, or a combination of the two. An implicit MOS involves incorporating conservative assumptions into the modeling process to ensure that the final TMDL is protective of water quality considering the unavoidable uncertainty in the modeling process. A MOS can also be incorporated explicitly into the TMDL development by setting aside a portion of the TMDL.

This TMDL includes both implicit and explicit MOSs. An example of implicit MOS assumptions incorporated into this TMDL are the inclusion of permitted loads at their maximum permitted rates, even when data shows that they are consistently discharging well below that threshold. An explicit MOS of 10% is also included in the sediment and phosphorus TMDLs.

6.2. Future Growth

An allocation of 2% of the total load is specifically set aside for future growth within this TMDL. This leaves flexibility in the plan for future permitted loads to be added within the watersheds, as the development of a TMDL looks at a snapshot in time of a dynamic system within the watershed and is not meant to prevent future economic growth.

6.3. TMDL Calculations

Sediment was determined in the stressor analysis (**8.0Appendix E**) as a primary cause of the benthic impairments in each of the impaired watersheds. Phosphorus was also determined to be a primary cause of the impairment in Oldtown Creek, Rohoic Creek, and Swift Creek. TMDLs were developed for sediment in each impaired watershed, and an additional TMDL for phosphorus was developed for Oldtown, Rohoic, and Swift.

6.3.1. Annual Average Loads

Total loads to downstream subwatersheds were summed from the loads of each contributing upstream subwatershed. The final sediment and phosphorus average annual loads allocated in the TMDL are presented in **Table 6-1** through **Table 6-6** and **Table 6-7** through **Table 6-9**, respectively. GWLF output data, being in monthly increments, is most logically presented as annual aggregates. Any apparent differences in calculated values are due to rounding. Model results were rounded to four significant figures, and calculated totals of those results were rounded to three significant figures to reflect the accuracy of model inputs and the intended accuracy of the model results.

Table 6-1. Annual average sediment TMDL components for Bailey Creek.*

Impairment	Allocated Point Sources (WLA) (lb/yr TSS)	Allocated Nonpoint Sources (LA) (lb/yr TSS)	Margin of Safety (MOS) (lb/yr TSS)	Total Maximum Daily Load (TMDL) (lb/yr TSS)	Existing Load (lb/yr TSS)	Overall Reduction (%)
Bailey Creek (VAP-G03R_BLY02A08, VAP-G03R_BLY01A98)	**424,000**	**656,400**	**119,600**	**1,200,000**	2,130,000	43.7%
VA0059161	*5,245*					
Concrete Facility Permits	*1,945*					
ISW Permits	*43,060*					
MS4 Permits	*316,500*					
Construction Permits	*33,500*					
Future Growth (2% of TMDL)	*23,930*					

Table 6-2. Annual average sediment TMDL components for Nuttree Branch. *

Impairment	Allocated Point Sources (WLA) (lb/yr TSS)	Allocated Nonpoint Sources (LA) (lb/yr TSS)	Margin of Safety (MOS) (lb/yr TSS)	Total Maximum Daily Load (TMDL) (lb/yr TSS)	Existing Load (lb/yr TSS)	Overall Reduction (%)
Nuttree Branch (VAP-J17R_NUT01A06)	**303,000**	**177,000**	**53,280**	**532,000**	861,000	38.2%
NMMM Permits	*45,700*					
Concrete Facility Permits	*326*					
ISW Permits	*8,888*					
MS4 Permits	*107,300*					
Construction Permits	*129,600*					
Future Growth (2% of TMDL)	*10,700*					

* Any apparent differences in calculated values are due to rounding. Model results were rounded to 4 significant figures and calculated totals of those results were rounded to 3 significant figures.

Table 6-3. Annual average sediment TMDL components for Oldtown Creek.*

Impairment	Allocated Point Sources (WLA) (lb/yr TSS)	Allocated Nonpoint Sources (LA) (lb/yr TSS)	Margin of Safety (MOS) (lb/yr TSS)	Total Maximum Daily Load (TMDL) (lb/yr TSS)	Existing Load (lb/yr TSS)	Overall Reduction (%)
Oldtown Creek (VAP-J15R_OTC01A00 VAP-J15R_OTC01B08)	**253,000**	**308,500**	**62,520**	**624,000**	1,590,000	60.8%
MS4 Permits	*159,700*					
Construction Permits	*80,810*					
Future Growth (2% of TMDL)	*12,500*					

Table 6-4. Annual average sediment TMDL components for Proctors Creek. *

Impairment	Allocated Point Sources (WLA) (lb/yr TSS)	Allocated Nonpoint Sources (LA) (lb/yr TSS)	Margin of Safety (MOS) (lb/yr TSS)	Total Maximum Daily Load (TMDL) (lb/yr TSS)	Existing Load (lb/yr TSS)	Overall Reduction (%)
Proctors Creek (VAP-G01R_PCT01A06)	**573,000**	**345,000**	**102,100**	**1,020,000**	3,290,000	69.0%
Concrete Facility Permits	*1,188*					
ISW Permits	*64,760*					
Vehicle Wash Permits	*55*					
MS4 Permits	*112,900*					
Construction Permits	*373,600*					
Future Growth (2% of TMDL)	*20,420*					

* Any apparent differences in calculated values are due to rounding. Model results were rounded to 4 significant figures and calculated totals of those results were rounded to 3 significant figures.

Table 6-5. Annual average sediment TMDL components for Rohoic Creek.*

Impairment	Allocated Point Sources (WLA) (lb/yr TSS)	Allocated Nonpoint Sources (LA) (lb/yr TSS)	Margin of Safety (MOS) (lb/yr TSS)	Total Maximum Daily Load (TMDL) (lb/yr TSS)	Existing Load (lb/yr TSS)	Overall Reduction (%)
Rohoic Creek (VAP-J15R_RHC01A06)	**377,000**	**206,000**	**64,870**	**648,000**	1,360,000	52.4%
NMMM Permits	*127,900*					
Concrete Facility Permits	*4,586*					
ISW Permits	*57,800*					
MS4 Permits	*43,510*					
Construction Permits	*130,500*					
Future Growth (2% of TMDL)	*12,970*					

Table 6-6. Annual average sediment TMDL components for Swift Creek (Nuttree Branch represented within the LA).*

Impairment	Allocated Permitted Point Sources (WLA) (lb/yr TSS)	Allocated Nonpoint Sources (LA) (lb/yr TSS)	Margin of Safety (MOS) (lb/yr TSS)	Total Maximum Daily Load (TMDL) (lb/yr TSS)	Existing Load (lb/yr TSS)	Overall Reduction (%)
Swift Creek (VAP-J17R_SFT01B98, VAP-J17R_SFT02A00)	**2,870,000**	**7,030,000**	**1,099,000**	**11,000,000**	20,100,000	45.3%
VA0006254	*91,380*					
VA0023426	*8,910*					
NMMM Permits	*137,100*					
ISW Permits	*101,700*					
Domestic Sewage Permits	*366*					
MS4 Permits	*993,200*					
Construction Permits	*1,314,000*					
Future Growth (2% of TMDL)	*219,800*					

* Any apparent differences in calculated values are due to rounding. Model results were rounded to 4 significant figures and calculated totals of those results were rounded to 3 significant figures.

Table 6-7. Annual average phosphorus TMDL components for Oldtown Creek.*

Impairment	Allocated Point Sources (WLA) (lb/yr TP)	Allocated Nonpoint Sources (LA) (lb/yr TP)	Margin of Safety (MOS) (lb/yr TP)	Total Maximum Daily Load (TMDL) (lb/yr TP)	Existing Load (lb/yr TP)	Overall Reduction (%)
Oldtown Creek (VAP-J15R_OTC01A00, VAP-J15R_OTC01B08)	**404**	**409.5**	**90.5**	**904**	2,720	66.8%
MS4 Permits	*327.7*					
Construction Permits	*58.2*					
Future Growth (2% of TMDL)	*18.1*					

Table 6-8. Annual average phosphorus TMDL components for Rohoic Creek.*

Impairment	Allocated Point Sources (WLA) (lb/yr TP)	Allocated Nonpoint Sources (LA) (lb/yr TP)	Margin of Safety (MOS) (lb/yr TP)	Total Maximum Daily Load (TMDL) (lb/yr TP)	Existing Load (lb/yr TP)	Overall Reduction (%)
Rohoic Creek (VAP-J15R_RHC01A06)	**426**	**163**	**65**	**654**	2,330	71.0%
NMMM Permits	*85.3*					
Concrete Facility Permits	*31.0*					
ISW Permits	*197.0*					
MS4 Permits	*6.3*					
Construction Permits	*94.0*					
Future Growth (2% of TMDL)	*13.1*					

* Any apparent differences in calculated values are due to rounding. Model results were rounded to 4 significant figures and calculated totals of those results were rounded to 3 significant figures.

Table 6-9. Annual average phosphorus TMDL components for Swift Creek.*

Impairment	Allocated Point Sources (WLA) (lb/yr TP)	Allocated Nonpoint Sources (LA) (lb/yr TP)	Margin of Safety (MOS) (lb/yr TP)	Total Maximum Daily Load (TMDL) (lb/yr TP)	Existing Load (lb/yr TP)	Overall Reduction (%)
Swift Creek (VAP-J17R_SFT01B98, VAP-J17R_SFT02A00)	**3,145**	**4,700**	**873**	**8,730**	20,200	56.8%
VA0006254	*9.6*					
VA0023426	*46.0*					
NMMM Permits	*121.8*					
ISW Permits	*377.1*					
Domestic Sewage Permits	*17.2*					
MS4 Permits	*1,359*					
Construction Permits	*1,040*					
Future Growth (2% of TMDL)	*174.6*					

6.3.2. Maximum Daily Loads

In 1991, the USEPA released a support document that included guidance for developing maximum daily loads (MDLs) for TMDLs (USEPA, 1991). A methodology detailed therein was used to determine the MDLs for the watersheds. The long-term average (LTA) daily loads, derived by dividing the average annual loads in **Table 6-1** through **Table 6-9** by 365.24, are converted to MDLs using the following equation:

$$MDL = LTA * \exp\left(Z_p\sigma_y - 0.5\sigma_y^2\right)$$

where Z_p = pth percentage point of the normal standard deviation, and
σ_y = sqrt(ln(CV^2+1)), with CV = coefficient of variation of the data.

The variable Z_p was set to 1.645 for this TMDL development, representing the 95th percentile. The CV values and final calculated multipliers to convert LTA to MDL values are summarized in **Table 6-10**.

* Any apparent differences in calculated values are due to rounding. Model results were rounded to 4 significant figures and calculated totals of those results were rounded to 3 significant figures.

Table 6-10. "LTA to MDL multiplier" components for TSS and TP TMDLs.

Pollutant	Watershed	CV of Average Annual Loads	"LTA to MDL Multiplier"
Sediment	Bailey Creek	0.23	1.42
	Nuttree Branch	0.26	1.47
	Oldtown Creek	0.23	1.42
	Proctors Creek	0.24	1.43
	Rohoic Creek	0.23	1.42
	Swift Creek	0.23	1.42
Phosphorus	Oldtown Creek	0.29	1.54
	Rohoic Creek	0.31	1.57
	Swift Creek	0.28	1.52

The daily WLA was estimated as the annual WLA divided by 365.24. The daily MOS was estimated as 10% of the MDL. Finally, the daily LA was estimated as the MDL minus the daily MOS minus the daily WLA. These results are shown in **Table 6-11** through **Table 6-16** and **Table 6-17** through **Table 6-19** for sediment and phosphorus, respectively.

Table 6-11. Maximum 'daily' sediment loads and components for Bailey Creek.*

Impairment	Allocated Point Sources (WLA) (lb/day TSS)	Allocated Nonpoint Sources (LA) (lb/day TSS)	Margin of Safety (MOS) (lb/day TSS)	Maximum Daily Load (MDL) (lb/day TSS)
Bailey Creek (VAP-G03R_BLY02A08, VAP-G03R_BLY01A98)	**1,161**	**3,038**	**467**	**4,665**
VA0059161	*14.4*			
Concrete Facility Permits	*5.3*			
ISW Permits	*117.9*			
MS4 Permits	*866.6*			
Construction Permits	*91.7*			
Future Growth (2% of TMDL)	*65.5*			

* Any apparent differences in calculated values are due to rounding. Model results were rounded to 4 significant figures and calculated totals of those results were rounded to 3 significant figures.

Table 6-12. Maximum 'daily' sediment loads and components for Nuttree Branch.*

Impairment	Allocated Point Sources (WLA) (lb/day TSS)	Allocated Nonpoint Sources (LA) (lb/day TSS)	Margin of Safety (MOS) (lb/day TSS)	Maximum Daily Load (MDL) (lb/day TSS)
Nuttree Branch (VAP-J17R_NUT01A06)	**830**	**1,097**	**214**	**2,141**
NMMM Permits	*125.1*			
Concrete Facility Permits	*0.9*			
ISW Permits	*24.3*			
MS4 Permits	*293.8*			
Construction Permits	*355*			
Future Growth (2% of TMDL)	*29*			

Table 6-13. Maximum 'daily' sediment loads and components for Oldtown Creek.*

Impairment	Allocated Point Sources (WLA) (lb/day TSS)	Allocated Nonpoint Sources (LA) (lb/day TSS)	Margin of Safety (MOS) (lb/day TSS)	Maximum Daily Load (MDL) (lb/day TSS)
Oldtown Creek (VAP-J15R_OTC01A00 VAP-J15R_OTC01B08)	**693**	**1,491**	**243**	**2,426**
MS4 Permits	*437.2*			
Construction Permits	*221.3*			
Future Growth (2% of TMDL)	*34.2*			

Table 6-14. Maximum 'daily' sediment loads and components for Proctors Creek.*

Impairment	Allocated Point Sources (WLA) (lb/day TSS)	Allocated Nonpoint Sources (LA) (lb/day TSS)	Margin of Safety (MOS) (lb/day TSS)	Maximum Daily Load (MDL) (lb/day TSS)
Proctors Creek (VAP-G01R_PCT01A06)	**1,569**	**2,025**	**399**	**3,994**
Concrete Facility Permits	*3.3*			
ISW Permits	*177.3*			
Vehicle Wash Permits	*0.2*			
MS4 Permits	*309.1*			
Construction Permits	*1,023*			
Future Growth (2% of TMDL)	*56*			

* Any apparent differences in calculated values are due to rounding. Model results were rounded to 4 significant figures and calculated totals of those results were rounded to 3 significant figures.

Table 6-15. Maximum 'daily' sediment loads and components for Rohoic Creek.*

Impairment	Allocated Point Sources (WLA) (lb/day TSS)	Allocated Nonpoint Sources (LA) (lb/day TSS)	Margin of Safety (MOS) (lb/day TSS)	Maximum Daily Load (MDL) (lb/day TSS)
Rohoic Creek (VAP-J15R_RHC01A06)	**1,032**	**1,235**	**252**	**2,519**
NMMM Permits	*350.2*			
Concrete Facility Permits	*12.6*			
ISW Permits	*158.3*			
MS4 Permits	*119.1*			
Construction Permits	*357*			
Future Growth (2% of TMDL)	*36*			

Table 6-16. Maximum 'daily' sediment loads and components for Swift Creek. *

Impairment	Allocated Point Sources (WLA) (lb/day TSS)	Allocated Nonpoint Sources (LA) (lb/day TSS)	Margin of Safety (MOS) (lb/day TSS)	Maximum Daily Load (MDL) (lb/day TSS)
Swift Creek (VAP-J17R_SFT01B98, VAP-J17R_SFT02A00)	**7,858**	**30,632**	**4,277**	**42,766**
VA0006254	*250.2*			
VA0023426	*24.4*			
NMMM Permits	*375.4*			
ISW Permits	*278.4*			
Domestic Sewage Permits	*1.0*			
MS4 Permits	*2,719.3*			
Construction Permits	*3,598*			
Future Growth (2% of TMDL)	*602*			

* Any apparent differences in calculated values are due to rounding. Model results were rounded to 4 significant figures and calculated totals of those results were rounded to 3 significant figures.

Table 6-17. Maximum 'daily' phosphorus loads and components for Oldtown Creek.[*]

Impairment	Allocated Point Sources (WLA) (lb/day TP)	Allocated Nonpoint Sources (LA) (lb/day TP)	Margin of Safety (MOS) (lb/day TP)	Maximum Daily Load (MDL) (lb/day TP)
Oldtown Creek (VAP-J15R_OTC01A00 VAP-J15R_OTC01B08)	**1.1**	**2.3**	**0.4**	**3.8**
MS4 Permits	*0.9*			
Construction Permits	*0.2*			
Future Growth (2% of TMDL)	*0.05*			

Table 6-18. Maximum 'daily' phosphorus loads and components for Rohoic Creek. [*]

Impairment	Allocated Point Sources (WLA) (lb/day TP)	Allocated Nonpoint Sources (LA) (lb/day TP)	Margin of Safety (MOS) (lb/day TP)	Maximum Daily Load (MDL) (lb/day TP)
Rohoic Creek (VAP-J15R_RHC01A06)	**1.2**	**1.4**	**0.3**	**2.8**
NMMM Permits	*0.2*			
Concrete Facility Permits	*0.1*			
ISW Permits	*0.5*			
MS4 Permits	*0.0*			
Construction Permits	*0.3*			
Future Growth (2% of TMDL)	*0.04*			

Table 6-19. Maximum 'daily' phosphorus loads and components for Swift Creek.[*]

Impairment	Allocated Point Sources (WLA) (lb/day TP)	Allocated Nonpoint Sources (LA) (lb/day TP)	Margin of Safety (MOS) (lb/day TP)	Maximum Daily Load (MDL) (lb/day TP)
Swift Creek (VAP-J17R_SFT01B98, VAP-J17R_SFT02A00)	**8.6**	**24.0**	**3.6**	**36.3**
VA0006254	*0.03*			
VA0023426	*0.1*			
NMMM Permits	*0.3*			
ISW Permits	*1.0*			
Domestic Sewage Permits	*0.05*			
MS4 Permits	*3.7*			
Construction Permits	*2.8*			
Future Growth (2% of TMDL)	*0.5*			

[*] Any apparent differences in calculated values are due to rounding. Model results were rounded to 4 significant figures and calculated totals of those results were rounded to 3 significant figures.

6.4. Allocation Scenarios

Multiple allocation scenarios were run to determine possible options for reducing the sediment and phosphorus loads to the recommended TMDL loads. Feedback from the TAC members guided the selection of the preferred allocation scenarios for each TMDL watershed. TAC members indicated that an even percentage-based reduction across all sediment and phosphorus sources was preferred for all study watersheds. The various sediment allocation scenarios are presented in **Table 6-20** through **Table 6-25,** and the various phosphorus allocation scenarios are presented in **Table 6-26** through **Table 6-28.** The selected allocation scenario for each watershed is Scenario 1.

Due to the level of reductions needed in the Rohoic Creek watershed, discussions between VADEQ and permittees resulted in the decision to reduce the allocated TSS and TP loading rates calculated for ISW permits in the Rohoic Creek watershed by 50%. Based on collected data, the majority of the ISW permits in the Rohoic Creek watershed are already discharging below the typical permitted rate.

Any apparent differences in calculated values are due to rounding. Model results were rounded to four significant figures, and calculated totals of those results were rounded to three significant figures.

Table 6-20. Allocation scenarios for Bailey Creek sediment loads.

Bailey Creek Watershed		Scenario 1 (preferred)		Scenario 2		Scenario 3	
Source	**Existing TSS (lb/yr)**	**Reduction (%)**	**Allocation TSS (lb/yr)**	**Reduction (%)**	**Allocation TSS (lb/yr)**	**Reduction (%)**	**Allocation TSS (lb/yr)**
Cropland	26,620	54.5	12,110	40.8	15,760	77.1	6,096
Hay	6,796	54.5	3,092	40.8	4,024	77.1	1,556
Pasture	6,592	54.5	2,999	40.8	3,902	77.1	1,510
Forest	52,790	-	52,790	-	52,790	-	52,790
Trees	65,790	-	65,790	-	65,790	-	65,790
Shrub	15,240	-	15,240	-	15,240	-	15,240
Harvested	38,880	54.5	17,690	40.8	23,020	77.1	8,904
Wetland	56,730	-	56,730	-	56,730	-	56,730
Barren	216,700	54.5	98,610	60.0	86,690	45.5	118,100
Turfgrass	78,630	54.5	35,780	60.0	31,450	45.5	42,850
Developed Pervious	10,940	54.5	4,975	60.0	4,374	45.5	5,960
Developed Impervious	219,200	54.5	99,720	60.0	87,660	45.5	119,400
Streambank Erosion	410,600	54.5	186,800	40.8	243,100	77.1	94,020
VA0059161	5,245	-	5,245	-	5,245	-	5,245
Concrete Facility Permits	1,945	-	1,945	-	1,945	-	1,945
ISW Permits	43,060	-	43,060	-	43,060	-	43,060
MS4	695,700	54.5	316,500	60.0	278,300	45.5	379,100
Construction Permits	33,500	-	33,500	-	33,500	-	33,500
Future Growth (2%)	23,930	-	23,930	-	23,930	-	23,930
MOS (10%)	119,600	-	119,600	-	119,600	-	119,600
TOTAL	**2,130,000**	**43.7**	**1,200,000**	**43.7**	**1,200,000**	**43.7**	**1,200,000**

Table 6-21. Allocation scenarios for Nuttree Branch sediment loads.

Nuttree Branch Watershed		Scenario 1 (preferred)		Scenario 2		Scenario 3	
Source	**Existing TSS (lb/yr)**	**Reduction (%)**	**Allocation TSS (lb/yr)**	**Reduction (%)**	**Allocation TSS (lb/yr)**	**Reduction (%)**	**Allocation TSS (lb/yr)**
Cropland	-	-	-	-	-	-	-
Hay	-	-	-	-	-	-	-
Pasture	-	-	-	-	-	-	-
Forest	16,410	-	16,410	-	16,410	-	16,410
Trees	32,270	-	32,270	-	32,270	-	32,270
Shrub	10,830	-	10,830	-	10,830	-	10,830
Harvested	-	-	-	-	-	-	-
Wetland	4,520	-	4,520	-	4,520	-	4,520
Barren	-	-	-	-	-	-	-
Turfgrass	44,640	59.9	17,900	68.4	14,110	62.7	16,650
Developed Pervious	3,547	59.9	1,422	68.4	1,121	62.7	1,323
Developed Impervious	164,700	59.9	66,040	68.4	52,040	62.7	61,430
Streambank Erosion	68,130	59.9	27,320	-	68,130	40.0	40,880
NMMM Permits	45,690	-	45,690	-	45,690	-	45,690
Concrete Facility Permits	326	-	326	-	326	-	326
ISW Permits	8,888	-	8,888	-	8,888	-	8,888
MS4	267,500	59.9	107,300	68.4	84,550	62.7	99,800
Construction Permits	129,600	-	129,600	-	129,600	-	129,600
Future Growth (2%)	10,660	-	10,660	-	10,660	-	10,660
MOS (10%)	53,280	-	53,280	-	53,280	-	53,280
TOTAL	**861,000**	**38.2**	**532,000**	**38.2**	**532,000**	**38.1**	**533,000**

Table 6-22. Allocation scenarios for Oldtown Creek sediment loads.

Oldtown Creek Watershed		**Scenario 1 (preferred)**		**Scenario 2**		**Scenario 3**	
Source	**Existing TSS (lb/yr)**	**Reduction (%)**	**Allocation TSS (lb/yr)**	**Reduction (%)**	**Allocation TSS (lb/yr)**	**Reduction (%)**	**Allocation TSS (lb/yr)**
Cropland	159,200	72.3	44,090	40.0	95,510	81.5	29,450
Hay	6,105	72.3	1,691	40.0	3,663	81.5	1,129
Pasture	1,690	72.3	468	40.0	1,014	81.5	313
Forest	37,250	-	37,250	-	37,250	-	37,250
Trees	19,720	-	19,720	-	19,720	-	19,720
Shrub	5,024	-	5,024	-	5,024	-	5,024
Harvested	24,670	72.3	6,834	40.0	14,800	81.5	4,564
Wetland	37,550	-	37,550	-	37,550	-	37,550
Barren	11,290	72.3	3,127	77.7	2,517	81.5	2,088
Turfgrass	31,170	72.3	8,635	77.7	6,952	81.5	5,767
Developed Pervious	3,218	72.3	891	77.7	718	81.5	595
Developed Impervious	179,100	72.3	49,620	77.7	39,940	81.5	33,140
Streambank Erosion	337,800	72.3	93,580	77.7	75,340	45.0	185,800
MS4	576,600	72.3	159,700	77.7	128,600	81.5	106,700
Construction Permits	80,810	-	80,810	-	80,810	-	80,810
Future Growth (2%)	12,500	-	12,500	-	12,500	-	12,500
MOS (10%)	62,520	-	62,520	-	62,520	-	62,520
TOTAL	**1,590,000**	**60.8**	**624,000**	**60.8**	**624,000**	**60.7**	**625,000**

Table 6-23. Allocation scenarios for Proctors Creek sediment loads.

Proctors Creek Watershed		Scenario 1 (preferred)		Scenario 2		Scenario 3	
Source	**Existing TSS (lb/yr)**	**Reduction (%)**	**Allocation TSS (lb/yr)**	**Reduction (%)**	**Allocation TSS (lb/yr)**	**Reduction (%)**	**Allocation TSS (lb/yr)**
Cropland	8,824	88.4	1,024	-	8,824	50.0	4,412
Hay	2,111	88.4	245	-	2,111	50.0	1,055
Pasture	3,043	88.4	353	-	3,043	50.0	1,521
Forest	36,460	-	36,460	-	36,460	-	36,460
Trees	45,160	-	45,160	-	45,160	-	45,160
Shrub	8,735	-	8,735	-	8,735	-	8,735
Harvested	-	-	-	-	-	-	-
Wetland	68,880	-	68,880	-	68,880	-	68,880
Barren	199,600	88.4	23,160	88.9	22,160	88.6	22,760
Turfgrass	58,680	88.4	6,807	88.9	6,514	88.6	6,690
Developed Pervious	4,151	88.4	482	88.9	461	88.6	473
Developed Impervious	361,100	88.4	41,880	88.9	40,080	88.6	41,160
Streambank Erosion	955,900	88.4	110,900	88.9	106,100	88.6	109,000
Concrete Facility Permits	1,188	-	1,188	-	1,188	-	1,188
Vehicle Wash Permits	55	-	55	-	55	-	55
ISW Permits	64,760	-	64,760	-	64,760	-	64,760
MS4	973,100	88.4	112,900	88.9	108,000	88.6	110,900
Construction Permits	373,600	-	373,600	-	373,600	-	373,600
Future Growth (2%)	20,420	-	20,420	-	20,420	-	20,420
MOS (10%)	102,100	-	102,100	-	102,100	-	102,100
TOTAL	**3,290,000**	**69.0**	**1,020,000**	**69.0**	**1,020,000**	**69.0**	**1,020,000**

Table 6-24. Allocation scenarios for Rohoic Creek sediment loads.

Rohoic Creek Watershed		Scenario 1 (preferred)		Scenario 2		Scenario 3	
Source	**Existing TSS (lb/yr)**	**Reduction (%)**	**Allocation TSS (lb/yr)**	**Reduction (%)**	**Allocation TSS (lb/yr)**	**Reduction (%)**	**Allocation TSS (lb/yr)**
Cropland	52,140	79.8	10,530	77.3	11,840	80.0	10,430
Hay	16,410	79.8	3,314	77.3	3,724	80.0	3,281
Pasture	4,153	79.8	839	77.3	943	80.0	831
Forest	22,270	-	22,270	-	22,270	-	22,270
Trees	31,910	-	31,910	-	31,910	-	31,910
Shrub	9,145	-	9,145	-	9,145	-	9,145
Harvested	4,129	79.8	834	77.3	937	80.0	826
Wetland	21,340	-	21,340	-	21,340	-	21,340
Barren	-	-	-	-	-	-	-
Turfgrass	68,250	79.8	13,790	80.0	13,650	79.6	13,920
Developed Pervious	9,356	79.8	1,890	80.0	1,871	79.6	1,909
Developed Impervious	198,800	79.8	40,160	80.0	39,760	79.6	40,560
Streambank Erosion	247,200	79.8	49,930	80.0	49,430	80.0	49,430
NMMM Permits	127,900	-	127,900	-	127,900	-	127,900
Concrete Facility Permits	4,586	-	4,586	-	4,586	-	4,586
ISW Permits	115,600	50.0	57,800	50.0	57,800	50.0	57,800
MS4	215,400	79.8	43,510	80.0	43,080	79.6	43,950
Construction Permits	130,500	-	130,500	-	130,500	-	130,500
Future Growth (2%)	12,970	-	12,970	-	12,970	-	12,970
MOS (10%)	64,870	-	64,870	-	64,870	-	64,870
TOTAL	**1,360,000**	**52.4**	**648,000**	**52.3**	**649,000**	**52.4**	**648,000**

Table 6-25. Allocation scenarios for Swift Creek sediment loads.

Swift Creek Watershed		Scenario 1 (preferred)		Scenario 2		Scenario 3		Scenario 4	
Source	**Existing TSS (lb/yr)**	**Reduction (%)**	**Allocation TSS (lb/yr)**	**Reduction (%)**	**Allocation TSS (lb/yr)**	**Reduction (%)**	**Allocation TSS (lb/yr)**	**Reduction (%)**	**Allocation TSS (lb/yr)**
Cropland	119,500	57.0	51,390	39.6	72,180	83.2	20,080	-	119,500
Hay	26,210	57.0	11,270	39.6	15,830	83.2	4,404	-	26,210
Pasture	144,700	57.0	62,210	39.6	87,380	83.2	24,310	-	144,700
Forest	305,700	-	305,700	-	305,700	-	305,700	-	305,700
Trees	142,300	-	142,300	-	142,300	-	142,300	-	142,300
Shrub	19,860	-	19,860	-	19,860	-	19,860	-	19,860
Harvested	70,200	57.0	30,190	39.6	42,400	83.2	11,790	-	70,200
Wetland	134,300	-	134,300	-	134,300	-	134,300	-	134,300
Barren	668,000	57.0	287,200	39.6	403,500	83.2	112,200	58.4	277,900
Turfgrass	155,500	57.0	66,860	39.6	93,910	83.2	26,120	58.4	64,680
Developed Pervious	20,960	57.0	9,015	39.6	12,660	83.2	3,522	58.4	8,721
Developed Impervious	1,517,000	57.0	652,100	39.6	916,000	83.2	254,800	58.4	630,900
Streambank Erosion	10,970,000	57.0	4,717,000	65.0	3,839,000	45.0	6,033,000	58.4	4,563,000
VA0006254	91,380	-	91,380	-	91,380	-	91,380	-	91,380
VA0023426	8,910	-	8,910	-	8,910	-	8,910	-	8,910
NMMM Permits	137,072	-	137,072	-	137,072	-	137,072	-	137,072
Domestic Sewage Permits	366	-	366	-	366	-	366	-	366
ISW Permits	101,700	-	101,700	-	101,700	-	101,700	-	101,700
MS4	2,310,000	57.0	993,200	39.6	1,395,000	83.2	388,000	58.4	960,900
Construction Permits	1,314,000	-	1,314,000	-	1,314,000	-	1,314,000	-	1,314,000
Future Growth (2%)	219,800	-	219,800	-	219,800	-	219,800	-	219,800
Nuttree Branch TMDL Target	533,000	-	533,000	-	533,000	-	533,000	-	533,000
MOS (10%)	1,099,000	-	1,099,000	-	1,099,000	-	1,099,000	-	1,099,000
TOTAL	**20,100,000**	**45.3**	**11,000,000**	**45.3**	**11,000,000**	**45.3**	**11,000,000**	**45.3**	**11,000,000**

Table 6-26. Allocation scenarios for Oldtown Creek phosphorus loads.

Oldtown Creek Watershed		Scenario 1 (preferred)		Scenario 2		Scenario 3	
Source	**Existing TP (lb/yr)**	**Reduction (%)**	**Allocation TP (lb/yr)**	**Reduction (%)**	**Allocation TP (lb/yr)**	**Reduction (%)**	**Allocation TP (lb/yr)**
Cropland	102.4	76.7	23.9	50.0	51.2	78.7	21.8
Hay	84.8	76.7	19.8	50.0	42.4	78.7	18.1
Pasture	3.1	76.7	0.7	50.0	1.5	78.7	0.6
Forest	18.0	-	18.0	-	18.0	-	18.0
Trees	13.4	-	13.4	-	13.4	-	13.4
Shrub	0.9	-	0.9	-	0.9	-	0.9
Harvested	7.1	76.7	1.7	50.0	3.6	78.7	1.5
Wetland	4.1	-	4.1	-	4.1	-	4.1
Barren	1.3	76.7	0.3	79.2	0.3	78.7	0.3
Turfgrass	238.6	76.7	55.6	79.2	49.6	78.7	50.8
Developed Pervious	4.7	76.7	1.1	79.2	1.0	78.7	1.0
Developed Impervious	394.1	76.7	91.8	79.2	82.0	78.7	83.9
Streambank Erosion	118.2	76.7	27.6	79.2	24.6	40.0	71.0
Septic	0.9	76.7	0.2	79.2	0.2	78.7	0.2
Groundwater	150.9	-	150.9	-	150.9	-	150.9
MS4	1,406.0	76.7	327.7	79.2	292.5	78.7	299.6
Construction Permits	58.2	-	58.2	-	58.2	-	58.2
Future Growth (2%)	18.1	-	18.1	-	18.1	-	18.1
MOS (10%)	90.5	-	90.5	-	90.5	-	90.5
TOTAL	**2,720.0**	**66.8**	**904.0**	**66.8**	**903.0**	**66.8**	**903.0**

Table 6-27. Allocation scenarios for Rohoic Creek phosphorus loads. Scenario 2 does not meet target reductions. Scenario 2 total is highlighted in red as it does not meet the target water quality goal.

Rohoic Creek Watershed		Scenario 1 (preferred)		Scenario 2	
Source	Existing TP (lb/yr)	Reduction (%)	Allocation TP (lb/yr)	Reduction (%)	Allocation TP (lb/yr)
Cropland	31.3	98.8	0.4	100.0	-
Hay	113.1	98.8	1.4	100.0	-
Pasture	4.1	98.8	0.0	100.0	-
Forest	9.7	-	9.7	-	9.7
Trees	14.3	-	14.3	-	14.3
Shrub	1.5	-	1.5	-	1.5
Harvested	1.2	98.8	0.0	100.0	-
Wetland	2.6	-	2.6	-	2.6
Barren	-	-	-	-	-
Turfgrass	290.9	98.8	3.5	100.0	-
Developed Pervious	9.7	98.8	0.1	100.0	-
Developed Impervious	437.4	98.8	5.2	100.0	-
Streambank Erosion	86.5	98.8	1.0	100.0	-
Septic	0.9	98.8	0.0	100.0	-
Groundwater	122.3	-	122.3	-	122.3
NMMM Permits	85.3	-	85.3	-	85.3
Concrete Facility Permits	31.0	-	31.0	-	31.0
ISW Permits	394.1	50.0	197.0	-	394.1
MS4	523.4	98.8	6.3	100.0	-
Construction Permits	94.0	-	94.0	-	94.0
Future Growth (2%)	13.1	-	13.1	-	13.1
MOS (10%)	65.4	-	65.4	-	65.4
TOTAL	**2,330.0**	**71.9**	**654.0**	**64.2**	**833.0**

Table 6-28. Allocation scenarios for Swift Creek phosphorus loads (inclusive of Nuttree Branch).

Swift Creek Watershed		Scenario 1 (preferred)		Scenario 2		Scenario 3	
Source	**Existing TP (lb/yr)**	**Reduction (%)**	**Allocation TP (lb/yr)**	**Reduction (%)**	**Allocation TP (lb/yr)**	**Reduction (%)**	**Allocation TP (lb/yr)**
Cropland	70.9	73.2	19.0	25.0	53.2	82.2	12.6
Hay	362.6	73.2	97.2	25.0	271.9	82.2	64.5
Pasture	190.9	73.2	51.2	25.0	143.2	82.2	34.0
Forest	143.3	-	143.3	-	143.3	-	143.3
Trees	115.1	-	115.1	-	115.1	-	115.1
Shrub	2.5	-	2.5	-	2.5	-	2.5
Harvested	22.6	73.2	6.1	25.0	16.9	82.2	4.0
Wetland	7.9	-	7.9	-	7.9	-	7.9
Barren	43.7	73.2	11.7	75.3	10.8	82.2	7.8
Turfgrass	1,267.0	73.2	339.5	75.3	312.9	82.2	225.5
Developed Pervious	35.3	73.2	9.5	75.3	8.7	82.2	6.3
Developed Impervious	4,237.0	73.2	1,135.0	75.3	1,046.0	82.2	754.1
Streambank Erosion	4,383.0	73.2	1,175.0	75.3	1,083.0	50.0	2,191.0
Septic	17.4	73.2	4.7	75.3	4.3	82.2	3.1
Groundwater	1,588.0	-	1,588.0	-	1,588.0	-	1,588.0
VA0006254	9.6	-	9.6	-	9.6	-	9.6
VA0023426	46.0	-	46.0	-	46.0	-	46.0
NMMM Permits	121.8	-	121.8	-	121.8	-	121.8
Domestic Sewage Permits	17.2	-	17.2	-	17.2	-	17.2
ISW Permits	377.1	-	377.1	-	377.1	-	377.1
MS4	5,071.0	73.2	1,359.0	75.3	1,253.0	82.2	902.7
Construction Permits	1,040.0	-	1,040.0	-	1,040.0	-	1,040.0
Future Growth (2%)	174.6	-	174.6	-	174.6	-	174.6
MOS (10%)	873.0	-	873.0	-	873.0	-	873.0
TOTAL	**20,200.0**	**56.8**	**8,730.0**	**56.8**	**8,720.0**	**56.8**	**8,720.0**

7.0 TMDL IMPLEMENTATION AND REASONABLE ASSURANCE

7.1. Regulatory Framework

There is a regulatory framework in place to help enforce the development and attainment of TMDLs and their stated goals on both the federal and the state level in Virginia. On the federal level, section 303(d) of the Clean Water Act and current USEPA regulations, while not explicitly requiring the development of TMDL implementation plans as part of the TMDL process, do require reasonable assurance that the load and waste load allocations can and will be implemented. Federal regulations also require that all new or revised National Pollutant Discharge Elimination System (NPDES) permits must be consistent with the assumptions and requirements of any applicable TMDL WLA (40 CFR §122.44 (d)(1)(vii)(B)).

At the state level, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (WQMIRA) directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters" (Section 62.1-44.19.7). WQMIRA also establishes that the implementation plan shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments. After DEQ approves the TMDL study, staff will present the study to the State Water Control Board (SWCB) and request that the SWCB adopt TMDL WLAs as part of the Water Quality Management Planning Regulation (9 VAC 25-270), in accordance with §2.2-4006A.14 and §2.2-4006B of the Code of Virginia. DEQ's public participation procedures relating to TMDL development can be found in DEQ's Guidance Memo No.14-2016 (VADEQ, 2014).

VADEQ regulates stormwater discharges associated with industrial activities through its VPDES program and stormwater discharges from construction sites and MS4s through its VSMP program. All new or revised permits must be consistent with the assumptions and requirements of any applicable TMDL WLA.

7.2. Implementation Plans

Implementation plans set intermediate goals and describe actions (with associated costs) that can be taken to clean up impaired streams. Some of the actions that may be included in an implementation plan to address excess sediment and phosphorus include:

- Fence out cattle from streams and provide alternative water sources
- Implement conservation tillage practices on cropland
- Conduct stream bank restoration projects in areas where banks are actively eroding

- Leave a band of 35 – 100 ft along the stream natural so that it buffers or filters out sediment from farm or residential land (a riparian buffer)
- Expand street sweeping programs in urban areas
- Install and/or retrofit urban stormwater BMPs
- Reduce runoff by increasing green spaces and reducing hardened spaces (asphalt or concrete)

Overall, implementation of TMDLs works best with a targeted, staged approach, directing initial efforts where the biggest impacts can be made with the least effort so that money, time, and other resources are spent efficiently to maximize the benefit to water quality. Progress towards meeting water quality goals defined in the implementation plan will be assessed during implementation by the tracking of new BMP installations and continued water quality monitoring by VADEQ. Several BMPs have already been implemented in the watershed and were accounted for in the development of this TMDL (**Section 4.4**).

Implementation plans also identify potential sources of funding to help in the clean-up efforts. Funds are often available in the form of cost-share programs, which share the cost of improvements with the landowner. Potential sources of funding include USEPA Section 319 funding for Virginia's Nonpoint Source Management Program, the USDA's Conservation Reserve Enhancement Program (CREP) and its Environmental Quality Incentive Program (EQIP), the Virginia State Revolving Loan Program, and the Virginia Water Quality Improvement Fund. The Virginia Guidance Manual for Total Maximum Daily Load Implementation Plans (VADEQ, 2017) contains information on a variety of funding sources, as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts. Additional sources are also often available for specific projects and regions of the state. State agencies and other stakeholders may help identify funding sources to support the plan, but implementing the improvements is up to those that live in the watershed. Part of the purpose of developing a TMDL and implementation plan is to increase education and awareness of the water quality issues in the watershed and encourage residents and stakeholders to work together to improve the watershed.

7.3. Reasonable Assurance

The following activities provide reasonable assurance that these TMDLs will be implemented and water quality will be restored in the James River Tributaries watersheds.

- Regulatory frameworks – Existing federal and state regulations require that new and existing permits comply with the developed TMDLs. State law also requires that implementation plans be developed to meet TMDL goals.
- Funding sources – Numerous funding sources (listed above) are available to defray the cost of TMDL implementation.

- Public participation – Public participation in the TMDL process informs and mobilizes watershed residents and stakeholders to take the necessary actions to implement the TMDL.
- Continued monitoring – Water quality and aquatic life monitoring will continue in the TMDL watersheds and track progress towards the TMDL goals. VADEQ will continue monitoring benthic macroinvertebrates and habitat in accordance with its biological monitoring program stations throughout the watershed.
- MS4 permit local TMDL action plans – In addition to developing action plans to address Chesapeake Bay TMDL requirements, MS4 permit holders are required to develop and implement action plans for local TMDLs to reduce pollutant loadings to local streams in addition to the Chesapeake Bay watershed. These reductions will help to improve local water quality in the James River tributaries as well as in the Chesapeake Bay.
- Current implementation actions – Many voluntary and subsidized best management practices have already been installed in these watersheds. The Soil and Water Conservation Districts and NRCS are actively working in these areas to promote and implement additional practices that can reduce sediment and phosphorus loads.

8.0 PUBLIC PARTICIPATION

Public participation was solicited at every stage of the TMDL development in order to receive input from stakeholders and to apprise the stakeholders of the progress made. A series of three Technical Advisory Committee (TAC) meetings took place during model and allocation development. The TAC included representatives from Chesterfield County, Chesterfield County School Board, John Tyler Community College, VDOT, the James River Association, CE&H Heritage Civic League, Addison Evans Water Production and Lab Facility, Aleris, Ashland Special Ingredients G.P., Branscome Incorporated, Dominion Energy, International Paper, LaBella Associates, Martin Marietta Materials, Inc., and Troutman Pepper in representation of the VA Manufacturers Association. Due to the State of Emergency related to the COVID-19 pandemic at the time, the first public meeting and first two TAC meetings were held virtually. The virtual meetings were recorded and posted on the DEQ website for increased accessibility.

The first public meeting (46 attendees, January 26th, 2021) was held virtually. This meeting introduced attendees to DEQ's water quality planning process, the TMDL purpose and process, reviewed benthic monitoring data collected from the study watersheds, discussed the impairments, and reviewed the preliminary results of the stressor analysis. This meeting represented the beginning of a 30-day public comment period on the benthic stressor analysis report draft. Received comments and responses are documented in **Appendix D**.

The first TAC meeting (24 attendees, February 3rd, 2021) was held virtually to discuss the draft of the Benthic Stressor Analysis and the CADDIS results, and to outline the next steps in the study process.

The second TAC meeting (22 attendees, April 14th, 2021) was held virtually. This meeting discussed the development of the GWLF models, source assessment and permits, and the All Forested Load Multiplier methodology.

The third TAC meeting (11 attendees, May 9th, 2022) was held in the Clover Hill Library in Midlothian, VA. This meeting reviewed permitted sources, the modeling approach, and endpoints developed using AllForX. Multiple allocation scenarios to achieve the target loads were presented. Committee members then voted on the allocation scenario that would be implemented in the TMDL for each creek.

A final public meeting was held on February 15, 2023 at the Clover Hill Library in Midlothian, VA to present the draft TMDL document. The public meeting marked the beginning of the official public comment period and was attended by 15 watershed residents and other stakeholders. The public comment period ended on March 17, 2023. This meeting represented the beginning of a 30-day public comment period on the draft TMDL report. Received comments and responses are documented in **Appendix D**.

References

Chesapeake Bay Program (CBP). 1998. Chesapeake Bay Watershed Model application and calculation of nutrient and sediment loadings. Appendix I: Model Operations Manual. A Report of the Chesapeake Bay Program Modeling Subcommittee. August 1998. Annapolis, MD.

Conservation Tillage Best Management Practice Expert Panel (CTBMPEP). 2016. Conservation Tillage Practices for use in Phase 6.0 of the Chesapeake Bay Program Watershed Model (CBP/TRS-308-16).

Daly, C., Halbleib, M., Smith, J. I., Gibson, W. P., Doggett, M. K., Taylor, G. H., . . . Pasteris, P. P. (2008). Physiographically sensitive mapping of climatological temperature and precipitation across the conterminous United States. *International Journal of Climatology*. doi:10.1002/joc.1688 https://prism.oregonstate.edu/documents/pubs/2008intjclim_physiographicMapping_daly.pdf.

Erosion and Sediment Control Expert Panel (ESCEP). 2014. Recommendations of the Expert Panel to Define Removal Rates for Erosion and Sediment Control Practices. Approved by Chesapeake Bay Water Quality Goal Implementation Team.

Evans, B. M., S. A. Sheeder, K. J. Corradini, and W. S. Brown. 2001. AVGWLF version 3.2. Users Guide. Environmental Resources Research Institute, Pennsylvania State University and Pennsylvania Department of Environmental Protection, Bureau of Watershed Conservation.

Evans, B.M., S. A. Sheeder, and D.W. Lehning. 2003. A spatial technique for estimating streambank erosion based on watershed characteristics. J. Spatial Hydrology, Vol. 3, No. 1.

Haith, D. A., R. Mandel, and R. S. Wu. 1992. GWLF. Generalized Watershed Loading Functions, version 2.0. User's Manual. Department of Agricultural and Biological Engineering, Cornell University. Ithaca, New York.

Hession, W. C., M. McBride, and L. Misiura. 1997. Revised Virginia nonpoint source pollution assessment methodology. A report submitted to the Virginia Department of Conservation and Recreation, Richmond, Virginia. The Academy of Natural Sciences of Philadelphia, Patrick Center for Environmental Research. Philadelphia, Pennsylvania.

NRCS. USDA. Soitl Survey Geographic (SSURGO) Database. Available online. Accessed October 2021.

PRISM Climate Group. 2021. Oregon State University. http://prism.oregonstate.edu. Accessed 12 May 2021.

State Water Control Board (SWCB). 2011. 9VAC 25-260 Virginia Water Quality Standards. https://www.epa.gov/sites/production/files/2014-12/documents/vawqs.pdf. Accessed 9 April 2020.

Street and Storm Drain Cleaning Expert BMP Review Panel (SSDCEP). 2015. Recommendations of the Expert Panel to Define Removal Rates for Street and Storm Drain Cleaning Practices. 18 September 2015.

Tetra Tech. 2003. A stream condition index for Virginia non-coastal streams. Prepared for USEPA Office of Science and Technology, USEPA Region 3 Environmental Services Division, and Virginia Department of Environmental Quality. Available at: https://www.deq.virginia.gov/Portals/0/DEQ/Water/WaterQualityMonitoring/BiologicalMonitoring/vsci.pdf. Accessed 9 April 2020.

US Census Bureau. 2020. Census QuickFacts. Available at: https://www.census.gov/quickfacts/fact/table/US/PST045216. Accessed 8 January 2019.

USEPA. 1991. Technical Support Document for Water Quality-based Toxics Control. EPA/505/2-90-001 PB91-127415. U.S. Environmental Protection Agency, Office of Water, Washington DC. March 1991.

USEPA. 2010. *Chesapeake Bay Phase 5.3 Community Watershed Model*. EPA 903S10002 - CBP/TRS-303-10. U.S. Environmental Protection Agency, Chesapeake Bay Program Office, Annapolis MD. December 2010.

VADCR. 2020. 2020 NPS Assessment Land Use/Land Cover Database. http://www.dcr.virginia.gov/soil-and-water/npsassmt. Accessed 1 March 2021.

VADEQ. 2005. Memorandum from Jutta Schneider, entitled "Error in Channel Erosion Calculation using GWLF". December 16, 2005. Virginia Department of Environmental Quality. Richmond, Virginia.

VADEQ. 2006. Using probabilistic monitoring data to validate the non-coastal Virginia Stream Condition Index. VADEQ Technical Bulletin WQA/2006-001. Richmond, Va.: Virginia Department of Environmental Quality; Water Quality Monitoring, Biological Monitoring and Water Quality Assessment Programs. Available at: http://www.deq.virginia.gov/Portals/0/DEQ/Water/WaterQualityMonitoring/ProbabilisticMonitoring/scival.pdf. Accessed 9 April 2020.

VADEQ. 2014. Guidance Memo No. 14-2016 Public Participation Procedures for Water Quality Management Planning. Available at: https://townhall.virginia.gov/l/GetFile.cfm?File=C:\TownHall\docroot\GuidanceDocs\440\GDoc_DEQ_2378_v2.pdf. Accessed 3 February 2023.

VADEQ. 2017. Guidance Manual for Total Maximum Daily Load Implementation Plans.

VADEQ. 2019. Guidance Memo No. GM19-2001 2020 Water Quality Assessment Guidance Manual. Available at: https://www.deq.virginia.gov/home/showpublisheddocument/2343/637436416905200000. Accessed 9 April 2020.

VADEQ. 2020. Final 2020 305(b)/303(d) Water Quality Assessment Integrated Report. Available at: https://www.deq.virginia.gov/water/water-quality/assessments/integrated-report. Accessed 9 April 2020.

Woods, A. J., J. M. Omernik, and D. D. Brown. 1999. Level III and IV Ecoregions of Delaware, Maryland, Pennsylvania, Virginia, and West Virginia. U. S. Environmental Protections Agency.

Yagow, G., S. Mostaghimi, and T. Dillaha. 2002. GWLF model calibration for statewide NPS assessment. Virginia NPS pollutant load assessment methodology for 2002 and 2004 statewide NPS pollutant assessments. January 1 – March 31, 2002 Quarterly Report. Submitted to Virginia Department of Conservation and Recreation, Division of Soil and Water Conservation. Richmond, Virginia.

Yagow, G. and W.C. Hession. 2007. Statewide NPS Pollutant Load Assessment in Virginia at the Sixth Order NWBD Level: Final Project Report. VT-BSE Document No. 2007-0003. Submitted to the Virginia Department of Conservation and Recreation, Richmond, Virginia.

Appendix A - GWLF Model Parameters

Various GWLF parameters used for the James River tributaries TMDL models are detailed below. **Table A-1** and **Table A-2** list the various watershed-wide parameters. The land use parameters for the watersheds are listed in **Table A-3** through **Table A-8**.

Table A-1. Watershed-wide GWLF parameters.

GWLF Parameter	Units	Value
Recession Coefficient	day^{-1}	0.21
Seepage Coefficient	day^{-1}	0.16
Leakage Coefficient	day^{-1}	0.075
Erosivity Coefficient (Nov-Mar)		0.15
Erosivity Coefficient (Apr-Oct)		0.3
Sediment P Concentration	mg/kg	700
Groundwater P Concentration	mg/L	0.013
Septic System Effluent P	g/person-day	1.37
Plant Nutrient Uptake P	g/person-day	0.4

Table A-2. Additional GWLF watershed parameters.

GWLF Parameter	Bailey Creek	Nuttree Branch	Oldtown Creek	Proctors Creek	Rohoic Creek	Swift Creek
Sediment Delivery Ratio	0.15	0.20	0.16	0.14	0.17	0.08
Unsaturated Water Capacity (cm)	21.77	19.65	20.86	20.35	21.99	20.20
aFactor	0.0002927	0.0003544	0.0002234	0.0003404	0.0002925	0.0001864
Total Stream Length (m)	24542	7319	28447	34308	21265	167230
Mean Channel Depth (m)	2.57	1.85	2.51	2.86	2.21	5.48
ET Cover Coefficient, Apr-Oct	0.896	0.820	0.915	0.821	0.869	0.913
ET Cover Coefficient, Nov-Mar	0.824	0.747	0.818	0.768	0.801	0.809

Table A-3. Pervious land cover parameters for Bailey Creek.

Land Cover	Area (ha)	CN	KLSCP	Runoff P (mg/L)	Sediment Build-up (kg/ha-d)	P in Sediment Build-up (kg/kg)
High_till	0.5	82.5	0.02699	0.18	n/a	n/a
Low_till	55.4	78.5	0.00328	0.141	n/a	n/a
Hay	80.7	68.1	0.00085	0.2	n/a	n/a
Pasture_Good	0.0	0.0	0	0.2	n/a	n/a
Pasture_Fair	3.7	76.8	0.00846	0.51	n/a	n/a
Pasture_Poor	1.0	84.4	0.01501	0.82	n/a	n/a
Forest	1100.2	66.4	0.00057	0.01	n/a	n/a
Trees	607.7	69.8	0.00536	0.03	n/a	n/a
Shrub	53.4	56.4	0.00486	0.03	n/a	n/a
Harvested Forest	35.8	71.2	0.00924	0.05	n/a	n/a
Water	6.9	98.0	0	0	n/a	n/a
Wetland	166.9	73.3	0.00394	0	n/a	n/a
Barren	7.3	76.0	0.22212	0.05	n/a	n/a
Turfgrass	962.2	71.3	0.00115	0.38	n/a	n/a
Developed pervious	80.7	71.0	0.00275	0.25	n/a	n/a
Developed impervious	322.8	98.0	0	n/a	6.2	0.00217
Impervious local dataset	204.8	98.0	0	n/a	2.8	0.00217

Table A-4. Pervious land cover parameters for Nuttree Branch.

Land Cover	Area (ha)	CN	KLSCP	Runoff P (mg/L)	Sediment Build-up (kg/ha-d)	P in Sediment Build-up (kg/kg)
High_till	0.0	0.0	0	0.18	n/a	n/a
Low_till	0.0	0.0	0	0.141	n/a	n/a
Hay	0.0	0.0	0	0.2	n/a	n/a
Pasture_Good	0.0	0.0	0	0.2	n/a	n/a
Pasture_Fair	0.0	0.0	0	0.51	n/a	n/a
Pasture_Poor	0.0	0.0	0	0.82	n/a	n/a
Forest	418.2	69.3	0.00035	0.01	n/a	n/a
Trees	335.4	72.4	0.00422	0.03	n/a	n/a
Shrub	15.6	59.8	0.00623	0.03	n/a	n/a
Harvested Forest	0.0	0.0	0	0.05	n/a	n/a
Water	17.1	98.0	0	0	n/a	n/a
Wetland	11.6	74.9	0.00241	0	n/a	n/a
Barren	0.0	0.0	0	0.05	n/a	n/a
Turfgrass	385.2	72.0	0.00129	0.38	n/a	n/a
Developed pervious	13.0	74.2	0.00325	0.25	n/a	n/a
Developed impervious	52.2	98.0	0	n/a	6.2	0.00217
Impervious local dataset	260.5	98.0	0	n/a	2.8	0.00217

Table A-5. Pervious land cover parameters for Oldtown Creek.

Land Cover	Area (ha)	CN	KLSCP	Runoff P (mg/L)	Sediment Build-up (kg/ha-d)	P in Sediment Build-up (kg/kg)
High_till	27.5	83.4	0.02151	0.18	n/a	n/a
Low_till	226.1	79.4	0.00261	0.141	n/a	n/a
Hay	97.5	67.9	0.00062	0.2	n/a	n/a
Pasture_Good	0.0	0.0	0	0.2	n/a	n/a
Pasture_Fair	0.0	0.0	0	0.51	n/a	n/a
Pasture_Poor	1.0	84.3	0.01094	0.82	n/a	n/a
Forest	1135.2	71.5	0.00028	0.01	n/a	n/a
Trees	404.0	71.9	0.00315	0.03	n/a	n/a
Shrub	12.5	69.3	0.00392	0.03	n/a	n/a
Harvested Forest	54.6	74.9	0.00372	0.05	n/a	n/a
Water	23.9	98.0	0	0	n/a	n/a
Wetland	203.0	75.8	0.00172	0	n/a	n/a
Barren	0.7	71.0	0.1364	0.05	n/a	n/a
Turfgrass	808.4	72.6	0.0006	0.38	n/a	n/a
Developed pervious	40.4	73.5	0.00231	0.25	n/a	n/a
Developed impervious	161.7	98.0	0	n/a	6.2	0.00217
Impervious local dataset	257.4	98.0	0	n/a	2.8	0.00217

Table A-6. Pervious land cover parameters for Proctors Creek.

Land Cover	Area (ha)	CN	KLSCP	Runoff P (mg/L)	Sediment Build-up (kg/ha-d)	P in Sediment Build-up (kg/kg)
High_till	0.2	83.6	0.01724	0.18	n/a	n/a
Low_till	30.7	79.6	0.00209	0.141	n/a	n/a
Hay	25.4	69.6	0.00115	0.2	n/a	n/a
Pasture_Good	0.0	0.0	0	0.2	n/a	n/a
Pasture_Fair	2.8	77.9	0.01146	0.51	n/a	n/a
Pasture_Poor	0.0	0.0	0	0.82	n/a	n/a
Forest	979.1	71.7	0.00035	0.01	n/a	n/a
Trees	975.4	70.6	0.00344	0.03	n/a	n/a
Shrub	28.5	63.0	0.00359	0.03	n/a	n/a
Harvested Forest	0.0	0.0	0	0.05	n/a	n/a
Water	33.7	98.0	0	0	n/a	n/a
Wetland	326.2	74.1	0.00213	0	n/a	n/a
Barren	17.7	79.7	0.10152	0.05	n/a	n/a
Turfgrass	1403.2	71.2	0.00089	0.38	n/a	n/a
Developed pervious	36.3	70.9	0.00288	0.25	n/a	n/a
Developed impervious	145.3	98.0	0	n/a	6.2	0.00217
Impervious local dataset	871.9	98.0	0	n/a	2.8	0.00217

Table A-7. Pervious land cover parameters for Rohoic Creek.

Land Cover	Area (ha)	CN	KLSCP	Runoff P (mg/L)	Sediment Build-up (kg/ha-d)	P in Sediment Build-up (kg/kg)
High_till	6.5	84.7	0.02318	0.18	n/a	n/a
Low_till	53.1	80.7	0.00282	0.141	n/a	n/a
Hay	109.6	69.6	0.00116	0.2	n/a	n/a
Pasture_Good	0.0	0.0	0	0.2	n/a	n/a
Pasture_Fair	0.0	0.0	0	0.51	n/a	n/a
Pasture_Poor	1.1	85.2	0.02058	0.82	n/a	n/a
Forest	702.8	69.9	0.00033	0.01	n/a	n/a
Trees	340.7	70.6	0.00445	0.03	n/a	n/a
Shrub	24.5	64.3	0.00453	0.03	n/a	n/a
Harvested Forest	7.2	77.0	0.00365	0.05	n/a	n/a
Water	22.8	98.0	0	0	n/a	n/a
Wetland	76.1	71.7	0.0022	0	n/a	n/a
Barren	0.0	0.0	0	0.05	n/a	n/a
Turfgrass	672.9	72.8	0.00103	0.38	n/a	n/a
Developed pervious	28.4	72.9	0.00298	0.25	n/a	n/a
Developed impervious	113.8	98.0	0	n/a	6.2	0.00217
Impervious local dataset	284.2	98.0	0	n/a	2.8	0.00217

Table A-8. Pervious land cover parameters for Swift Creek.

Land Cover	Area (ha)	CN	KLSCP	Runoff P (mg/L)	Sediment Build-up (kg/ha-d)	P in Sediment Build-up (kg/kg)
High_till	19.5	82.9	0.03859	0.18	n/a	n/a
Low_till	166.6	78.9	0.00469	0.141	n/a	n/a
Hay	490.5	66.3	0.00098	0.2	n/a	n/a
Pasture_Good	22.6	70.1	0.00251	0.2	n/a	n/a
Pasture_Fair	171.1	76.0	0.01004	0.51	n/a	n/a
Pasture_Poor	16.5	83.9	0.0179	0.82	n/a	n/a
Forest	14107.1	66.6	0.00039	0.01	n/a	n/a
Trees	3988.4	68.3	0.004	0.03	n/a	n/a
Shrub	120.0	58.1	0.00621	0.03	n/a	n/a
Harvested Forest	192.8	76.1	0.00486	0.05	n/a	n/a
Water	829.8	98.0	0	0	n/a	n/a
Wetland	769.4	75.1	0.00249	0	n/a	n/a
Barren	61.4	78.9	0.20792	0.05	n/a	n/a
Turfgrass	4179.0	70.6	0.00115	0.38	n/a	n/a
Developed pervious	176.1	70.4	0.00346	0.25	n/a	n/a
Developed impervious	704.6	98.0	0	n/a	6.2	0.00217
Impervious local dataset	2079.4	98.0	0	n/a	2.8	0.00217

Appendix B - Sensitivity Analysis

Analyses were conducted to assess the sensitivity of the model to changes in hydrologic and water quality parameters, as well as to assess the potential impact of uncertainty in parameter determination. Sensitivity analyses were run for each study watershed on the parameters listed in **Table A-1** through **Table A-8**, which served as the baseline value for each watershed. The outputs from model runs using the listed base parameter values were compared to model runs changing each of the parameters by +10% and -10% of the base value. The results are shown in **Table B-1**.

The relationships exhibit linear responses except for sediment response to changes in curve numbers. Changes in variables specific to sediment such as KLSCP had no impact on hydrology, which was to be expected. Sediment related parameters impacted phosphorus loads, but phosphorus-specific parameters such as the concentration of phosphorus in soil only affected phosphorus loads. Changes in curve numbers had the most influence on both the flow and pollutant loads. Changes in other hydrologic parameters had more impact on runoff volume than on sediment load, with the seepage and recession coefficients having the next largest impacts on hydrology after curve number and ET-CV.

Table B-1. Results of the GWLF sensitivity analysis, averaged across all watersheds.

Model Parameter	Parameter Change (%)	Total Runoff Volume Change (%)	Total Sediment Load Change (%)	Total Phosphorus Load Change (%)
CN	+10	12.9%	17.6%	32.6%
	-10	-12.3%	-23.0%	-32.9%
KLSCP	+10	0.0%	4.4%	0.4%
	-10	0.0%	-4.4%	-0.4%
Runoff P	+10	0.0%	0.0%	3.1%
	-10	0.0%	0.0%	-3.1%
Sediment Build-up	+10	0.0%	2.4%	4.1%
	-10	0.0%	-2.4%	-4.1%
P in Sediment Build-up	+10	0.0%	0.0%	3.8%
	-10	0.0%	0.0%	-3.8%
Recession Coefficient	+10	2.3%	0.4%	0.6%
	-10	-2.6%	-0.5%	-0.7%
Seepage Coefficient	+10	-2.3%	-0.5%	-0.6%
	-10	2.5%	0.5%	0.7%
Leakage Coefficient	+10	0.6%	0.2%	0.2%
	-10	-0.6%	-0.2%	-0.2%
AWC	+10	-0.4%	-0.1%	-0.1%
	-10	0.6%	0.2%	0.2%
ET-CV	+10	-6.9%	-1.5%	-2.0%
	-10	8.1%	1.8%	2.3%

Appendix C - AllForX Development

The method used to set TMDL endpoint loads for the James River Tributaries is called the "all-forest load multiplier" (AllForX) approach, introduced in **Section 5.0**. AllForX is the ratio calculated by dividing the simulated pollutant load under existing conditions by the pollutant load from an all-forest simulated condition for the same watershed. In other words, AllForX is an indication of how much higher current pollutant loads are above an undeveloped condition. After calculating AllForX values for a range of monitoring stations (**Table C-1**), a regression is developed between the AllForX values and corresponding VSCI scores at those stations (**Figure C-1** and **Figure C-2**). This relationship between AllForX values and VSCI scores can be used to quantify the AllForX value that corresponds to the VSCI threshold score of 60.

These multipliers were calculated for a total of 15 watersheds of similar size and within the same ecoregion as the TMDL watersheds (**Figure C-3**). These watersheds included both unimpaired and impaired streams to represent a wide distribution of current conditions. Watersheds used in developing the VSCI and AllForX regression were selected to be similar in size and located near the study watersheds to minimize differences in flow regime, soils, and other physiographic properties. Additionally, the watersheds must have adequate and recent VSCI data for a watershed to be a useful data point.

For the purposes of building the AllForX regression, permitted sources were not included. This was to leave the flexibility of potentially incorporating other watersheds into the regression that may have less available data and be able to compare the trends more fairly. The same set of watershed models were run a second time, changing all of the land use parameters to reflect forested land cover while preserving the unique soil and slope characteristics of each watershed. The AllForX value was calculated for each modeled watershed by dividing the original model loads by the all-forested model loads. This data is presented in **Table C-1**.

A regression was then developed between the Virginia Stream Condition Index (VSCI) scores at monitoring stations and the corresponding AllForX value calculated for the watershed draining to each station. The regression for sediment (TSS) resulted in an R^2 value of 0.373, and the regression for phosphorus (TP) resulted in an R^2 value of 0.422. These regressions were used to quantify the values of AllForX corresponding to the benthic health threshold (VSCI = 60) for sediment and phosphorus. Based on the regressions, a VSCI score of 60 corresponded to a target AllForX value of 5.85 for sediment and 3.36 for phosphorus. This means that the TMDL streams are expected to achieve consistently healthy benthic conditions if sediment loads are less than 5.85 times the simulated load of an all-forested watershed, and phosphorus less than 3.36 times the all-forested load. The allowable sediment or phosphorus TMDL load was then calculated by applying the AllForX threshold where VSCI = 60 (5.85 for TSS or 3.36 for TP) to the All-Forest simulated pollutant load of the target watershed to determine the final target TMDL loading. An explicit margin of safety was implemented based on this target loading rate, setting aside 10% of the allowable load specifically for the margin of safety.

Table C-1. Model run results for AllForX value development.

Station ID	VASCI avg	TSS (t/yr)	TSS All-Forested (lb/yr)	TSS Multiplier	TP (lb/yr)	TP All-Forested (lb/yr)	TP Multiplier
2-BLY005.73	32.0	300	23	12.9	2,104.0	81.1	25.9
2-OTC001.54	49.7	567	46	12.3	2,418.0	256.4	9.4
2-RHC000.58	48.8	220	25	8.8	1,559.0	88.0	17.7
2-JOH004.23	60.6	116	26	4.5	1,040.0	124.9	8.3
2-SFT012.84	71.62	11,389	1,260	9.0	22,613	3,430.5	6.6
2-SFT019.15	43.0	7,426	827	9.0	16,380.0	2,412.0	6.8
2-SFT025.32	44.7	5,588	616	9.1	13,080.0	1,857.0	7.0
2-NUT000.62	51.4	245	29	8.5	1,199.0	104.4	11.5
2-OTC005.38	50.8	222	23	9.6	993.9	133.0	7.5
2DTRO001.88	67.2	172	29	5.8	860.8	141.7	6.1
2-PCT002.46	49.3	958	65	14.7	4,077.0	291.0	14.0
2-SFT019.02	48.0	7,646	845	9.0	16,770.0	2,459.0	6.8
2-LIA000.50	56.4	665	106	6.3	2,619.0	611.5	4.3
2-FIN000.81	58.8	504	67	7.6	2,338.0	449.9	5.2
2-NWD004.15	64.0	387	61	6.4	1,996.0	426.8	4.7

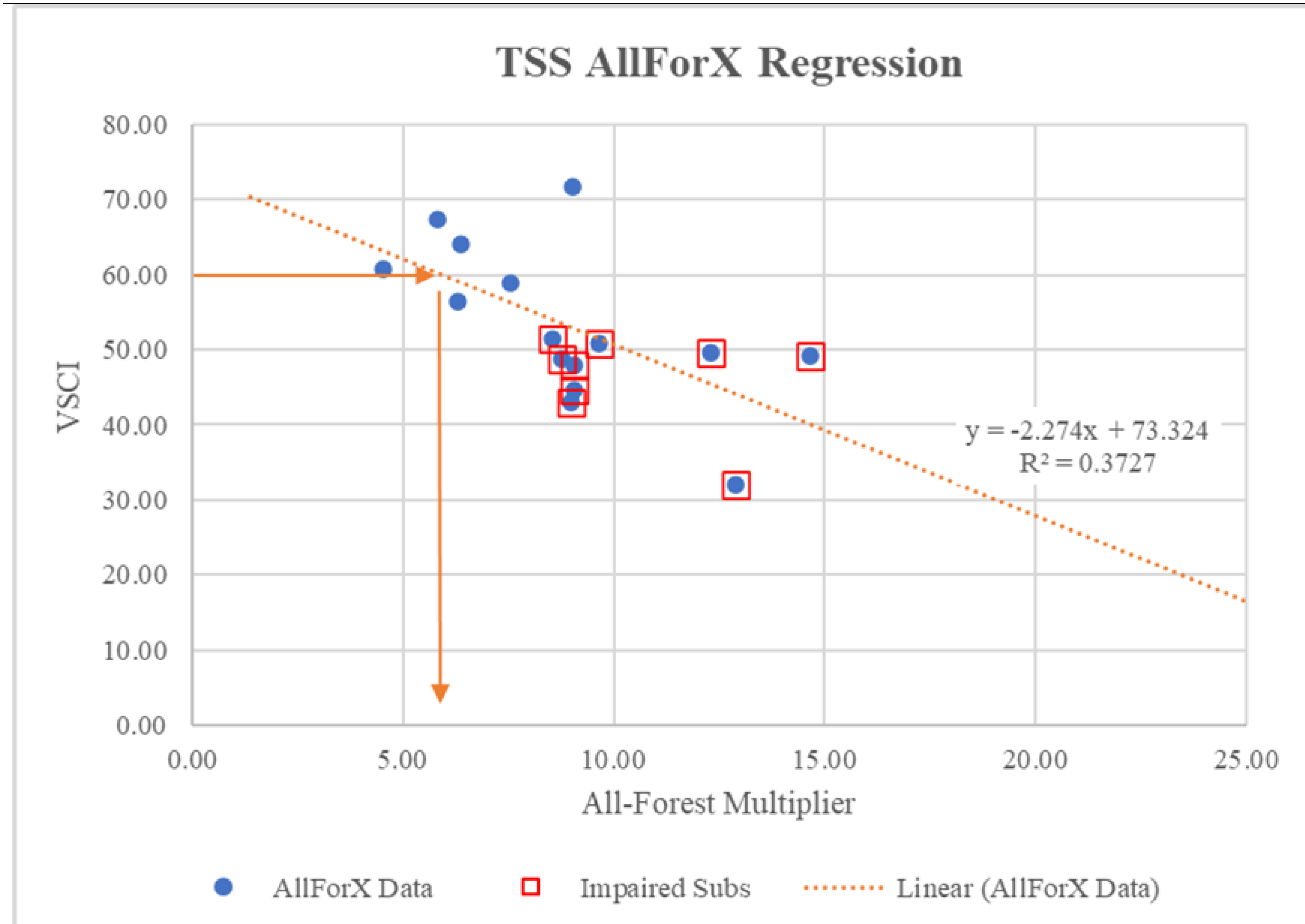


Figure C-1. Regression for sediment in the James River tributaries TMDL, resulting AllForX target value of 5.85.

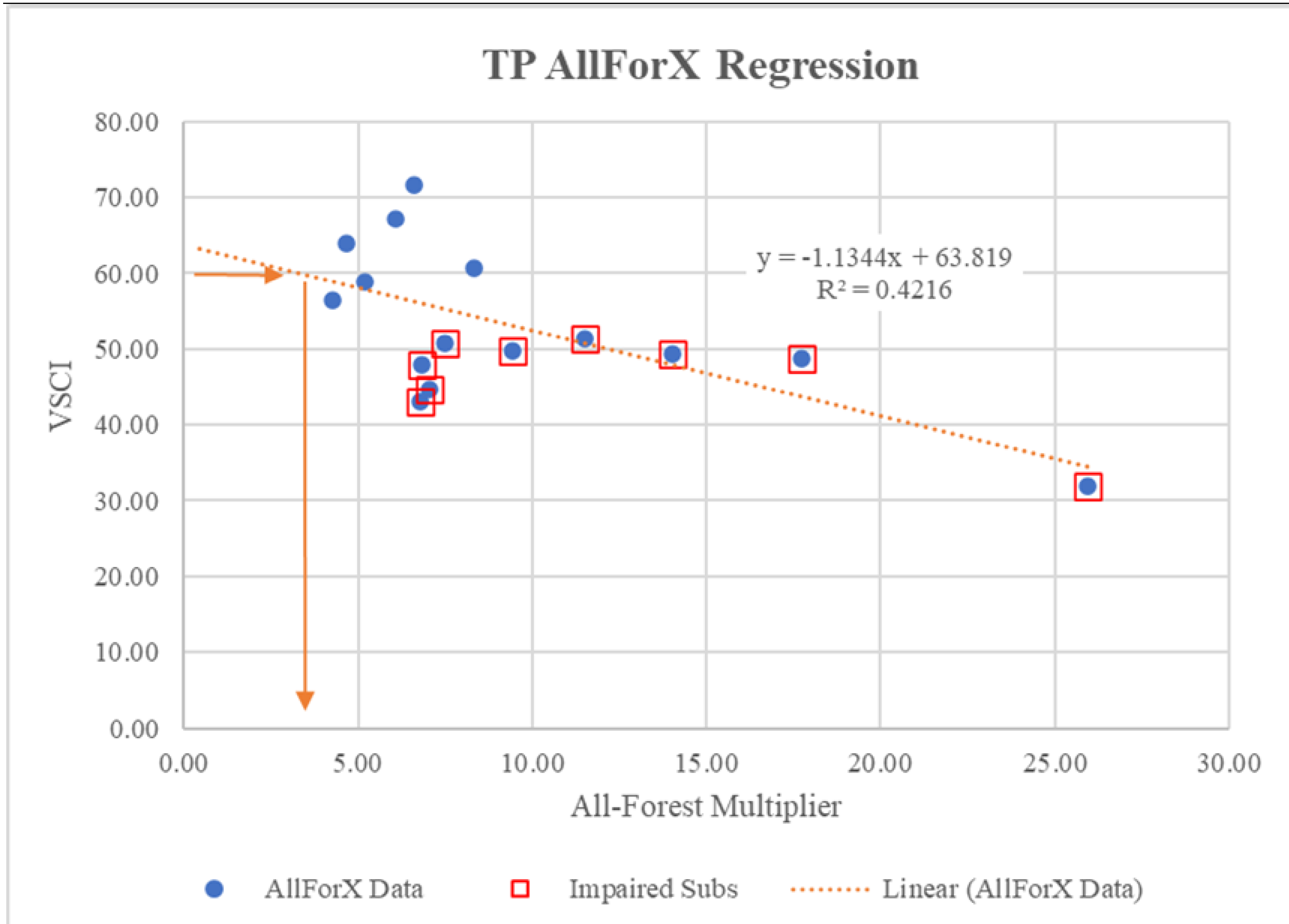


Figure C-2. Regression for Phosphorus in the James River tributaries TMDL, resulting AllForX target value of 3.36.

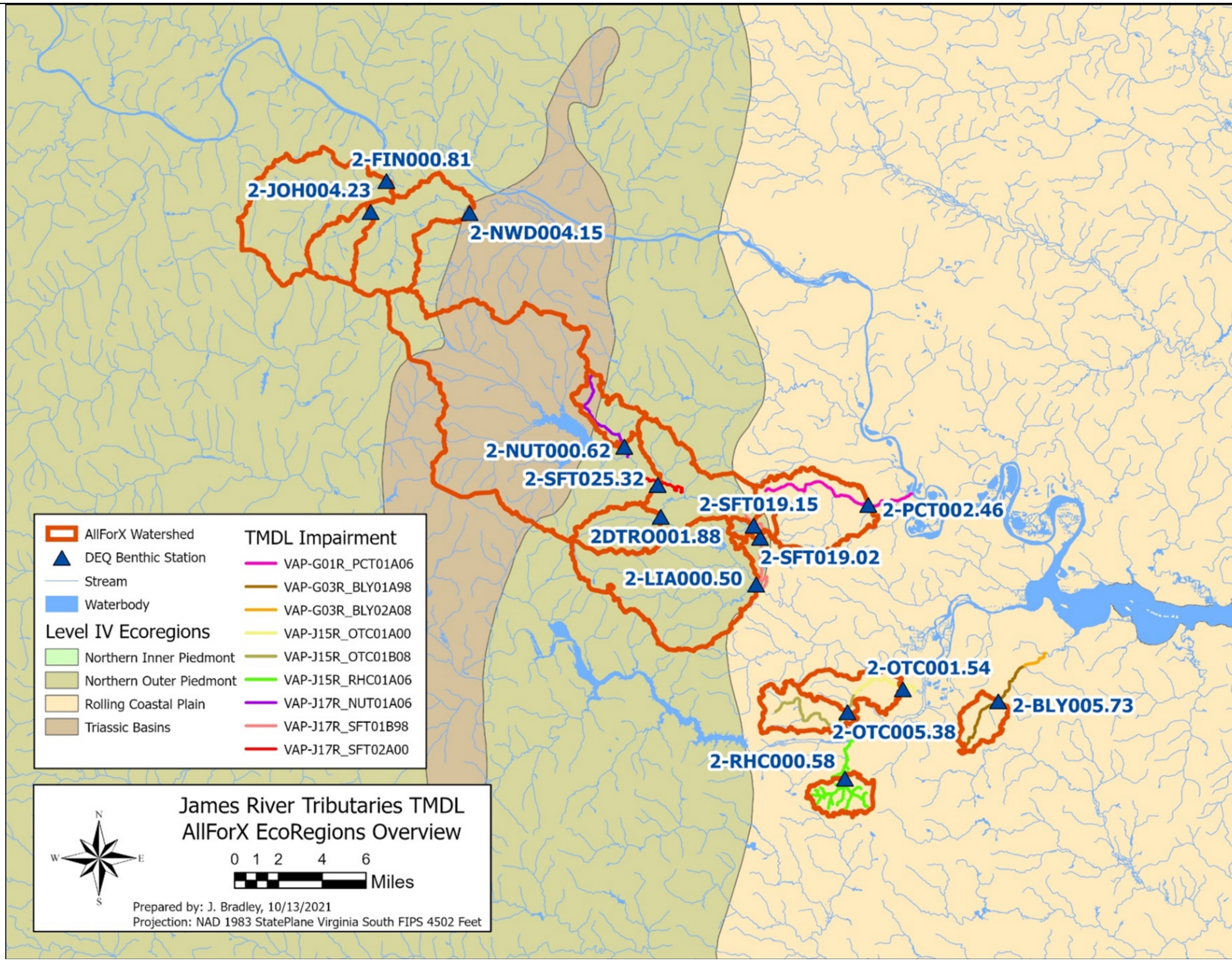


Figure C-3. Location of James River tributaries AllForX TMDL watersheds and ecoregions .

Appendix D - Public Comments and Responses

Response to Comments Document for James River Tributaries Benthic TMDL First Public Comment Period

First Comment Period

The First Public meeting for the James River Tributaries Benthic TMDL was held on January 26,2021. This meeting presented the preliminary findings of the Benthic Stressor Analysis for Total Maximum Daily Load (TMDL) development on Bailey Creek, Nuttree Branch, Oldtown Creek, Proctors Creek, Rohoic Creek, and Swift Creek (collectively referred to as the James River Tributaries Project). The draft Benthic Stressor Analysis document was made available to the public for review and a 30-day public comment period was held after the meeting from January 27, 2021 – February 26, 2021. During the public comment period, comments were received from W. Weedon Cloe III (Chesterfield County Department of Environmental Engineering) and Andrea W. Wortzel (Troutman Pepper Hamilton Sanders representing VMA). The full text of the original comments and VDEQ's response to those comments are provided below.

Comments from Mr. W. Weedon Cloe III and *DEQ responses*:

February 25, 2021

1. Chesterfield County supports the conclusion that sediment, and in select systems phosphorus, represent the primary stressors on benthic macroinvertebrate communities in the watersheds evaluated.
   DEQ Response: DEQ thanks the commenter for their support.

2. We would like to reiterate the importance of accounting for the underlying geology of the Swift Creek system as the entirety of the portion of the watershed upstream of the reservoir's dam lies in the Triassic Basin. The streams tributary to the reservoir all have shifting sand bottoms which impact available habitat for the benthic community and sediment TMDLs will need to account for this natural condition.
   DEQ Response: DEQ agrees and has modified the Benthic Stressor Analysis to acknowledge "underlying geology" as a contributing factor to the sediment stressor in James River Tributaries Project streams. During TMDL development, DEQ will consider underlying geology in selecting appropriate reference conditions that will be used in sediment TMDL endpoint determination.

3. Attached is the most recent (2019) Swift Creek Reservoir Water Quality Report. Of interest is the improvement in Chlorophyll *a* and Total Phosphorus as compared to 2017/2018. Those two years witnessed historically high concentrations of these two analytes and subsequent measurements have demonstrated a return to acceptable levels.
   DEQ Response: Thank you for this additional reference. DEQ has incorporated the results of the 2019 Swift Creek Reservoir Water Quality Report into the Benthic Stressor Analysis.

Comments from Mrs. Andrea W. Wortzel and *DEQ responses*:
February 26, 2021

1. We understand that one aspect of TMDL development is determining the cause of the benthic impairment. In the initial meeting and related materials pertaining to TMDL development, it was suggested that chlorophyll a could be a contributing factor to the impairments. There has been extensive study relating to chlorophyll a and its impacts in the James River over the past several years, culminating in the adoption of new water quality standards. The nitrogen and phosphorus allocations in the James River have been reassessed to ensure compliance with the new chlorophyll a standards. There are also a number of other regulatory actions and TMDLs that affect water quality in the James and its tributaries. Accordingly, one of VMA's concerns is better understanding how all of these regulatory requirements will relate to each other, and whether the impacts of these developments are considered as part of the TMDL development to address benthic impairment.
   DEQ Response: DEQ understands VMA's concerns. With regards to the chlorophyll a mentioned in the stressor analysis, that was from data in the Swift Creek Reservoir. We received comments from Chesterfield County that included more recent data showing improvements in the chlorophyll a levels in the reservoir and we are updating the stressor analysis to include those data. Regardless, chlorophyll a was just mentioned as a potential indicator of nutrient over-enrichment as opposed to a specific contributing factor. This really will not have an effect on the TMDL because the chlorophyll a standard is only for tidal waters and reservoirs, neither of which are included in this TMDL. Regarding waste load allocations for nutrients or other pollutants, existing WLAs will definitely be taken into account when determining WLAs for this project. At the next two TAC meetings, we will be going into greater detail about the TMDL endpoint development and allocations and we will certainly welcome any more questions or concerns VMA has regarding these regulatory requirements.

2. Additionally, we would like to better understand how some of the naturally occurring conditions, such as low DO, will be considered in the benthic TMDL development process.
   DEQ Response: Naturally occurring conditions are considered throughout the monitoring, assessment, and TMDL development process. When determining benthic impairments, there are two separate indices that DEQ uses: Virginia Species Condition Index (VSCI) and Coastal Plain Macroinvertebrate Index (CPMI). Both are multi-metric indices that calculate a score for a benthic sample to determine if that stream is impaired. VSCI is used in non-coastal streams and is the more commonly used index. CPMI is used for the coastal plain where naturally occurring conditions may limit the benthic communities that are present even when they are not impaired.
   In the Benthic Stressor Analysis, a number of probable stressors were identified, and in some cases natural conditions either contributed to these stressors or were believed to be wholly responsible for the stress. For instance, the low pH stress in Proctors Creek and

Oldtown Creek was due to the natural conditions of anaerobic decomposition in connected wetlands. In this case, a TMDL will not be developed to address pH as a stressor.
In Oldtown Creek and Swift Creek, natural conditions contributed to the low dissolved oxygen stress. The naturally connected wetlands contributed to low dissolved oxygen in Oldtown Creek, and the naturally low slope and presence of the dam and impoundments on Swift Creek contributed to low dissolved oxygen in this stream. In these cases, the natural contribution of low dissolved oxygen was confounded by the additional stressor of excess phosphorus. A TMDL will be developed to address the total phosphorus stressor in these streams, but DEQ recognizes that reducing phosphorus loads in these streams may not completely eliminate low dissolved oxygen conditions. Specifically in the stream segment just below Swift Creek Reservoir, DEQ will be collecting additional dissolved oxygen data and would likely pursue a Category 4C Assessment (impaired but not needing a TMDL) if the dissolved oxygen issue is determined to be solely caused by either naturally occurring conditions or the dam on Swift Creek Reservoir.

3. VMA looks forward to working with DEQ on the development of this TMDL and the related implementation plan. VMA requests that DEQ include Laura Nicklin, with Ashland Specialty Ingredients, as VMA's representative on the technical advisory panel for the TMDL development. Her email address is llnicklin@ashland.com.
   DEQ Response: Laura Nicklin has been added to the contact list for the James River Tributaries Project TMDL TAC and will be notified about all upcoming meetings.

Response to Comments Document for James River Tributaries Benthic TMDL Second Public Comment Period

Second Comment Period

The final public meeting for the James River Tributaries Benthic TMDL was held on February 15, 2023. The draft TMDL study was presented at the meeting and made available on the Virginia Department of Environmental Quality (VDEQ) website. A 30-day public comment period was held after the meeting from February 15, 2023 – March 17, 2023. During the public comment period, comments were received from Mr. Tom Mckee (VMN, SOS, Chesapeake Bay Alliance) and Mrs. Erin Reilly (James River Association). The full text of the original comments and VDEQ's response to those comments are provided below.

Comments from Mr. Tom Mckee:

February 16, 2023

Hello Kelley

When I signed in yesterday afternoon at the meeting I identified as a Virginia Master Naturalist - Pocahontas Chapter. I am also a member of the Izaak Walton League - Save Our Streams Program and Chesapeake Bay Alliance - River Trends Monitoring Team Program. My wife and I are leaders of BSA Venture Crew 2831 (coed youth 14-20). In late 2017, due to my wife's physical issues, we changed from leading high adventure backpacking to ecology studies at Albright Scout Reservation (ASR - a 568 acre primitive weekend camp on the north shore of Lake Chesdin/Appomattox River). We have been uploading River Trends monitoring data from Stoney Creek as it crosses through ASR (data-SC at TBR) and the ASR beach on Lake Chesdin (data-LC at WC11) for several years. In addition we have been monitoring subwatersheds from the 9 ponds at ASR (attached map) since January 2018 through the IWLA-SOS program. The local BSA Council was forced to sell the camp in late 2022 in order to fund their part of a settlement against the nationwide BSA program. Subsequently we are in the process of moving our water quality monitoring program to the Third Branch and Swift Creek watersheds in Pocahontas State Park. This change of venue sparked our interest in your James River Tributaries Program (outstanding work). In addition, we have a personal interest as we have lived in the Brandermill/Woodlake area since moving here from Texas in 1990. I am currently working my way through your reports, somewhat slowly, as I match up the various codes with recognizable water quality information. I am sure I will have some questions but will try to keep from bothering you and your team any more than necessary.

Yours in Cheerful Service, Keeping the Vigil !!!!

Tom R McKee, PhD

Pocahontas Chapter VA Master Naturalist and Chesapeake Bay Steward

ASR Heritage Committee & Conservation Focus Group

VDEQ response to Mr. Tom Mckee:

Mr. McKee,

Thank you for your comments on the Draft James River Tributaries Benthic TMDL Report. We appreciate all of your hard work and look forward to your involvement in the project in the future!

Thank you,

Kelley West

Comments from Mrs. Erin Reilly:

March 17, 2023

Dear Ms. West,

Thank you for the opportunity to provide comments on the James River Tributaries Benthic TMDL. The James River Association (JRA) is a member-supported nonprofit organization founded in 1976 to serve as a guardian and voice for the James River. Throughout the James River's 10,000-square mile watershed, JRA works toward its vision of a fully healthy James River supporting thriving communities. Our thousands of members and supporters have important economic, professional, and personal interests in the health of the James River, and we are pleased to offer a voice for the River and its stakeholders through these comments. We participated in the technical advisory committee and public meetings for this process and appreciate the time and effort that has gone into preparing this TMDL. We are generally supportive of the James River Tributaries TMDL. With that said, we do have concerns with the feasibility of achieving many of the required reductions without decreases in the permitted loads, which was only proposed for Rohoic Creek. Each of the tributaries' respective watersheds will be required to make reductions greater than 50% for all land uses, and in some cases, these required reductions will be as high as 98.8%. We hope that the feasibility of achieving the required reductions is addressed during the implementation plan development process. If it is concluded that it is not possible to achieve the necessary load reductions for these tributaries with corresponding BMPs for each of the respective land use types, it would be appropriate to examine the option of reducing permitted loads. Additionally, we would like to be considered as an interested party in this matter, and would seek inclusion in the development of any implementation plans for these tributaries. Thank you for your consideration of these comments.

Sincerely,

Erin Reilly

Senior Staff Scientist

VDEQ response to Mrs. Erin Reilly:

Dear Mrs. Reilly,

Thank you for your comments on the James River Tributaries Benthic TMDL Draft Report. We are grateful for your continued support throughout the TMDL process and understand your concerns regarding the feasibility of achieving required reductions set by the TMDL. During the next phase *of Implementation Planning (IP), DEQ and the watershed stakeholders will determine which BMPs to install locally to meet the reductions that are set in the TMDL as well as a milestone and timeline for attaining the aquatic life use through the installation of BMPs. Once the IP is approved, it will allow for funding in the watersheds to become available through 319 grants for BMPs. After all recommended BMPs are in place and become fully operational, the goals and milestones for the project will be reviewed. If these milestones and goals are not achieved during the timelines set within the IP, then DEQ can revisit the TMDL to determine if other reductions are needed and modify accordingly in order to meet the instream aquatic life use.*

We appreciate your interest in the development of the implementation plan and will keep you informed when that process begins.

Thank you,

Kelley West
Environmental Planner
Department of Environmental Quality
4949A Cox Road Glen Allen VA 23060
804-432-7946
kelley.west@deq.virginia.gov
www.deq.virginia.gov

Appendix E - Stressor Identification Analysis Report

Stressor Identification Analysis for the James River Tributaries
Prepared by: James Madison University and EEE Consulting, Inc.
Prepared for: Virginia Department of Environmental Quality
March 2021

Available for download under separate cover.
https://www.deq.virginia.gov/home/showpublisheddocument/8493/637546017802100000
or contact appropriate VADEQ staff member.