Total Maximum Daily Load Development For Bacteria (*E. coli*) Impairment in Hogue Creek, Frederick County, Virginia

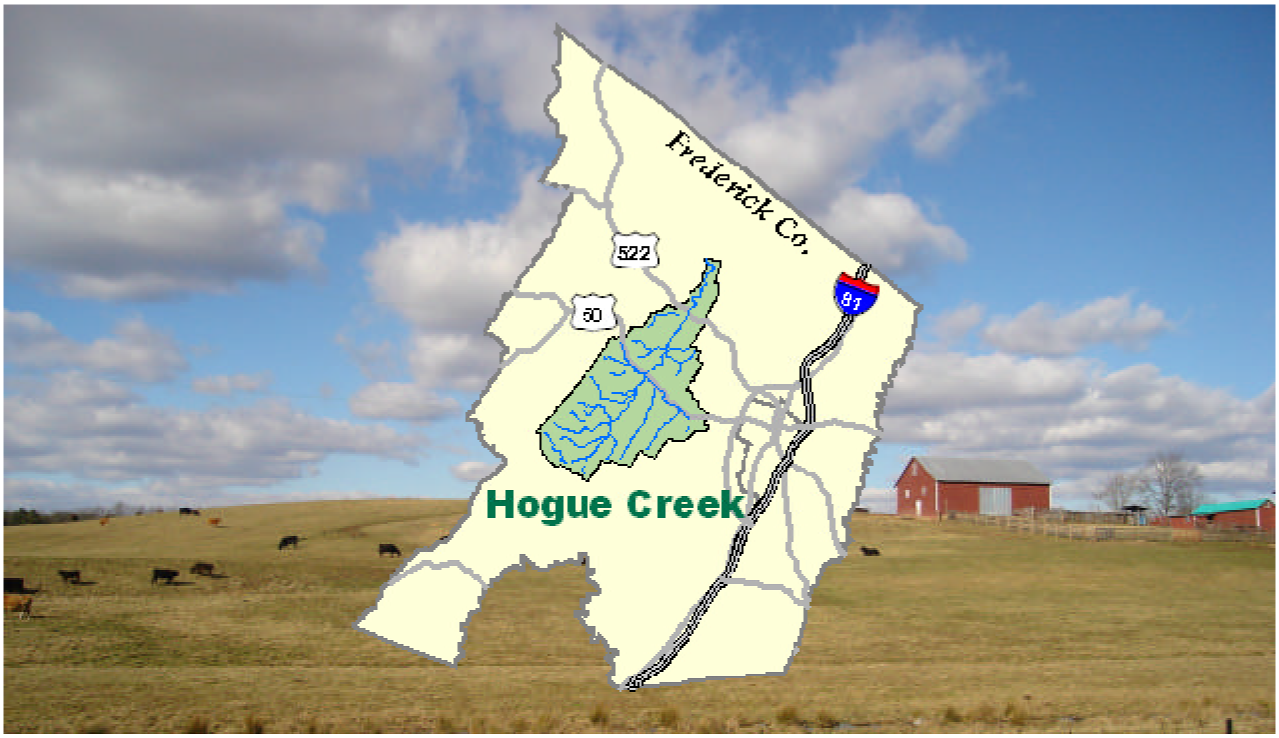

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Table of Contents

List of Tables

List of Figures

CHAPTER 1: EXECUTIVE SUMMARY

1.1. BACKGROUND

Hogue Creek (Watershed ID VAV-B06R) is located in Frederick County west of Winchester, Virginia. Hogue Creek drains a land area of 26,686 acres. This area (the Hogue Creek watershed) is mostly covered by forest (79%), with 19% covered by pasture or hay. Hogue Creek flows north into Back Creek, which flows into West Virginia and joins the Potomac River (USGS Hydrologic Unit Code 02070004). The Potomac River empties into the Chesapeake Bay.

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

1.2. THE PROBLEM – TOO MUCH BACTERIA

The Virginia Department of Environmental Quality (VADEQ) sets water quality standards or limits on the amount of pollution that is allowed in rivers and streams. To make sure that rivers are safe to swim and play in, VADEQ limits the amount of bacteria in the water. According to this standard, streams like Hogue Creek should not have more than 400 fecal coliforms or 235 *Escherichia coli* (*E. coli*) bacteria in every 100 milliliters (ml) of water. Fecal coliforms and *E. coli* are special types of bacteria that live in the guts of humans and animals. Finding these bacteria in the water means that human feces or manure is in the water and could make you sick.

> Frequently Asked Question:
>
> *What's wrong with having bacteria in streams, isn't it natural?* Finding fecal coliform and E. coli bacteria means that human feces or animal manure is in the water. Since feces carry many germs, there is a chance of getting sick if water gets in your mouth, nose, eyes, or an open wound.

Since 1991, VADEQ has been measuring the amount of bacteria in Hogue Creek. Twenty-one percent of the time there has been more than the safe amount (Figure 1-1). Any stream that exceeds the safe amount more than 10.5% of the time is placed on Virginia's "Dirty Waters List" (or 303(d) List) and must have a clean-up plan. Hogue Creek was placed on this list in 2004, and this report is the first step in developing a clean-up plan for Hogue Creek. This report summarizes a study of bacteria in Hogue Creek and sets goals for the clean-up plan. The study is called a Total Maximum Daily Load

(TMDL) Study, because it determines the maximum amount of bacteria that can get into Hogue Creek without going over the safe level.

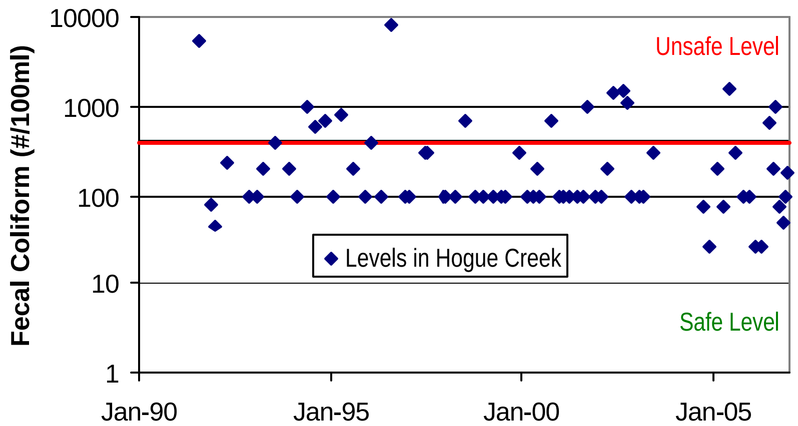


Figure 1-1. Bacteria (Fecal Coliform) Levels in Hogue Creek.

1.3. SOURCES OF BACTERIA

Fecal coliforms come from the guts of humans and warm-blooded animals, so the sources of these bacteria in Hogue Creek must be from humans and animals living in the area that drains to Hogue Creek (the watershed). In this study, VADEQ estimated the amount of bacteria coming from humans, pets, livestock (farm animals), and wildlife. The livestock that were considered in this study included beef cattle, horses, sheep, and goats. Wildlife included deer, raccoon, beaver, muskrat, geese, ducks, and turkeys.

Some of the bacteria from these sources can get into Hogue Creek directly when a cow or wild animal defecates in the stream. Bacteria from humans can get into the stream directly from sewage treatment plants, or if houses have straight pipes right to the stream instead of a septic system. These straight pipes are illegal and VADEQ estimated that there were probably only a few (about 7) along Hogue Creek. The Indian Hollow Elementary School and the new Gainesboro Elementary School both have sewage treatment plants that discharge into Hogue Creek. There are also 46 homes in the area that have individual mini sewage treatment plants. These treatment plants typically do a good job of removing bacteria and are permitted by

VADEQ to discharge into Hogue Creek as long as they keep bacteria levels below the safe amount.

While some sources can deposit bacteria directly into the stream, the majority of bacteria is deposited on the land and makes its way into Hogue Creek as runoff when it rains. The majority of bacteria from pets, livestock, and wildlife gets to the stream in this way. Bacteria from humans can also get to the stream this way if septic systems are failing and untreated sewage pools over the septic system drain field. Overall, 99.9% of the bacteria produced in the Hogue Creek watershed is first deposited on the land. Livestock account for most of the bacteria produced (97%), while wildlife account for 1.7%, pets account for 1.3%, and humans account for less than 1%. To figure out how many of these bacteria end up in Hogue Creek, VADEQ used a computer model.

1.4. COMPUTER MODELING

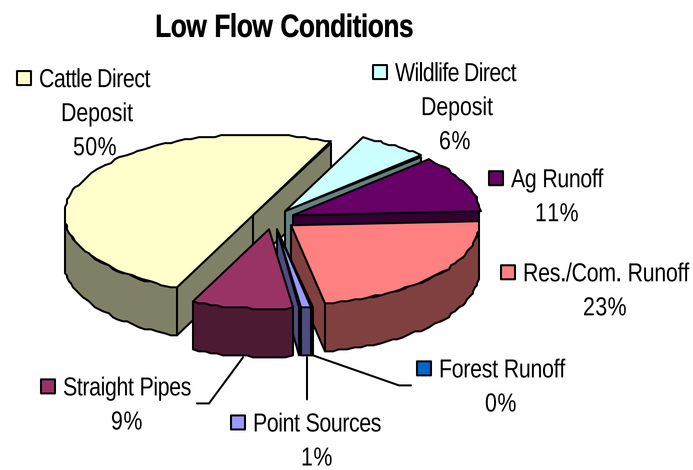
VADEQ used a computer model called the Loading Simulation Program C++ model (or LSPC) to track bacteria from the source, to the land, to the stream, and then downstream to Back Creek. The amount of bacteria that ends up in the stream depends on the amount of bacteria that is deposited, how quickly it dies, how much and when it rains, and how much runoff is generated. The model considered these and other factors to predict the amount of bacteria in Hogue Creek at any given time. To make sure that the predictions were accurate, the model was tested with real-world data. The model was used to predict bacteria levels in Hogue Creek from 2000 to 2005, and these predictions were compared to bacteria samples collected from Hogue Creek during that time period. The model was found to be accurate within 5% of the measured data. Once the model passed this test, it could be used to make predictions about how bacteria levels in Hogue Creek might change if we better controlled the bacteria sources.

Frequently Asked Question:

Why use a computer model?
Sampling and testing tells 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.

1.5. CURRENT CONDITIONS

VADEQ used the tested computer model to figure out where the bacteria in Hogue Creek were currently coming from. The answer to this question depends a lot on whether it has been raining or not. Figure 1-2 shows that when it has not rained much in a while and stream flows are low, most of the bacteria in Hogue Creek (50%) comes from cattle that wade and defecate in the water. Significant amounts also come from runoff of residential and commercial lands (23%), agricultural or farm runoff (11%) and straight pipes (9%).



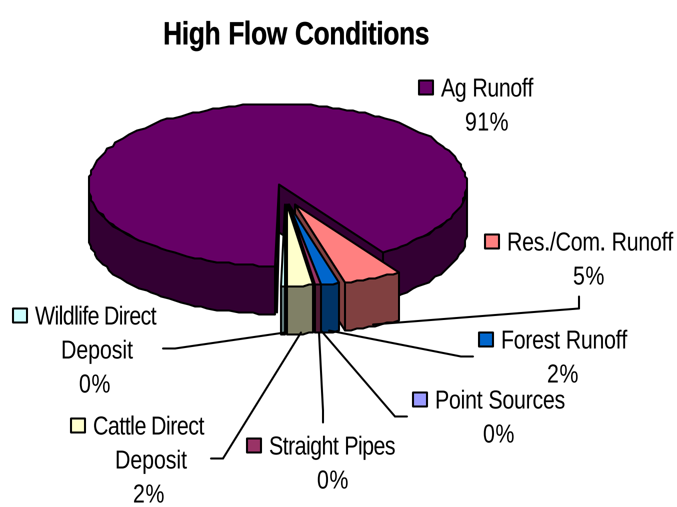


Figure 1-2. Where are the Bacteria Currently Coming From?

When it has been raining a lot and stream flows are high, almost all of the bacteria in Hogue Creek (91%) seems to be coming from farm runoff. At higher flows, only 5% of bacteria comes from residential/commercial runoff, 2% from forest runoff, and 2% from cattle direct deposit.

1.6. FUTURE GOALS (THE TMDL)

After figuring out where the bacteria in Hogue Creek is currently coming from, the computer model was used to figure out how much bacteria loads need to be reduced to clean up Hogue Creek. The ultimate goal is for Hogue Creek never to exceed the safe level. To do this, all of the straight pipes would need to be fixed, bacteria from cattle wading in the stream would need to be lowered by 97%, and runoff from farm land and residential/commercial land would also need to be lowered by 97% (Table 1-1). If these reductions were made, the water quality standard for bacteria would be met and less than 2.20 x 10^{13} *E. coli* per year would enter Hogue Creek. This safe amount, known as the total maximum daily load (TMDL), is the maximum amount of bacteria that can enter Hogue Creek and still meet water quality standards. A small portion of this amount (6.58 x 10^{11} *E. coli* per year) is reserved for the permitted sewage treatment plants in the area (point sources), but most of the amount allows for bacteria from runoff and sources that do not come out of a pipe (nonpoint sources) (Table 1-2).

> **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.

Table 1-1. Reductions in Bacteria Needed to Clean Up Hogue Creek.

Source	Bacteria Reductions Necessary to Not Violate the Safe Level More than 10.5% of the Time	Bacteria Reductions Necessary to Meet Safe Level All of the Time
Land Based		
Forest Runoff	0%	0%
Farm Runoff	67%	97%
Residential/Commercial Runoff	67%	97%
Direct		
Straight Pipes	100%	100%
Cattle Direct Deposit	67%	97%
Wildlife Direct Deposit	0%	0%
Permitted Point Sources	0%	0%

> **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).

Table 1-2. Total Maximum Daily Load of Bacteria (*E. coli*) in Hogue Creek that will Meet the Water Quality Standard.

Stream	Amount from Permitted Point Sources (WLA) (cfu/yr)	Amount from Nonpoint Sources (LA) (cfu/yr)	Margin of Safety	Total Maximum Daily Load (cfu/yr)
Hogue Creek (VAV-B06R)	6.58E+11	2.13E+13	Implicit	2.20E+13

1.7. WHAT HAPPENS NEXT

VADEQ will ask for 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 goal for Hogue Creek, but the next step is a clean-up plan (or Implementation Plan) that lays out how that goal will be reached. The clean-up plan will set intermediate goals and describe actions that should be taken to clean up Hogue Creek. Many of these actions are obvious and can be taken right now to improve the health and safety of Hogue Creek. Some of these actions are listed below:

- Fence out cattle from streams and provide alternative water sources
- Find and fix straight pipes
- Leave a band of 35 – 100 ft along the stream natural so that it buffers or filters out bacteria from farm or residential land (a riparian buffer)
- Find and fix failing septic systems
- Pick up pet waste on residential and commercial land

These and other actions will be listed in the clean-up plan with associated costs and how much of each action it will take to meet the goals. The clean-up plan will also identify potential sources of money to help in the clean-up efforts. Most of this money will probably be available in the form of cost-share programs, which share the cost of improvements with the landowner. Please be aware that the state or federal government will not fix the problems with Hogue Creek. It is primarily the responsibility of individual landowners and local governments to take the actions necessary to improve Hogue Creek. The state agencies will help with developing the plan and finding money to support the plan, but actually making the improvements is up to those that live in the Hogue Creek 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 Hogue Creek.

VADEQ will continue to sample bacteria in Hogue Creek and monitor the progress of clean up. This sampling will let us know when the clean up has reached certain milestones listed in the plan. One of these important milestones will be the point at which Hogue Creek is taken off the "Dirty Waters List". This can happen when Hogue Creek bacteria are above the safe level no more than 10.5% of the time. Using the computer model, we think that we can get to that point by eliminating straight pipes and reducing cattle direct deposits and farm and residential runoff by 67%. This is an achievable step, and it should take considerably less effort than meeting the ultimate goal of the TMDL. Most of the suggested actions to reduce bacteria (best management practices) are more than 67% effective, so this intermediate goal is achievable without everyone participating in the clean-up. To begin moving towards these clean-up goals, VADEQ recommends that concerned citizens bond 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.

Frequently Asked Question:

How will the TMDL be implemented? 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.

CHAPTER 2: INTRODUCTION

2.1. WATERSHED LOCATION AND DESCRIPTION

The Hogue Creek watershed (Watershed ID VAV-B06R) is located in Frederick County west of Winchester, Virginia (Figure 2-1). Hogue Creek is situated in a relatively narrow valley on the eastern slope of the Appalachian Mountains between Great North Mountain and Little North Mountain, in the Ridge and Valley EcoRegion (Woods *et al.*, 1999). The Hogue Creek watershed is 26,686 acres in size and is primarily forested (79%). The remainder of the land use is pasture or hay (19%), with less than 1% in open water, row crops, transitional, or urban land uses. Hogue Creek flows north and discharges into Back Creek, which flows into West Virginia and joins the Potomac River (USGS Hydrologic Unit Code 02070004). The Potomac River empties into the Chesapeake Bay.

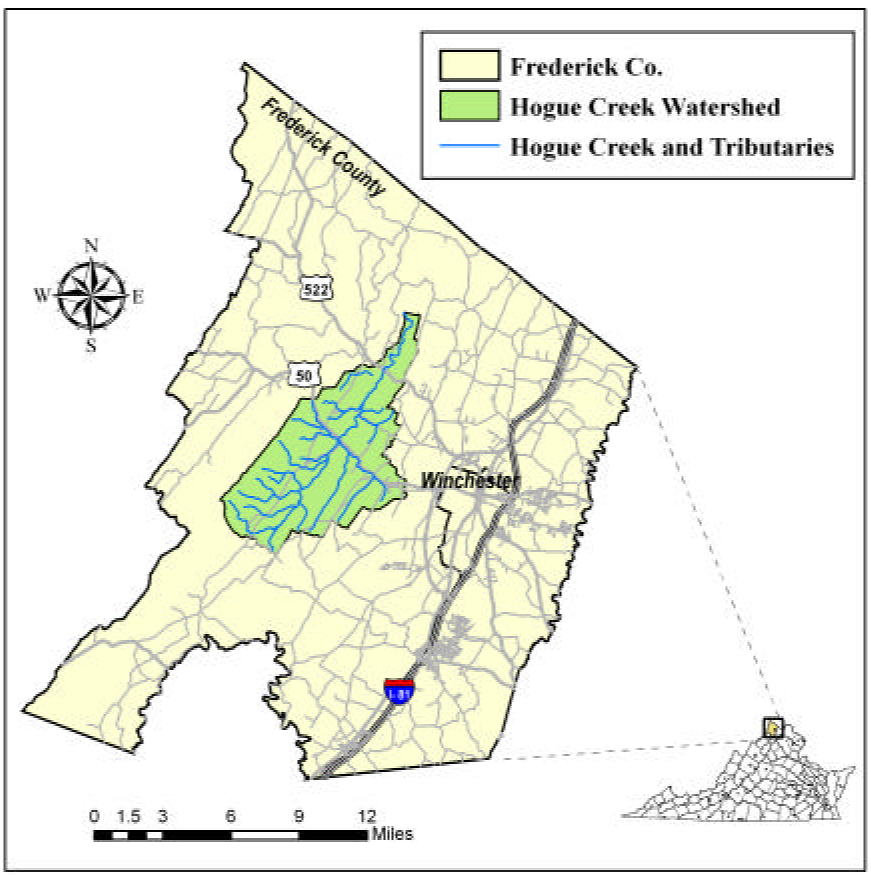


Figure 2-1. Location of Hogue Creek Watershed.

2.2. DESIGNATED USES AND APPLICABLE WATER QUALITY STANDARDS

Virginia's Water Quality Standards (9 VAC 25-260-5) 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"* (State Water Control Board, 2006).

The above listed uses are designated for all state waters, including Hogue Creek. Hogue Creek does not support the recreational (swimming) designated use due to violations of the water quality criterion for bacteria.

2.2.2. Bacteria Water Quality Criterion (9 VAC 25-260-170)

Because many human diseases and pathogens are transmitted through the feces, the presence of fecal matter in the water poses a human health risk. Swimming in fecally-contaminated water increases the risk of gastrointestinal illness and infection. To protect human health during primary contact recreation (e.g., swimming), the Commonwealth of Virginia has set limits on the amount of specific fecal bacteria in all state waters. The current bacteria criterion for freshwater (effective January 15, 2003) includes limits on the amount of fecal coliform bacteria in water and the amount of *Escherichia coli* (*E. coli*) in water. Fecal coliforms are a group of bacteria that are found in the intestinal tract of warm-blooded animals. Even though most fecal coliforms are not pathogenic, their presence in water indicates contamination by fecal material. *E. coli* is a specific bacteria species within the group of fecal coliforms. Studies have shown that there is a stronger correlation between the concentration of *E. coli* and the incidence of gastrointestinal illness than there is with fecal coliform (USEPA, 1986), so the state is transitioning from a fecal coliform standard to an *E. coli* standard. All freshwaters are subject to the *E. coli* standard described below, and until June 30, 2008, the interim fecal coliform standard described below will also apply to any sampling stations with fewer than 12 *E. coli* samples.

The following bacteria criteria shall apply to all freshwaters in the Commonwealth in order to protect primary contact recreational uses (State Water Control Board, 2006):

Interim Fecal Coliform Criterion:

> *Fecal coliform bacteria shall not exceed a geometric mean of 200 fecal coliform bacteria per 100 mL of water for two or more samples over a calendar month nor shall more than 10% of the total samples taken during any calendar month exceed 400 fecal coliform bacteria per 100 mL of water. This criterion shall not apply for a sampling station after the bacterial indicators described in subdivision 2 of this subsection [E. coli criterion] have a minimum of 12 data points or after June 30, 2008, whichever comes first.*

***Escherichia coli* Criterion:**

> *E. coli bacteria concentrations for freshwater shall not exceed a geometric mean of 126 counts per 100 mL for two or more samples taken during any calendar month and shall not exceed an instantaneous single sample maximum of 235 cfu/100mL.*

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”, or the “303(d) List”, or the “TMDL List”, or even the “Dirty Waters List”. The Commonwealth of Virginia accomplishes both of these requirements through the publishing of an Integrated 305(b)/303(d) Water Quality Assessment Report ever two years. Each report assesses water quality by evaluating monitoring data from a five-year window. The assessment window for the most recent 2006 305(b)/303(d) Integrated Water Quality Assessment Report was from January 1, 2000 through December 31, 2004.

> **Interesting Fact:**
>
> Over 9,000 miles of Virginia streams and rivers were listed as impaired in the 2006 Water Quality Assessment Report.

According to VADEQ’s Water Quality Assessment Guidance Manual (VADEQ, 2005), water bodies are assessed as Fully Supporting the recreational designated use if 10.5% or fewer samples within the 5-year monitoring window violate the applicable bacteria standard. Water bodies are assessed as Not Supporting the recreational designated use (or "Impaired") if more than 10.5% of samples within the 5-year monitoring window exceed the applicable bacteria standard.

2.3.1. Hogue Creek Impairment Listing

Hogue Creek was initially listed as impaired on Virginia's 2004 303(d) Impaired Waters List (VADEQ, 2004a) due to water quality violations of the bacteria standard (Section 2.2). During the 2004 assessment window (January 1, 1998 to December 31, 2002), 6 out of 27 (or 22%) of the fecal coliform samples collected from Hogue Creek exceeded the bacteria standard. Since the violation rate exceeded 10.5%, Hogue Creek was listed as impaired. This impaired listing continued in the 2006 303(d) Impaired Waters List (VADEQ, 2006). During the 2006 assessment window (January 1, 2000 to December 31, 2004), 8 out of 23 (or 35%) of the fecal coliform samples collected from Hogue Creek exceeded the bacteria standard. The bacterial impairment designated in the 303(d) listing extends from the headwaters of Hogue Creek to its confluence with Back Creek, for a total of 16.58 miles (Assessment Unit ID: VAV-B06R_HOC01A00).

In addition to the bacteria impairment addressed by this TMDL, Hogue Creek is listed on the 2006 303(d) Impaired Waters List (VADEQ, 2006) for water quality violations of the temperature standard for stockable trout waters. Trout are seasonally stocked in Hogue Creek, however, according to the Virginia Department of Game and Inland Fisheries (VADGIF, 2005), Hogue Creek is not considered a cold water fishery, and the stream should not be expected to meet the temperature standard for stockable trout waters (21°C maximum) year round. For this reason, the Hogue Creek temperature impairment was listed in the 2006 Report as a Category 4C water – Impaired, but not needing a TMDL due to natural conditions. VADEQ is considering revising the temperature standard for stockable trout waters to better reflect the seasonal application of this designated use in some waters.

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 water bodies 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 water body, allocates the load among the pollutant contributors, and provides a framework for taking actions to restore water quality.

Due to the bacteria impairment listed for Hogue Creek, this segment was scheduled for TMDL development by 2014 and assigned a TMDL Group ID of 01595. This report establishes the bacteria TMDL for this impaired segment.

2.4.1. Applicable Water Quality Standard for TMDL Development

The Hogue Creek TMDL will be developed to meet the geometric mean and instantaneous *E. coli* standards of 126 and 235 cfu/100ml, respectively. Because the majority of historic water quality monitoring data has been for fecal coliform rather than *E. coli*, the modeling will be conducted with fecal coliform inputs, and then a translator equation will be used to convert the output to *E. coli* (see Section 5.3.5).

CHAPTER 3: WATERSHED CHARACTERIZATION

3.1. WATER RESOURCES

The Hogue Creek watershed is located just west of the city of Winchester, and includes the town of Hayfield. The watershed was divided into 11 sub-watersheds to assist in the characterization of spatially distributed pollutant sources for modeling purposes, as shown in Figure 3-1. The main branch of Hogue Creek runs for 16.584 miles from the headwaters until it enters Back Creek. The Hogue Creek watershed contains intermittent tributaries as well as perennial tributaries. Named tributaries within the Hogue Creek watershed include Bucher Run, Bear Run, Poplar Run, Gap Run, and Keckley Run.

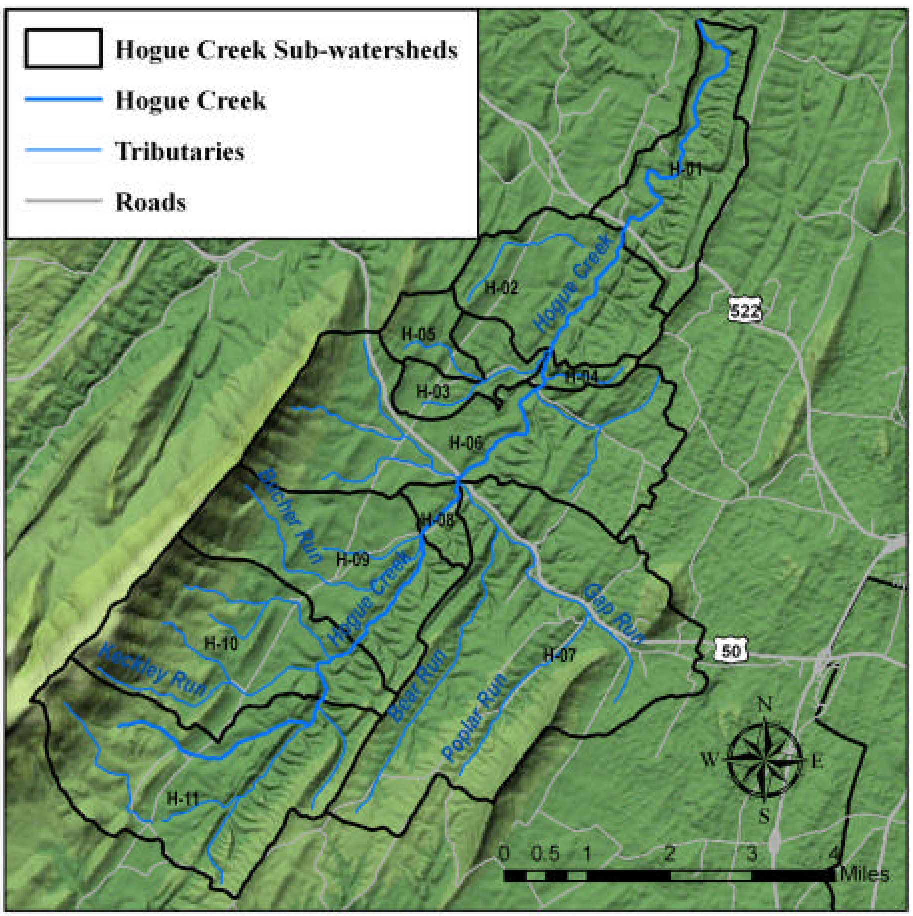


Figure 3-1. Hogue Creek Sub-watersheds and Tributaries.

3.2. ECOREGION

The Hogue Creek watershed is located in the Ridge and Valley Level III Ecoregion (Woods *et al.*, 1999). The Ridge and Valley Level III Ecoregion is characterized by its generation from sedimentary rocks, including sandstone, shale, limestone, and dolomite. This ecoregion consists of alternating forested ridges and agricultural valleys that are elongated and folded and faulted. Level IV Ecoregions within the watershed include the Northern Sandstone Ridges on Great North Mountain to the west, a thin band of Northern Limestone/Dolomite Valleys at the base of Great North Mountain, and a majority of Northern Shale Valleys.

The Northern Sandstone Ridges are characterized by high, steep, forested ridges with narrow crests. The ridges are primarily vegetated with Appalachian Oak forests. Elevations on the ridge forming the western boundary of the watershed range from approximately 1800 to 2200 feet. Streams flowing off of this ridge are high gradient and have low buffering capacity due to the underlying sandstone.

The Northern Limestone/Dolomite Valley Level IV Ecoregion, found at the base of Great North Mountain, is characterized by broad, level to undulating, fertile valleys that are extensively farmed, and contain scattered woodlands on steeper slopes. Sinkholes, underground streams, and other karst features have developed on the underlying limestone and dolomite. Streams tend to flow year-round and have gentle slopes.

The Northern Shale Valley Level IV Ecoregion, which comprises the eastern two-thirds of the Hogue Creek watershed, is characterized by rolling valleys and low hills and is underlain mostly by shale, siltstone, and fine-grained sandstone. Soils are generally less fertile than limestone-derived soils at the base of Great North Mountain.

3.3. SOILS AND GEOLOGY

Soils data were obtained from the U.S. General Soil Map (STATSGO) database (NRCS, 2006). The predominant soils in the Hogue Creek watershed are the Berks-Weikert-Bedington series (VA0066). These soils are found in the center and eastern portions of the watershed (Figure 3-2) in roughly the same area characterized as the Northern Shale Valley Level IV Ecoregion. These soils are moderately deep, well drained soils weathered from shale, siltstone, and fine-grained sandstone. Permeability in these soils is moderate to moderately rapid, and depth to a seasonal high water table is more than six feet. These soils are in hydrologic soil group C.

Along the Great North Mountain ridge are Wallen-Dekalb-Drypond series soils (VA005). These soils are moderately deep, somewhat excessively drained soils weathered from fine-grained sandstone, siltstone, and shale. These soils are typically on mountain tops and have moderately rapid permeability. These soils are in hydrologic soil group B.

Along the base of Great North Mountain, there is a band of Frederick-Carbo-Timberville soils (VA003) that are coincident with the Northern Limestone/Dolomite Valley Level IV Ecoregion. These soils consist of very deep, well drained soils derived mainly from dolomitic limestone with interbeds of sandstone, siltstone, and shale. Depth of these soils to bedrock is more than 72 inches, and permeability is moderate. These soils are in hydrologic soil group B.

A small portion of the watershed consists of Hagerstown-Duffield-Clarksburg soils (VA069). These soils consist of deep and very deep, well drained soils formed in residuum of hard gray limestone. Rock outcrops are common in this soil type, and permeability is moderate. These soils are in hydrologic soil group C.

For modeling purposes, the soil types in each sub-watershed were characterized as either B, C, or mixed B/C hydrologic soils as described in Table 3-1.

Table 3-1. Hydrologic Soil Types in Hogue Creek Sub-watersheds.

Sub-watershed	Hydrologic Soil Type
H-01	C
H-02	C
H-03	C
H-04	C
H-05	B
H-06	B/C
H-07	C
H-08	C
H-09	B/C
H-10	B/C
H-11	B/C

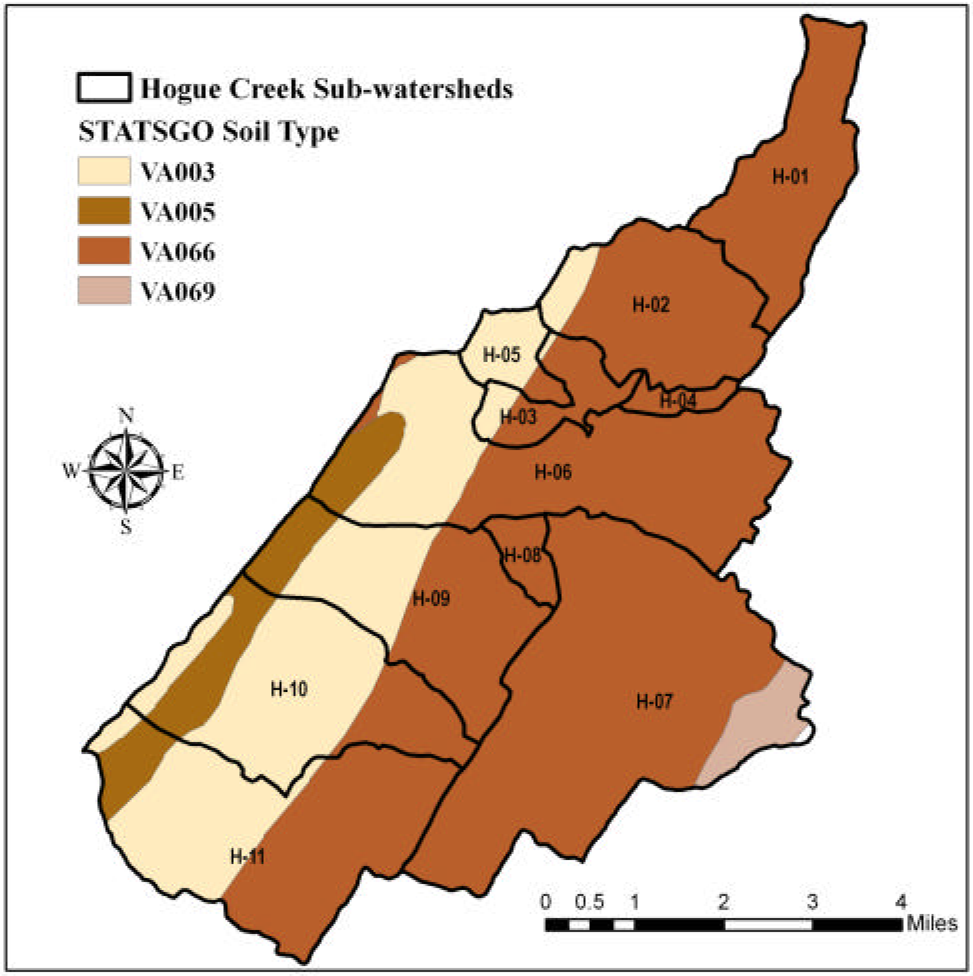


Figure 3-2. Soil Types Within Hogue Creek Watershed.

3.4. CLIMATE

Climate data from the nearby Winchester 3ESE weather station can be used to characterize the Hogue Creek watershed (SERCC, 2006). The average annual precipitation at this location from 1948-2005 is 38.6 inches, with average monthly precipitation varying from 2.41 inches in January to 3.90 inches in July. Average annual snowfall is 22.4 inches, occurring in November through April, with 57% occurring in January and February. The average annual maximum and minimum temperatures are 65.0 and 42.3°F, respectively. The average monthly maximum temperature of 86.6°F occurs in July, and the average monthly minimum temperature of 22.3°F occurs in January.

3.5. LAND COVER

Land cover data for the Hogue Creek watershed was obtained from the 1992 National Land Cover Dataset (NLCD) for Virginia (USGS, 1999). This database was developed from satellite imagery captured in the early 1990s, and is currently the most detailed and up-to-date land cover data available for the Hogue Creek watershed. Figure 3-3 shows the land cover in the Hogue Creek watershed. This watershed is primarily forested (78.7%), with most of the remainder in pasture or hay (18.9%). Those agricultural lands in the watershed are mostly located along the stream corridor and in a band to the west of Hogue Creek, where slopes are shallow and more fertile dolomite/limestone derived soils are present. Only slightly above 1% of the watershed consists of commercial, transitional, urban, and residential land cover. These areas are primarily confined to the US Route 50 corridor, which bisects the watershed from east to west.

Table 3-2 shows the acreage and percentage of each land cover type in the Hogue Creek watershed. These 15 land cover categories were further summarized into 6 aggregated land cover categories (plus open water) to simplify modeling efforts. Section 5.2.2 describes how land cover data was modified to provide an accurate land use data set for modeling the watershed.

An analysis of riparian land cover was conducted using a geographic information system (GIS). Land cover was characterized within a 100-foot buffer on either side of streams in the Hogue Creek watershed. In general, land cover within the riparian corridor was similar to overall watershed-scale land cover. Overall, 86% of the riparian corridor was forested, and 12% was in pasture and hay (Table 3-3). Only 1% was considered residential, and <1% was in row crops and transitional/commercial land. Within specific sub-watersheds, however, significantly less land within the riparian corridor was forested. For instance, in sub-watershed H-03, as little as 56% of the riparian corridor was forested. In those sub-watersheds with less than the average 86% of forested riparian area (H-03, H-05, H-06, H-08), pasture and hay lands contributed from 24 to 43% of the land cover in riparian areas.

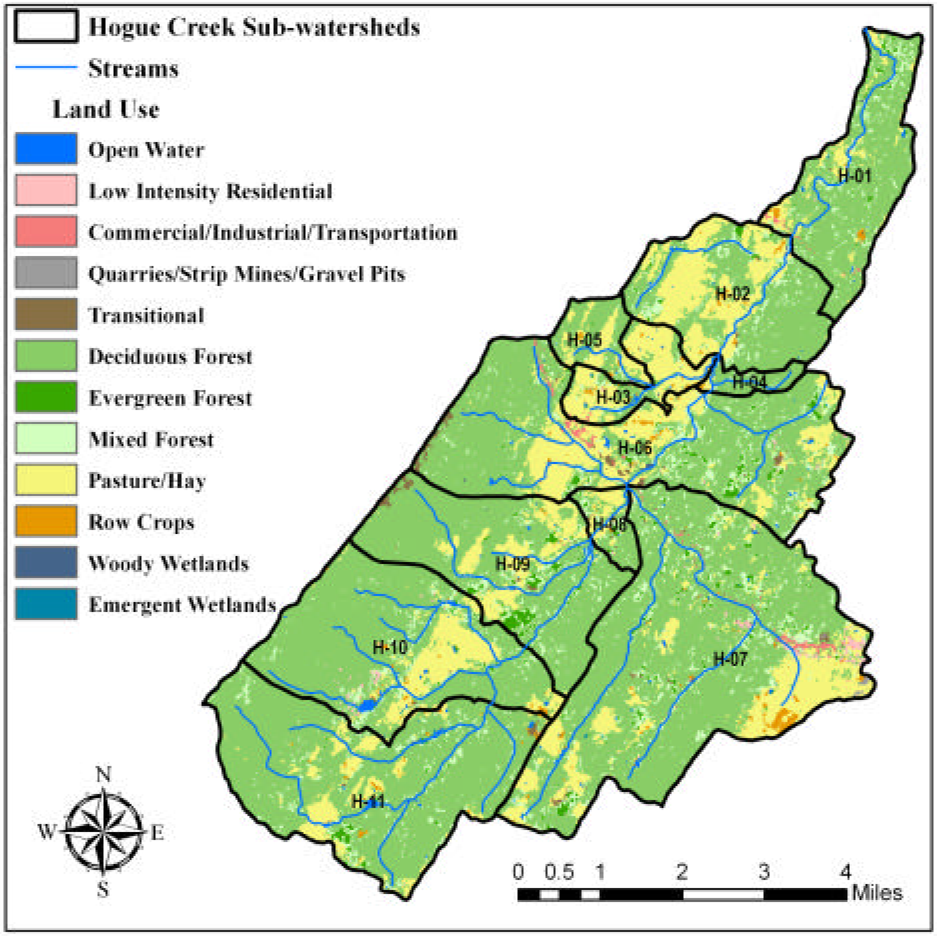


Figure 3-3. Land Cover in the Hogue Creek Watershed.

Table 3-2. Summary of Land Cover in the Hogue Creek Watershed.

Land Cover	Acres	Percent	Aggregated Land Cover	Acres	Percent
Deciduous Forest	18,628	68.8%	Forest	20,993	78.7%
Evergreen Forest	409	1.5%			
Mixed Forest	1,938	7.3%			
Woody Wetlands	9.6	<0.1%			
Emergent Wetlands	8.7	<0.1%			
Open Water	106	0.4%	Water	106	0.4%
Pasture/Hay	5,048	18.9%	Pasture/Hay	5,048	18.9%
Row Crops	198	0.7%	Row Crops	198	0.7%
Transitional	138	0.5%	Transitional/ Commercial	248	0.9%
Bare Rock/Sand/Clay	0	0.0%			
Quarries/Strip Mines/Gravel Pits	12	0.1%			
Commercial/Industrial/Transportation	97	0.4%			
Low Intensity Residential	93	0.4%	Low Intensity Residential	93	0.4%
Urban/Recreational Grasses	0	0.0%			
High Intensity Residential	0	0.0%	High Intensity Residential	0	0.0%
Total	**26,686**	**100.0%**	**Total**	**26,686**	**100.0%**

Table 3-3. Land Cover Percentages within the Riparian Corridor of Hogue Creek and Tributaries (100-foot buffer around streams).

Sub-watershed	Forest	Pasture/Hay	Row Crops	Transitional/ Commercial	Low Intensity Residential	High Intensity Residential
H-01	91%	8%	1%	0%	0%	0%
H-02	86%	12%	0%	2%	0%	0%
H-03	56%	43%	0%	0%	0%	0%
H-04	91%	8%	1%	1%	0%	0%
H-05	67%	26%	5%	1%	1%	0%
H-06	74%	25%	0%	0%	0%	0%
H-07	86%	10%	1%	0%	3%	0%
H-08	76%	24%	0%	0%	0%	0%
H-09	91%	9%	0%	0%	0%	0%
H-10	93%	6%	0%	0%	0%	0%
H-11	96%	4%	0%	0%	0%	0%
All Sub-watersheds	**86%**	**12%**	**<1%**	**<1%**	**1%**	**0%**

3.6. STREAM FLOW DATA

The U.S. Geological Survey (USGS) operates a flow monitoring gage on Hogue Creek near Hayfield, Virginia (Station 01613900). This station has been in operation since 1961, with the exception of a period from 1987-1992 when the station was inactive. For the 38 years of record, the annual mean flow averaged 15.9 cfs. The year of highest annual mean flow was 1996, when flow averaged 35.1 cfs. The year of lowest annual mean flow was 1969, when flow averaged 4.18 cfs. Figure 3-4 shows the annual average flow in Hogue Creek for each year of record.

Stream flows in Hogue Creek are generally highest in the spring and decrease through the summer and fall (Figure 3-5). The average monthly stream flow peaks in March at 37.7 cfs and decreases to a low of 4.7 cfs in July. Stream flows during the winter and spring are also much more variable than throughout the summer and fall. Upper 95% confidence intervals (based on a lognormal distribution) for average monthly stream flows were as high as 75.5 cfs in March.

Interesting Fact:

The highest recorded flow in Hogue Creek was 4090 cubic feet per second following Hurricane Fran on September 6, 1996. That is more than 250 times the average annual flow and is enough to fill an Olympic-size swimming pool every 21 seconds.

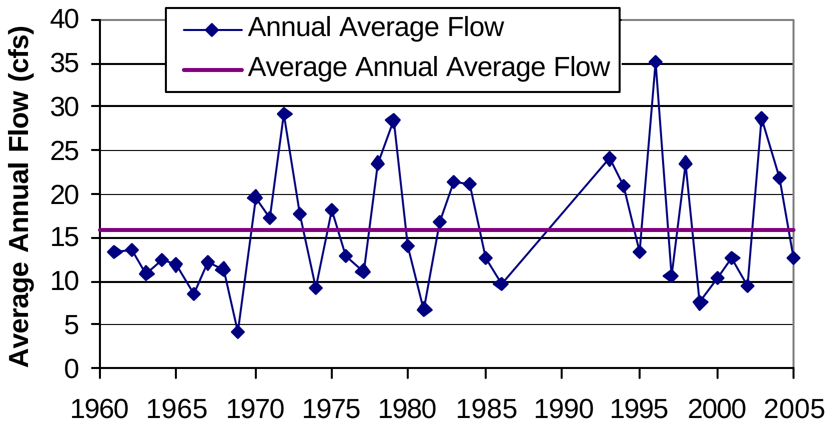
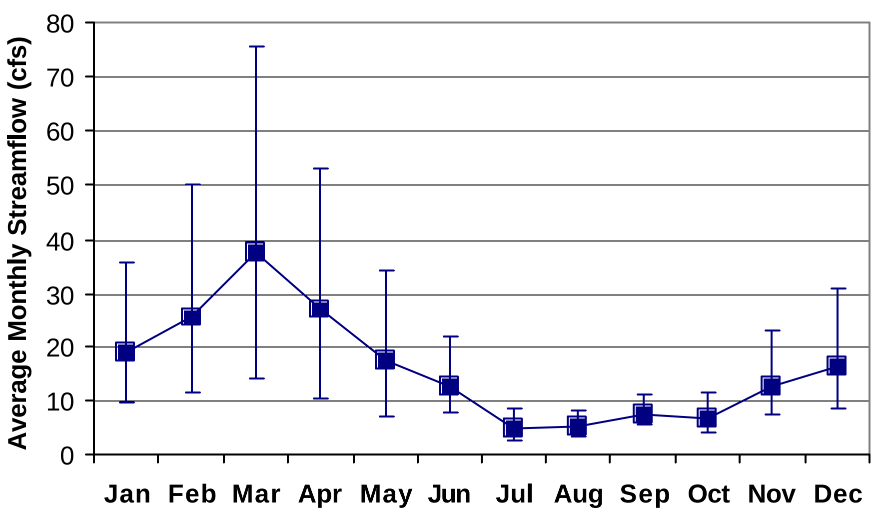


Figure 3-4. Annual Average Flow in Hogue Creek.



* Error bars represent upper and lower 95% confidence intervals based on a lognormal distribution.

Figure 3-5. Average Monthly Stream Flow in Hogue Creek.

3.7. WATER QUALITY DATA

VADEQ has been monitoring fecal coliform in Hogue Creek since 1991. Since that time, VADEQ has collected 72 fecal coliform samples from the primary monitoring station (1AHOC006.23) on Indian Hollow Road (Figure 3-6). In July 2006, two additional monitoring stations were added (1AHOC003.67 and 1AHOC008.96) to provide more information for this study. Table 3-4 summarizes fecal coliform data from each station. Within the limited data set for stations 1AHOC003.67 and 1AHOC008.96, the fecal coliform water quality standard (400 cfu/100ml) has not been violated. At station 1AHOC006.23, fecal coliform samples have violated the fecal coliform standard 21% of the time since 1991. Fecal coliform levels at this location have exceeded the maximum measurement range (<8000 cfu/100ml) on occasion and averaged above the standard (average of 471 cfu/100ml). Figure 3-7 shows the measured fecal coliform concentrations in Hogue Creek since 1991.

> Frequently Asked Question:
>
> ***How bad is Hogue Creek compared to other streams?***
> Comparing fecal coliform data within the last five years, Hogue Creek ranks 78th out of 108 monitoring stations in DEQ's Valley Region. This places Hogue Creek in the bottom 28%.

In 2004, VADEQ began monitoring *E. coli* as well as fecal coliform in Hogue Creek. Table 3-5 summarizes *E. coli* data from each Hogue Creek monitoring station. No violations of the *E. coli* standard (235 cfu/100ml) were observed at station 1AHOC003.67, and one violation (17%) was observed at station 1AHOC008.96. At station 1AHOC006.23, violation rates of the *E. coli* standard (24%) were similar to fecal coliform violation rates. *E coli* levels ranged from <25 to 1400 cfu/100ml and averaged 204 cfu/100ml. Figure 3-8 shows the measured *E. coli* concentrations in Hogue Creek since 2004.

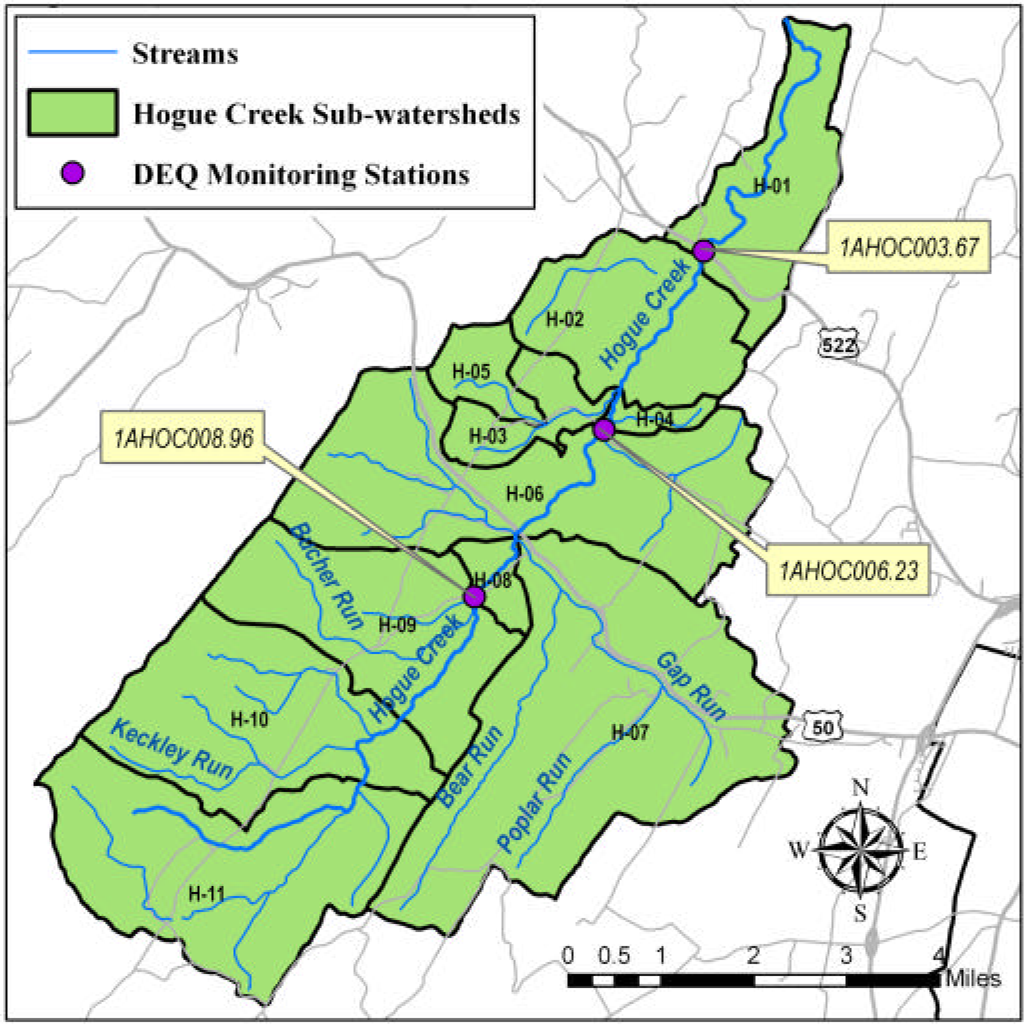


Figure 3-6. Water Quality Monitoring Stations in the Hogue Creek Watershed.

Table 3-4. Summary Statistics for Fecal Coliform Data Collected from Hogue Creek.

	1AHOC003.67	1AHOC006.23	1AHOC008.96
Sampling Dates	7/24/06 - 12/19/06	7/30/91 - 12/19/06	7/24/06 - 12/19/06
Number of Samples	6	72	6
Min	<25	<25	<25
Max	180	>8000	220
Average	106	471	96
Median	113	100	63
Geometric Mean	78	187	67
Violation Rate	0%	21%	0%

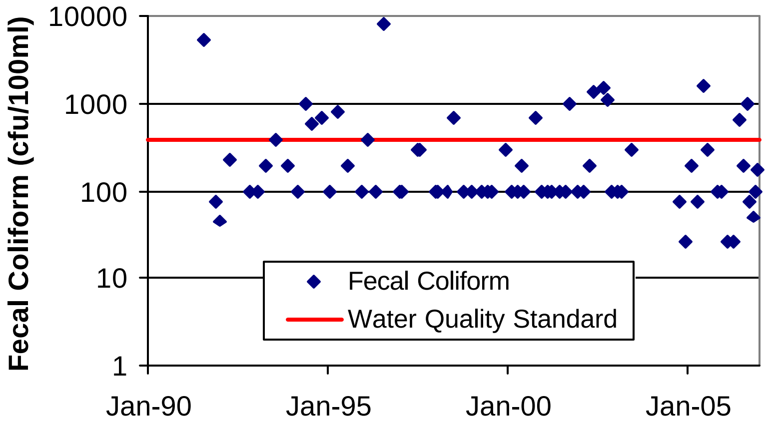


Figure 3-7. Fecal Coliform Levels in Hogue Creek.

Table 3-5. Summary Statistics for *E. coli* Data Collected from Hogue Creek.

	1AHOC003.67	1AHOC006.23	1AHOC008.96
Sampling Dates	7/24/06 - 12/19/06	10/6/04 - 12/19/06	7/24/06 - 12/19/06
Number of Samples	6	17	6
Min	<25	<25	25
Max	150	1400	250
Average	50	204	92
Median	25	50	75
Geometric Mean	38	79	67
Violation Rate	0%	24%	17%

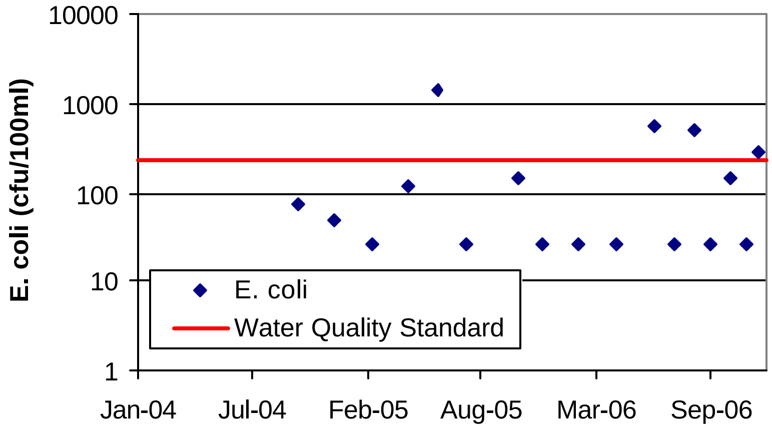


Figure 3-8. *E. coli* Levels in Hogue Creek.

3.7.1. Temporal Variation

While individual fecal coliform levels vary substantially from sample to sample, there is little trend in fecal coliform levels since 1990. Table 3-6 summarizes fecal coliform data within 5-year windows from 1990 to present. Fecal coliform levels were higher in 1990-1995 with a violation rate of 31% and geometric mean of 285 cfu/100ml. Since that time period, levels have been relatively consistent. Geometric means within the three most recent periods have varied only from 188 to 195 cfu/100ml, and violation rates have been from 14 to 22%.

Table 3-6. Fecal Coliform Violation Rates and Geometric Means Since 1990.

	1990-1995	1995-2000	2000-2005	2005-2006
Number of Samples	13	21	23	15
Number of Violations	4	3	5	3
% Violation Rate	31%	14%	22%	20%
Geometric Mean	285	193	188	195

3.7.2. Seasonal Variation

Fecal coliform data from Hogue Creek were analyzed for seasonal trends by plotting the violation rates for each month (Figure 3-9). A very strong seasonal trend was observed. No violations of the fecal coliform standard were observed during winter months (December-March). Violation rates peaked to as much as 50% in the warmer months of May-October. The overall violation rate for May-October was 42% compared to only 5% for the 6 months from November-April. This distinct seasonal trend indicates that the majority of bacteria are from seasonal sources such as direct deposit from livestock or runoff from seasonal applications of manure. Bacteria from these sources are more prevalent in the warmer months because cattle wade in streams more frequently and manure applications are typically made during the growing season. Other sources such as wildlife, pets, septic systems, and point sources are more constant throughout the year and would not explain the observed seasonal patterns.

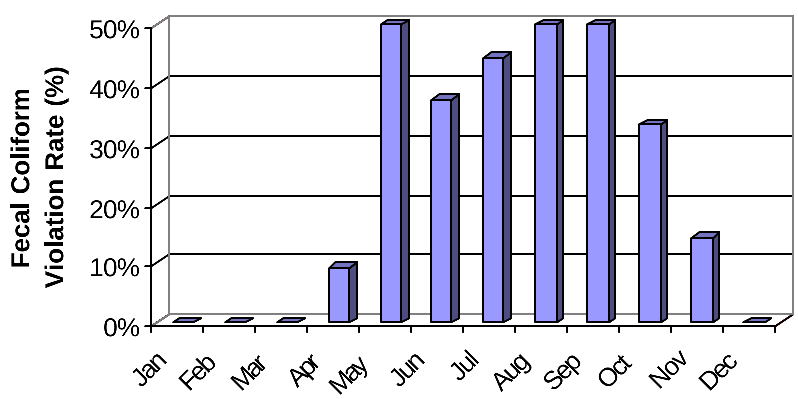


Figure 3-9. Monthly Violation Rate of Fecal Coliform Standard in Hogue Creek.

3.7.3. Variation with Flow

Fecal coliform levels were compared across Hogue Creek flow regimes to determine if violations occurred more frequently under specific flow conditions. Figure 3-10 plots fecal coliform levels in Hogue Creek against the flow frequency curve. Fecal coliform samples were collected under all flow regimes from very low flow to very high flow. Violation rates were highest (40%) for samples collected during very low flow conditions (lowest 10th percentile of flows). Violation rates were slightly lower (32%), but still relatively high, under low flow conditions (from 10th to 40th percentile flows). Under moderate flow conditions (from 40th to 60th percentile flows) violation rates were lower (25%), and under high flow conditions no violations occurred. Under very high flow conditions, violation rates increased to 25%. Clearly, violations of the fecal coliform standard are more prevalent under low flow conditions. Ten of the 14 violations (or 71%) occurred at less than median flow. Violation rates also steadily increased from moderate flow conditions to low flow conditions to very low flow conditions. This suggests that the primary bacteria sources in the watershed are direct instream sources and not land derived sources. This would include straight pipes, point sources, and cattle or wildlife direct deposit. Combined with information about seasonal trends, this would indicate that cattle direct deposits may be the primary source of bacteria violations in Hogue Creek. The other low flow sources of bacteria would be relatively consistent throughout the year.

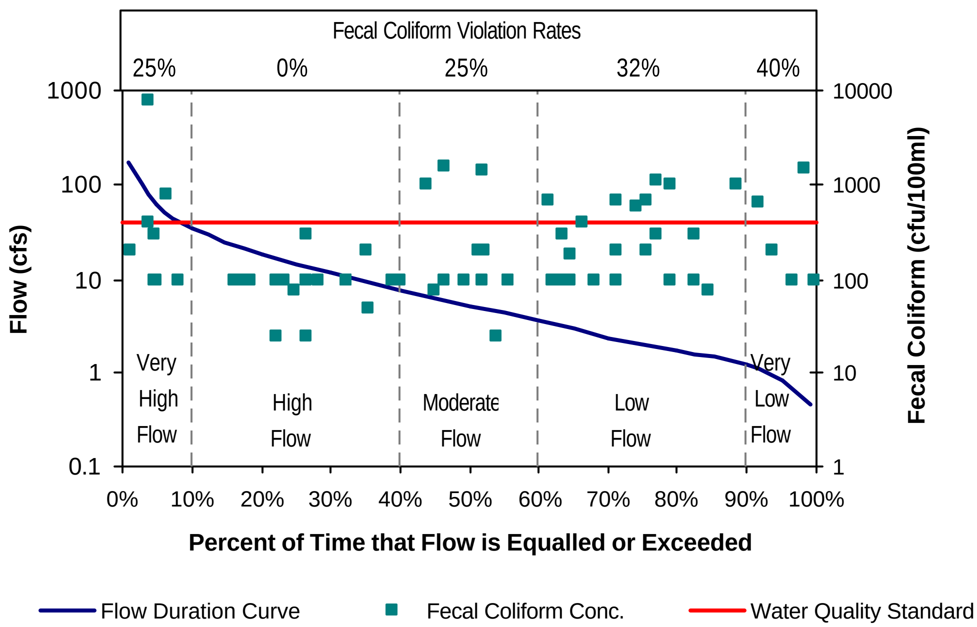


Figure 3-10. Fecal Coliform Levels in Hogue Creek Under Various Flow Frequencies.

CHAPTER 4: SOURCE ASSESSMENT OF FECAL COLIFORM

Fecal coliform sources in the Hogue Creek watershed were assessed using information from the following sources: VADEQ, Virginia Department of Conservation and Recreation (VADCR), Virginia Department of Agriculture and Consumer Services (VDACS), Virginia Department of Health (VDH), Virginia Department of Game and Inland Fisheries (VADGIF), Virginia Cooperative Extension (VCE), Lord Fairfax Soil and Water Conservation District, public participation, watershed reconnaissance and monitoring, published information, and professional judgment. Fecal coliform sources in the watershed include humans, pets, livestock, and wildlife. Point and nonpoint human sources are present. This section describes and quantifies the fecal coliform loads from each source within the watershed.

4.1. PERMITTED POINT SOURCES

Within the Hogue Creek watershed, there are two dischargers that hold individual Virginia Pollutant Discharge Elimination System (VPDES) permits. These include Indian Hollow Elementary School (VA0071927) and Gainesboro Elementary School (VA0091898). Indian Hollow Elementary School is permitted to discharge up to 7,000 gal/d of treated sewage with a fecal coliform concentration less than 200 cfu/100ml. Typical flows from this facility are considerably less than the permitted flow and have averaged 2,500 gal/d since 2001. Gainesboro Elementary School is permitted to discharge up to 10,000 gal/d of treated sewage with a fecal coliform concentration less than 200 cfu/100ml. While this permit was issued in July 2006, the facility is not yet constructed and operating.

In addition to the two individual VPDES permits in the Hogue Creek watershed, there are 46 Single Family Home (SFH) Domestic Sewage general permits. These permits are issued for alternative waste treatment systems for homes that are not approved for traditional septic systems. These general permits allow the discharge of up to 1,000 gal/d of treated sewage with a fecal coliform concentration less than 200 cfu/100ml. Table 4-1 lists the permitted point sources in the Hogue Creek watershed along with bacteria wasteload allocations (WLA) for those permitted discharges. Figure 4-1 shows the location of point source discharges in the Hogue

Creek watershed. Those SFH permits that discharge to perennial streams are shown in red, and those that discharge to dry ditches or intermittent streams are shown in yellow.

Table 4-1. Permitted Point Sources in the Hogue Creek Watershed.

Facility	Permit #	Permitted Flow (MGD)	Permitted Fecal Conc. (cfu/100ml)	Permitted *E. coli* Conc. (cfu/100ml)	Permitted Fecal WLA (cfu/yr)	Permitted *E. coli* WLA (cfu/yr)
Indian Hollow Elementary School	VA0071927	0.007	200	126	1.93E+10	1.22E+10
Gainesboro Elementary School	VA0091898	0.01	200	126	2.76E+10	1.74E+10
46 Single Family Home General Permits	Various	0.046	200	126	1.27E+11	8.01E+10
Total					**1.74E+11**	**1.10E+11**

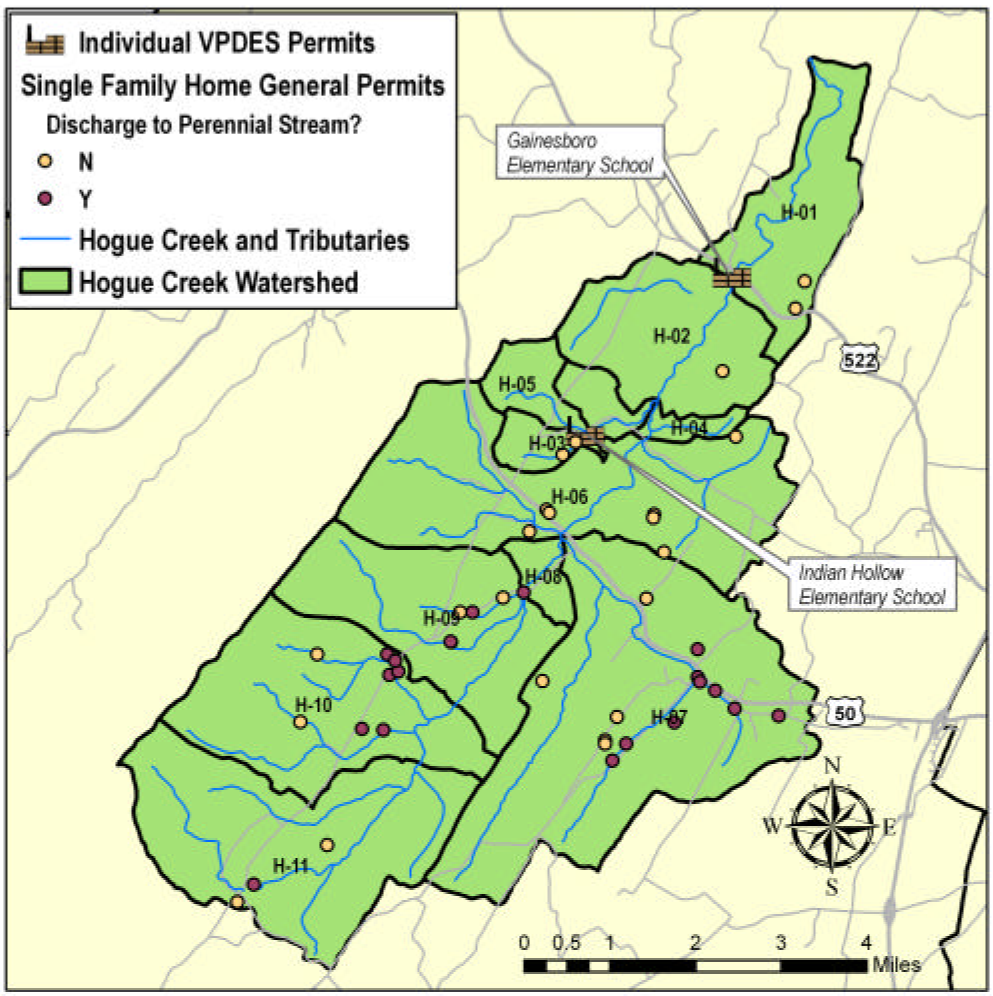


Figure 4-1. Point Source Dischargers in the Hogue Creek Watershed.

4.2. HUMANS

The human population in the Hogue Creek watershed was calculated from census block level data obtained in the 2000 U.S. census (Census Bureau, 2000). Populations for each sub-watershed were calculated from area-weighted proportions of population in census blocks covering each sub-watershed. Based on this area-weighted method, the Hogue Creek watershed has an estimated human population of 4,260 (Table 4-2). Human population densities throughout the watershed are relatively low. Areas with the highest population densities include the area around Gainesboro, areas along Rt 50 towards Winchester, and the Shawnee Land development in sub-watershed H-10 (Figure 4-2).

Table 4-2. Estimated Human Population in the Hogue Creek Watershed.

Sub-watershed	Population	Households	Average Occupancy Rate
H-01	148	56	2.6
H-02	155	60	2.6
H-03	96	39	2.4
H-04	16	6	2.5
H-05	52	20	2.6
H-06	542	228	2.4
H-07	1336	544	2.5
H-08	19	8	2.3
H-09	321	111	2.9
H-10	1308	554	2.4
H-11	267	115	2.3
Total	**4260**	**1741**	

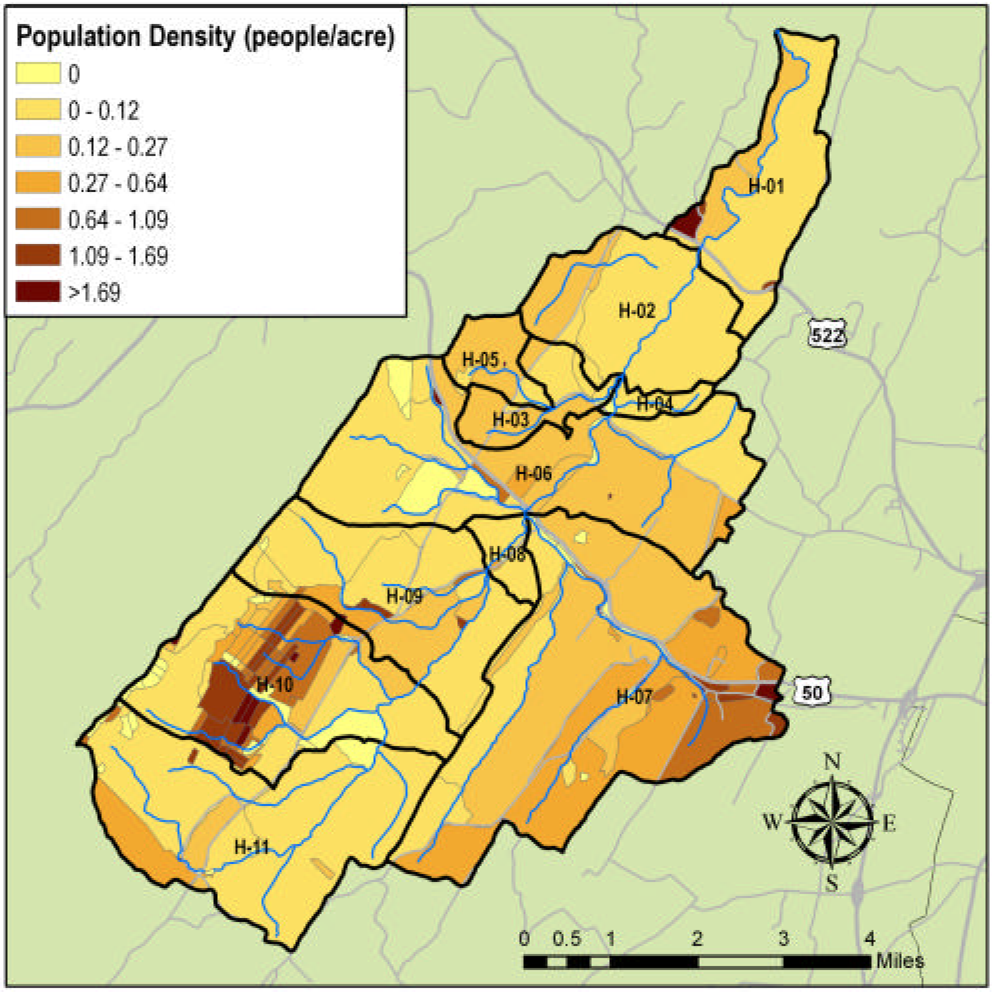


Figure 4-2. Population Density in the Hogue Creek Watershed.

The number of houses in the Hogue Creek watershed was also estimated from area-weighted 2000 census block data. There are an estimated 1,741 houses in the Hogue Creek watershed (Table 4-2), for approximately 2.45 people per household. The houses were broken into three age categories (prior to 1970, 1970-1989, or after 1989) in order to assess potential bacteria contributions. Houses were divided into age categories based on area-weighted 2000 census block group data (Table 4-3). For the watershed as a whole, approximately 46% of houses were built between 1970 and 1989, with 30% built before 1970, and 24% built after 1989.

There is no sewer system serving the Hogue Creek watershed, so all homes have on-site treatment. Human sources of bacteria to Hogue Creek would include permitted SFH treatment systems (see Section 4.1), failed septic systems, or straight pipes. Properly functioning septic systems are considered to provide no bacteria load to surface waters.

Table 4-3. Ages of Houses in the Hogue Creek Watershed.

Sub-watershed	Total Houses	Houses per Age Category		
		Pre 1970	1970-1989	Post 1989
H-01	56	25	19	12
H-02	60	22	23	15
H-03	39	11	19	9
H-04	6	3	2	1
H-05	20	5	9	6
H-06	228	84	105	39
H-07	544	175	263	106
H-08	8	3	3	2
H-09	111	34	47	30
H-10	554	128	252	174
H-11	115	30	52	33
Total	**1741**	**520**	**794**	**427**

4.2.1. Failing Septic Systems

A portion of the homes in the Hogue Creek watershed were estimated to have failing septic systems. Septic system failure can be evidenced by the rise of effluent to the soil surface. Under these conditions the waste is not filtered through the soil matrix, so the waste is not treated and bacteria are not removed. Surface runoff can then transport the effluent containing fecal coliform to receiving waters.

The number of failing septic systems in the watershed was estimated from the age of homes and standard failure rates for septic systems of that age. Table 4-3 shows the number of houses in each age category. Based on information from waste treatment experts, other nearby water quality studies, and local health department experts, septic system failure rates for houses pre-1970, 1970-1989, and post-1989 were assumed to be 35%, 20%, and 3%, respectively. Based on these failure rates, there is an estimated 353 failing septic systems in the Hogue Creek watershed (Table 4-4).

Table 4-4. Estimated Number of Failing Septic Systems in the Hogue Creek Watershed.

Sub-watershed	Houses per Age Category			Failure rate			Failing Systems			
	Pre 1970	1970-1989	Post 1989	Pre 1970	1970-1989	Post 1989	Pre 1970	1970-1989	Post 1989	Total
H-01	25	19	12	0.35	0.2	0.03	9	4	0	13
H-02	22	23	15	0.35	0.2	0.03	8	5	0	13
H-03	11	19	9	0.35	0.2	0.03	4	4	0	8
H-04	3	2	1	0.35	0.2	0.03	1	0	0	1
H-05	5	9	6	0.35	0.2	0.03	2	2	0	4
H-06	84	105	39	0.35	0.2	0.03	29	21	1	51
H-07	175	263	106	0.35	0.2	0.03	61	53	3	117
H-08	3	3	2	0.35	0.2	0.03	1	1	0	2
H-09	34	47	30	0.35	0.2	0.03	12	9	1	22
H-10	128	252	174	0.35	0.2	0.03	45	50	5	100
H-11	30	52	33	0.35	0.2	0.03	11	10	1	22
Subtotal	**520**	**794**	**427**				**183**	**159**	**11**	**353**
Total	**1741**						**353**			

Daily total fecal coliform load to the land surface from a failing septic system in a particular sub-watershed was determined from the average occupancy rate for that sub-watershed (Table 4-2), a typical septic waste flow of 70 gal/person/day (Metcalf and Eddy, 1991), and a typical fecal coliform concentration in septic waste of 10^5 cfu/100ml (Metcalf and Eddy, 1991). Based on these estimates, a daily fecal coliform load of 2.29 x 10^{11} cfu/d is delivered to the land surface from failing septic systems in the Hogue Creek watershed (Table 4-5). Some portion of this load is then available for washoff and may contribute to instream fecal coliform loads.

Table 4-5. Fecal Coliform Loading to Land Surface from Failing Septic Systems.

Sub-watershed	Failing Septic Systems	Average Occupancy Rate	Septic Flow (gal/person/d)	Fecal Coliform Conc. (cfu/100ml)	Daily Fecal Coliform Loading (cfu/d)	Annual Fecal Coliform Loading (cfu/yr)
H-01	13	2.6	70	1.00E+05	9.07E+09	3.31E+12
H-02	13	2.6	70	1.00E+05	8.84E+09	3.23E+12
H-03	8	2.4	70	1.00E+05	5.18E+09	1.89E+12
H-04	1	2.5	70	1.00E+05	6.49E+08	2.37E+11
H-05	4	2.6	70	1.00E+05	2.74E+09	9.99E+11
H-06	51	2.4	70	1.00E+05	3.21E+10	1.17E+13
H-07	117	2.5	70	1.00E+05	7.61E+10	2.78E+13
H-08	2	2.3	70	1.00E+05	1.24E+09	4.52E+11
H-09	22	2.9	70	1.00E+05	1.69E+10	6.16E+12
H-10	100	2.4	70	1.00E+05	6.26E+10	2.28E+13
H-11	22	2.3	70	1.00E+05	1.36E+10	4.95E+12
Total	**353**				**2.29E+11**	**8.36E+13**

4.2.2. Straight Pipes

In addition to the contribution of fecal coliform from failing septic systems, there is a potential for fecal coliform loading from straight pipes. Straight pipes are illicit discharges of untreated sewage directly to surface waters. There is a potential for straight pipes in areas with very old homes located close to streams. At the time these homes were built, discharge of waste to the nearby stream may have been standard practice. If these homes have not been updated in several decades and appropriate waste treatment installed, some straight pipes may still exist.

To estimate the number of potential straight pipes in the Hogue Creek watershed, houses built prior to 1965 and located within 100 ft of perennial streams were identified from 1:24,000 topographic maps. There were 32 such homes in the Hogue Creek watershed. It is not likely, however, that all of these homes have straight pipes. Some may have been constructed with septic systems prior to 1965 and others may have been upgraded since initial construction. To determine what proportion of these homes might represent straight pipes, information on sewage disposal from the 1990 census (Census Bureau, 2000) was used. In the 1990 census, homes were categorized as having sewage collection, a septic system (or cesspool), or “other”. The “other” category is assumed to be some type of illicit discharge. The proportion of homes built prior to 1969 that listed “other” as the sewage disposal system in each census block group was applied to the number of pre-1965 homes within 100 ft of perennial streams to estimate the number of straight pipes in each census block group. This information was then overlaid by sub-watershed boundaries to estimate the number of straight pipes in each sub-watershed. Based on this method, an estimate of 7 straight pipes was made for the Hogue Creek watershed (Table 4-6).

Fecal coliform loading from these straight pipes was calculated based on the average occupancy rate for each sub-watershed, a septic waste flow of 70 gal/person/day, and a fecal coliform concentration of 10^5 cfu/100ml (as described above for failing septic systems). Fecal coliform loadings from straight pipes, unlike failing septic systems, are discharged directly to surface waters and do not need rainfall events to transport bacteria to the stream. The fecal coliform loading from straight pipes in the Hogue Creek watershed was estimated at 1.69×10^{12} cfu/yr (Table 4-7).

Table 4-6. Estimated Number of Straight Pipes in the Hogue Creek Watershed.

Sub-watershed	Pre-1965 Homes Within 100 ft of Stream	Estimated Straight Pipes
H-01	0	0
H-02	0	0
H-03	0	0
H-04	0	0
H-05	0	0
H-06	2	1
H-07	22	4
H-08	0	0
H-09	4	1
H-10	2	1
H-11	2	0
Total	**32**	**7**

Table 4-7. Fecal Coliform Loading From Straight Pipes in the Hogue Creek Watershed.

Sub-watershed	Estimated Straight Pipes	Average Occupancy Rate	Septic Flow (gal/ person/d)	Fecal Coliform Conc. (cfu/100ml)	Daily Fecal Coliform Loading (cfu/d)	Annual Fecal Coliform Loading (cfu/yr)
H-01	0	2.6	70	1.00E+05	0.00E+00	0.00E+00
H-02	0	2.6	70	1.00E+05	0.00E+00	0.00E+00
H-03	0	2.4	70	1.00E+05	0.00E+00	0.00E+00
H-04	0	2.5	70	1.00E+05	0.00E+00	0.00E+00
H-05	0	2.6	70	1.00E+05	0.00E+00	0.00E+00
H-06	1	2.4	70	1.00E+05	6.30E+08	2.30E+11
H-07	4	2.5	70	1.00E+05	2.60E+09	9.50E+11
H-08	0	2.3	70	1.00E+05	0.00E+00	0.00E+00
H-09	1	2.9	70	1.00E+05	7.67E+08	2.80E+11
H-10	1	2.4	70	1.00E+05	6.26E+08	2.28E+11
H-11	0	2.3	70	1.00E+05	0.00E+00	0.00E+00
Total	**7**				**4.63E+09**	**1.69E+12**

4.3. PETS

Assuming one pet per household, there is an estimated 1,741 pets in the Hogue Creek watershed (Table 4-8). Each pet is considered a "pet unit", which could be a dog or several cats. Using a fecal coliform production rate of 4.5 x 10^8 cfu/day for a dog (Weiskel *et al.*, 1996), pets in the Hogue Creek watershed produce an estimated 2.86 x 10^{14} cfu/yr (Table 4-8). This load is deposited on the land surface in residential areas and is available for washoff and transport to surface waters.

Table 4-8. Fecal Coliform Loading to the Land Surface from Pets in the Hogue Creek Watershed.

Sub-watershed	Households	Pets	Fecal Production Rate Per Animal (cfu/d)	Daily Fecal Coliform Loading (cfu/d)	Annual Fecal Coliform Loading (cfu/yr)
H-01	56	56	4.50E+08	2.53E+10	9.24E+12
H-02	60	60	4.50E+08	2.72E+10	9.92E+12
H-03	39	39	4.50E+08	1.76E+10	6.44E+12
H-04	6	6	4.50E+08	2.86E+09	1.04E+12
H-05	20	20	4.50E+08	9.01E+09	3.29E+12
H-06	228	228	4.50E+08	1.03E+11	3.74E+13
H-07	544	544	4.50E+08	2.45E+11	8.94E+13
H-08	8	8	4.50E+08	3.65E+09	1.33E+12
H-09	111	111	4.50E+08	4.99E+10	1.82E+13
H-10	554	554	4.50E+08	2.49E+11	9.09E+13
H-11	115	115	4.50E+08	5.16E+10	1.88E+13
Total	**1741**	**1741**		**7.84E+11**	**2.86E+14**

4.4. LIVESTOCK

Fecal coliform in waste from livestock can be directly excreted to the stream, or it can be transported to the stream by surface runoff from animal waste deposited on pastures or applied to crop, pasture, and hay land. The number of animals within the Hogue Creek watershed was estimated from 2002 and 2006 agricultural statistics data for Frederick County (USDA-NASS, 2002; USDA-NASS, 2006), information from VADEQ, VADCR, and VDACS, and input from local stakeholders. Table 4-9 shows the estimated number of livestock within the Hogue Creek watershed.

Table 4-9. Estimated Livestock Populations in the Hogue Creek Watershed.

Sub-watershed	Estimated Livestock Population					
	Beef Cattle	Dairy Cows	Horses	Sheep	Goats	Poultry
H-01	41	0	6	2	1	0
H-02	156	0	24	7	5	0
H-03	98	0	15	4	3	0
H-04	3	0	0	0	0	0
H-05	33	0	5	1	1	0
H-06	193	0	30	9	7	0
H-07	214	0	34	10	7	0
H-08	19	0	3	1	1	0
H-09	79	0	12	4	3	0
H-10	105	0	16	5	4	0
H-11	79	0	12	4	3	0
Total	**1020**	**0**	**157**	**47**	**35**	**0**

4.4.1. Beef Cattle

The number of beef cattle in the Hogue Creek watershed was estimated from 2006 agriculture statistics data for Frederick County (USDA-NASS, 2006). To determine the number of beef cattle in each sub-watershed, the number of cattle in Frederick County was weighted by the ratio of pasture land in each sub-watershed to the acreage of pasture in Frederick County. Based on this weighting, 1064 beef cattle were estimated in the Hogue Creek watershed. After discussions with the local Soil and Water Conservation District and the Local Steering Committee, this estimate was revised to 1020 beef cattle. With each beef cow producing approximately 4.46 x 10^{10} fecal coliforms per day (ASAE, 1998), beef cattle within Hogue Creek produce an estimated annual load of 1.66 x 10^{16} fecal coliforms (Table 4-10). This load is deposited either directly onto pasture as animals are grazing or directly into perennial streams while cattle are wading. Beef cattle within the watershed were assumed to not be kept in confinement. Bacterial loads to the pasture land surface are available for washoff and transport to surface waters during precipitation events. The load that is deposited while cattle are wading in perennial streams directly affects instream bacterial loads and concentrations.

To determine the percentage of the bacterial load from beef cattle that is deposited directly in the stream versus on the land surface, the amount of pasture with stream access was determined. Figure 4-3 shows the perennial stream reaches that are contiguous with pasture. Throughout the watershed, pasture is contiguous with 7.261 miles of perennial streams. This is 12% of the 59 miles of total perennial stream length in the watershed. Pasture acreage within 500 feet of those stream access points was assumed to provide beef cattle within that pasture access to the stream for watering. A total of 964 acres of pasture (or 19% of pasture) was estimated as providing stream access (Table 4-11). Multiplying the beef cattle in each sub-watershed by the ratio of pasture with stream access to total pasture, a total of 198 beef cattle were estimated to have perennial stream access.

Table 4-10. Fecal Coliform Loading to the Land Surface and Perennial Streams from Beef Cattle in the Hogue Creek Watershed.

Sub-watershed	Beef Cattle	Fecal Production Rate per Animal (cfu/d)	Daily Fecal Coliform Loading (cfu/d)	Annual Fecal Coliform Loading (cfu/yr)
H-01	41	4.46E+10	1.83E+12	6.67E+14
H-02	156	4.46E+10	6.96E+12	2.54E+15
H-03	98	4.46E+10	4.37E+12	1.60E+15
H-04	3	4.46E+10	1.34E+11	4.88E+13
H-05	33	4.46E+10	1.47E+12	5.37E+14
H-06	193	4.46E+10	8.61E+12	3.14E+15
H-07	214	4.46E+10	9.54E+12	3.48E+15
H-08	19	4.46E+10	8.47E+11	3.09E+14
H-09	79	4.46E+10	3.52E+12	1.29E+15
H-10	105	4.46E+10	4.68E+12	1.71E+15
H-11	79	4.46E+10	3.52E+12	1.29E+15
Total	**1020**		**4.55E+13**	**1.66E+16**

For beef cattle that do not have stream access, all of the bacterial load produced is deposited on pasture. For those beef cattle that have stream access, the amount of bacterial load deposited on pasture and directly in the stream was determined by the percentage of time that the cattle spent wading. Estimates of the amount of time that beef cattle spend grazing and wading (Table 4-12) were based on a study of cattle stream access (VADCR, 2002) and revised according to Local Steering Committee input. Initial estimates from an average of three farms in the VADCR study were 0.5 hr/cow/day in the summer and 0.2 hr/cow/day in the winter. The Local Steering Committee commented that access hours in the winter were high compared to local knowledge, so the winter value was decreased to 0.1 hr/cow/day. Direct deposit loading of fecal coliform from beef cattle directly to the stream was determined from daily fecal coliform loading rates and time spent in the stream. Calibration of the water quality model revealed that initial estimates of direct deposits were too high, so cattle and wildlife direct deposits were reduced by 75% in order to obtain a successful calibration (see Section 5.5.3). Table 4-13 shows the calibrated daily load of fecal coliform deposited by cattle directly in the stream.

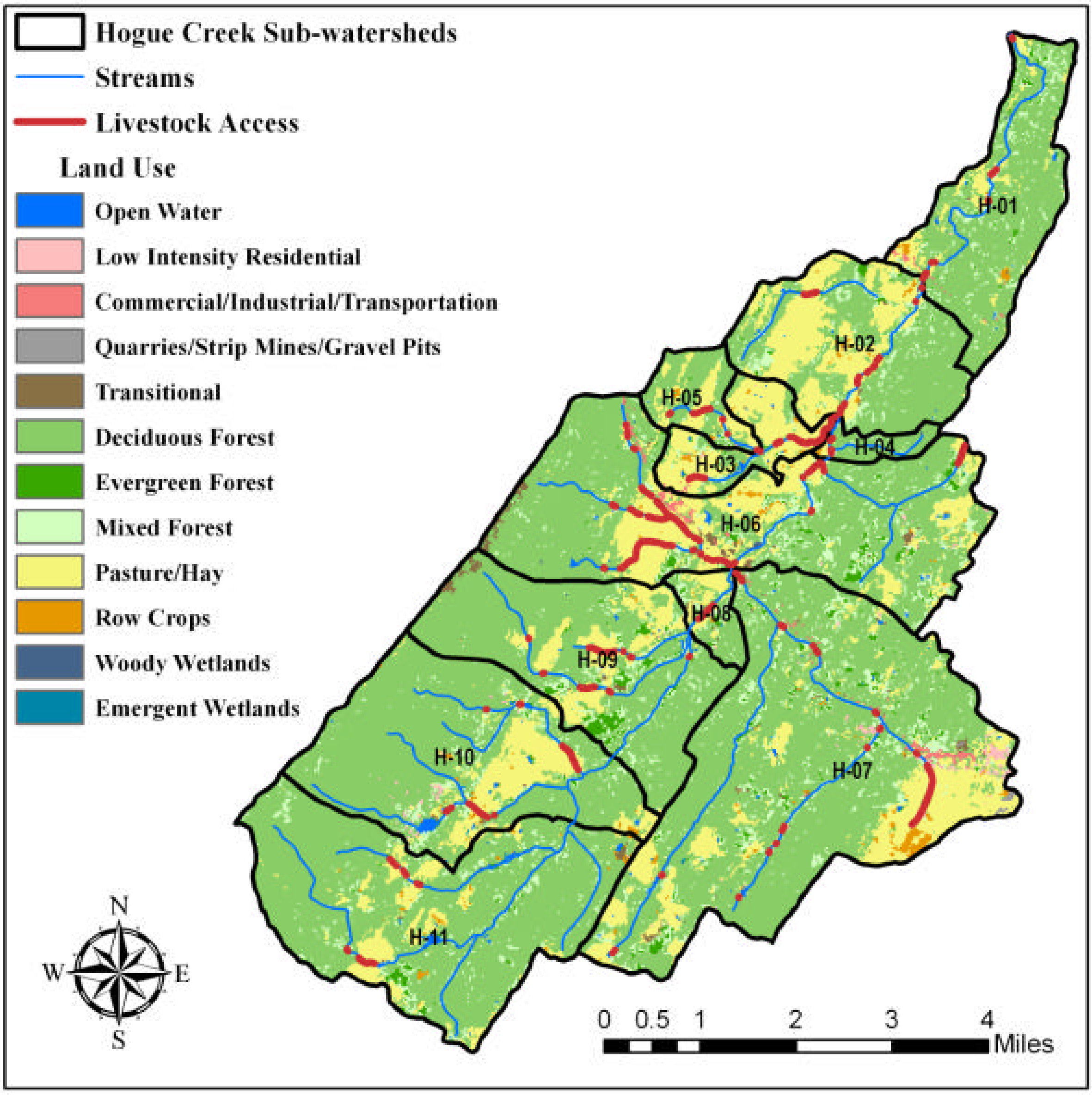


Figure 4-3. Perennial Stream Reaches with Livestock Access in the Hogue Creek Watershed.

Table 4-11. Beef Cattle with Access to Perennial Streams.

Sub-watershed	Total Pasture Acreage (acres)	Total Beef Cattle	Perennial Stream Access (miles)	Pasture Acreage with Stream Access (acres)	Percent of Pasture with Stream Access (%)	Beef Cattle with Stream Access
H-01	201.93	41	0.44	32.69	16.19%	7
H-02	764.69	156	0.576	96.96	12.68%	20
H-03	478.89	98	1.008	110.31	23.03%	23
H-04	13.90	3	0.065	13.90	100.00%	3
H-05	161.34	33	0.228	50.93	31.57%	10
H-06	944.98	193	2.443	304.46	32.22%	62
H-07	1050.43	214	0.983	116.76	11.12%	24
H-08	95.61	19	0.192	24.46	25.59%	5
H-09	385.35	79	0.465	86.29	22.39%	18
H-10	514.87	105	0.574	68.05	13.22%	14
H-11	385.61	79	0.287	58.93	15.28%	12
Total	**4997.60**	**1020**	**7.261**	**963.75**	**19.28%**	**198**

Table 4-12. Daily Hours Spent by Beef Cattle on Pasture and in the Stream.

Month	Time Spent in Pasture (hr/d)	Time Spent In Stream (hr/d)
January	23.90	0.1
February	23.90	0.1
March	23.90	0.1
April	23.50	0.5
May	23.50	0.5
June	23.50	0.5
July	23.50	0.5
August	23.50	0.5
September	23.50	0.5
October	23.90	0.1
November	23.90	0.1
December	23.90	0.1

Table 4-13. Instream Direct Deposit Loading of Fecal Coliform (#/d) from Beef Cattle in the Hogue Creek Watershed.

Sub-watershed	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
H-01	3.25E+08	3.25E+08	3.25E+08	1.63E+09	1.63E+09	1.63E+09	1.63E+09	1.63E+09	1.63E+09	3.25E+08	3.25E+08	3.25E+08
H-02	9.29E+08	9.29E+08	9.29E+08	4.65E+09	4.65E+09	4.65E+09	4.65E+09	4.65E+09	4.65E+09	9.29E+08	9.29E+08	9.29E+08
H-03	1.07E+09	1.07E+09	1.07E+09	5.34E+09	5.34E+09	5.34E+09	5.34E+09	5.34E+09	5.34E+09	1.07E+09	1.07E+09	1.07E+09
H-04	1.39E+08	1.39E+08	1.39E+08	6.97E+08	6.97E+08	6.97E+08	6.97E+08	6.97E+08	6.97E+08	1.39E+08	1.39E+08	1.39E+08
H-05	4.65E+08	4.65E+08	4.65E+08	2.32E+09	2.32E+09	2.32E+09	2.32E+09	2.32E+09	2.32E+09	4.65E+08	4.65E+08	4.65E+08
H-06	2.88E+09	2.88E+09	2.88E+09	1.44E+10	1.44E+10	1.44E+10	1.44E+10	1.44E+10	1.44E+10	2.88E+09	2.88E+09	2.88E+09
H-07	1.12E+09	1.12E+09	1.12E+09	5.58E+09	5.58E+09	5.58E+09	5.58E+09	5.58E+09	5.58E+09	1.12E+09	1.12E+09	1.12E+09
H-08	2.32E+08	2.32E+08	2.32E+08	1.16E+09	1.16E+09	1.16E+09	1.16E+09	1.16E+09	1.16E+09	2.32E+08	2.32E+08	2.32E+08
H-09	8.36E+08	8.36E+08	8.36E+08	4.18E+09	4.18E+09	4.18E+09	4.18E+09	4.18E+09	4.18E+09	8.36E+08	8.36E+08	8.36E+08
H-10	6.50E+08	6.50E+08	6.50E+08	3.25E+09	3.25E+09	3.25E+09	3.25E+09	3.25E+09	3.25E+09	6.50E+08	6.50E+08	6.50E+08
H-11	5.58E+08	5.58E+08	5.58E+08	2.79E+09	2.79E+09	2.79E+09	2.79E+09	2.79E+09	2.79E+09	5.58E+08	5.58E+08	5.58E+08
Total	**9.20E+09**	**9.20E+09**	**9.20E+09**	**4.60E+10**	**4.60E+10**	**4.60E+10**	**4.60E+10**	**4.60E+10**	**4.60E+10**	**9.20E+09**	**9.20E+09**	**9.20E+09**

4.4.2. Dairy Cows

The number of dairy cows in the Hogue Creek watershed was estimated based on information provided by the VDACS. VDACS maintains a database of Grade A dairies in Virginia, and the addresses of these dairies were compared to the Hogue Creek watershed. Based on this analysis, no Grade A dairies were located in the Hogue Creek watershed, so the dairy cow population in Hogue Creek was estimated at zero. The Local Steering Committee confirmed that there were no dairies in the Hogue Creek watershed.

4.4.3. Horses

The number of horses in the Hogue Creek watershed was estimated from 2002 agriculture statistics data for Frederick County (USDA-NASS, 2002). To determine the number of horses in each sub-watershed, the number of horses in Frederick County was weighted by the ratio of pasture land in each sub-watershed to the acreage of pasture in Frederick County. Based on this weighting, 80 horses were estimated in the Hogue Creek watershed. After discussions with the Local Steering Committee, this estimate was nearly doubled to 157 horses in the watershed. With each horse producing approximately 5.15 x 10^{10} fecal coliforms per day (ASAE, 1998), horses within Hogue Creek produce an estimated annual load of 2.95 x 10^{15} fecal coliforms (Table 4-14). This load is deposited and is available for washoff and transport to surface waters during precipitation events.

Table 4-14. Fecal Coliform Loading to the Land Surface from Horses in the Hogue Creek Watershed.

Sub-watershed	Horses	Fecal Production Rate per Animal (cfu/d)	Daily Fecal Coliform Loading (cfu/d)	Annual Fecal Coliform Loading (cfu/yr)
H-01	6	5.15E+10	3.09E+11	1.13E+14
H-02	24	5.15E+10	1.24E+12	4.51E+14
H-03	15	5.15E+10	7.73E+11	2.82E+14
H-04	0	5.15E+10	0.00E+00	0.00E+00
H-05	5	5.15E+10	2.58E+11	9.40E+13
H-06	30	5.15E+10	1.55E+12	5.64E+14
H-07	34	5.15E+10	1.75E+12	6.39E+14
H-08	3	5.15E+10	1.55E+11	5.64E+13
H-09	12	5.15E+10	6.18E+11	2.26E+14
H-10	16	5.15E+10	8.24E+11	3.01E+14
H-11	12	5.15E+10	6.18E+11	2.26E+14
Total	**157**		**8.09E+12**	**2.95E+15**

4.4.4. Sheep

The number of sheep in the Hogue Creek watershed was estimated from 2002 agriculture statistics data for Frederick County (USDA-NASS, 2002). To determine the number of sheep in each sub-watershed, the number of sheep in Frederick County was weighted by the ratio of pasture land in each sub-watershed to the acreage of pasture in Frederick County. Based on this weighting, 47 sheep were estimated in the Hogue Creek watershed. With each sheep producing approximately 1.96 x 10^{10} fecal coliforms per day (ASAE, 1998), sheep within Hogue Creek produce an estimated annual load of 3.36 x 10^{14} fecal coliforms (Table 4-15). Because sheep are not assumed to be confined in areas where manure is collected and stored, this load is deposited directly onto pasture and is available for washoff and transport to surface waters during precipitation events.

Table 4-15. Fecal Coliform Loading to the Land Surface from Sheep in the Hogue Creek Watershed.

Sub-watershed	Sheep	Fecal Production Rate per Animal (cfu/d)	Daily Fecal Coliform Loading (cfu/d)	Annual Fecal Coliform Loading (cfu/yr)
H-01	2	1.96E+10	3.92E+10	1.43E+13
H-02	7	1.96E+10	1.37E+11	5.01E+13
H-03	4	1.96E+10	7.84E+10	2.86E+13
H-04	0	1.96E+10	0.00E+00	0.00E+00
H-05	1	1.96E+10	1.96E+10	7.15E+12
H-06	9	1.96E+10	1.76E+11	6.44E+13
H-07	10	1.96E+10	1.96E+11	7.15E+13
H-08	1	1.96E+10	1.96E+10	7.15E+12
H-09	4	1.96E+10	7.84E+10	2.86E+13
H-10	5	1.96E+10	9.80E+10	3.58E+13
H-11	4	1.96E+10	7.84E+10	2.86E+13
Total	**47**		**9.21E+11**	**3.36E+14**

4.4.5. Goats

The number of goats in the Hogue Creek watershed was estimated from 2002 agriculture statistics data for Frederick County (USDA-NASS, 2002). To determine the number of goats in each sub-watershed, the number of goats in Frederick County was weighted by the ratio of pasture land in each sub-watershed to the acreage of pasture in Frederick County. Based on this weighting, 23 goats were estimated in the Hogue Creek watershed. After discussions with the Local Steering Committee, this estimate was increased by 50% to 35. With each goat producing approximately 5.59 x 10^{10} fecal coliforms per day (ASAE, 1998), goats within Hogue Creek produce an estimated annual load of 7.14 x 10^{14} fecal coliforms (Table 4-16). Because goats are not assumed to be confined in areas where manure is collected and stored, this load is deposited directly onto pasture and is available for washoff and transport to surface waters during precipitation events.

Table 4-16. Fecal Coliform Loading to the Land Surface from Goats in the Hogue Creek Watershed.

Sub-watershed	Goats	Fecal Production Rate per Animal (cfu/d)	Daily Fecal Coliform Loading (cfu/d)	Annual Fecal Coliform Loading (cfu/yr)
H-01	1	5.59E+10	5.59E+10	2.04E+13
H-02	5	5.59E+10	2.80E+11	1.02E+14
H-03	3	5.59E+10	1.68E+11	6.12E+13
H-04	0	5.59E+10	0.00E+00	0.00E+00
H-05	1	5.59E+10	5.59E+10	2.04E+13
H-06	7	5.59E+10	3.91E+11	1.43E+14
H-07	7	5.59E+10	3.91E+11	1.43E+14
H-08	1	5.59E+10	5.59E+10	2.04E+13
H-09	3	5.59E+10	1.68E+11	6.12E+13
H-10	4	5.59E+10	2.24E+11	8.16E+13
H-11	3	5.59E+10	1.68E+11	6.12E+13
Total	**35**		**1.96E+12**	**7.14E+14**

4.4.6. Poultry

VADEQ issues confined animal feeding operation (CAFO) permits for poultry facilities that contain more than 20,000 chickens or 11,000 turkeys. Based on VADEQ's database of CAFO permits, there are no permitted poultry facilities in the Hogue Creek watershed. VADEQ also maintains a database of poultry litter that is transferred from permitted facilities to other watersheds for land application. No poultry litter transfers into the Hogue Creek watershed were recorded in the database. Based on this information, VADEQ estimated no bacterial load from poultry in the Hogue Creek watershed. This assumption was also confirmed by the Local Steering Committee.

4.4.7. Other Livestock

While additional livestock species, such as pigs or llamas, may exist in the watershed, the numbers of these animals within the Hogue Creek watershed would be extremely small and have little impact on overall watershed-level bacteria loadings. For this reason, no other livestock were included in the Hogue Creek TMDL model. The Local Steering Committee confirmed this assumption.

4.5. WILDLIFE

Wildlife populations in the watershed were determined based on estimates of the available habitat for each species and the population density of animals within that habitat. Habitat descriptions and population density estimates were obtained from the TMDL developed for the neighboring Upper Opequon Creek watershed (VADEQ, 2004b) and information provided by VADGIF. Based on these estimates and available land use in the watershed, populations were estimated for deer, raccoon, muskrat, beaver, goose, wood duck, and wild turkey (Table 4-17). For instance, muskrats were assumed to be found within 66 feet of streams or impoundments in forest and cropland. A geographic information system (GIS) was used to calculate the acreage of forest and cropland within 66 feet of perennial streams or lakes. This acreage was then multiplied by the population density of muskrats to obtain an estimate of the population in the watershed. Initial wildlife population estimates calculated using this method were presented to the Local Steering Committee. Based on comments, geese and beaver population estimates were doubled, and muskrat and wood duck population estimates were cut in half. Table 4-18 shows final estimated populations for each wildlife species in each Hogue Creek sub-watershed.

Fecal coliform loads from wildlife were determined by multiplying the population of each wildlife species by the daily fecal production rates (VADEQ, 2004b). This fecal coliform load can be deposited directly into streams or on the land surface, where it is available for washoff and transport to surface waters during precipitation events. Fecal coliform from wildlife was distributed based on the wildlife habitat and habits of each species. For instance, fecal coliform from muskrats was assumed to be deposited in the stream 2.5% of the time, with the remaining load deposited on forest and cropland within 66 feet of streams and impoundments. Estimates of the percentage of fecal coliform load deposited in the stream were made based on best professional judgment and were adjusted during calibration of the water quality model. Table 4-19 shows the annual fecal coliform loading to the land surface from wildlife. Deer and geese accounted for the majority of fecal coliform loadings from wildlife in the Hogue Creek watershed. This was primarily due to the large population of deer in the watershed and the relatively high fecal coliform production rate by geese. Calibration of the water quality model revealed that initial estimates of direct deposits were too high, so cattle and wildlife direct deposits were reduced by 75% in order to obtain a successful calibration (see Section 5.5.3). Table 4-20 shows the calibrated daily load of fecal coliform deposited by wildlife directly in the stream. Wildlife direct deposit loads were dominated by geese and wood duck contributions.

Table 4-17. Wildlife Habitat and Initial Population Estimates in the Hogue Creek Watershed.

Wildlife Type	Habitat	Acres of Habitat	Population Density (animals/ac-habitat)	Population (#)	Fecal Coliform Production Rate (cfu/animal/d)	Direct Deposition in Streams (%)
Deer	Entire Watershed	26580	0.047	1249	3.47E+08	0.0%
Raccoon	600 ft buffer around streams and impoundments	8460	0.07	592	1.13E+08	1.0%
Muskrat	66 ft buffer around streams and impoundments in forest and cropland	832	2.75	2289	2.50E+07	2.5%
Beaver	300 ft buffer around main streams and impoundments in forest and pasture	4187	0.015	63	3.00E+05	50.0%
Geese - off season	300 ft buffer around main streams and impoundments	1780	0.078	139	7.99E+08	2.5%
Geese - in season	300 ft buffer around main streams and impoundments	1780	0.1092	194	7.99E+08	2.5%
Wood Duck - off season	300 ft buffer around main streams and impoundments	1780	0.0624	111	2.43E+09	2.5%
Wood Duck - in season	300 ft buffer around main streams and impoundments	1780	0.0936	167	2.43E+09	2.5%
Wild Turkey	Entire watershed except urban and residential	25888	0.01	259	9.30E+07	0.0%

Table 4-18. Final Wildlife Population Estimates in Hogue Creek Sub-Watersheds.

Sub-watershed	Deer	Raccoon	Muskrat	Beaver	Geese-off season	Geese-in season	Wood Duck-off season	Wood Duck-in season	Wild Turkey
H-01	91	39	84	9	44	62	9	13	19
H-02	103	40	70	8	21	29	4	6	22
H-03	33	17	23	4	11	15	2	3	7
H-04	10	13	31	3	5	7	1	2	2
H-05	24	12	20	3	14	20	3	4	5
H-06	207	102	171	21	22	30	4	6	43
H-07	294	107	195	22	48	67	10	14	60
H-08	16	8	13	2	9	13	2	3	3
H-09	130	60	129	13	19	27	4	6	27
H-10	152	88	181	19	22	31	4	7	31
H-11	189	106	226	22	62	87	12	19	40
Total	**1249**	**592**	**1143**	**126**	**277**	**388**	**55**	**83**	**259**

Table 4-19. Annual Fecal Coliform Loading (cfu/yr) to the Land Surface from Wildlife in the Hogue Creek Watershed.

Sub-watershed	Deer	Raccoon	Muskrat	Beaver	Geese	Wood Duck	Wild Turkey
H-01	1.15E+13	1.61E+12	7.67E+11	9.86E+08	1.54E+13	9.75E+12	6.45E+11
H-02	1.30E+13	1.65E+12	6.39E+11	8.76E+08	7.29E+12	4.43E+12	7.47E+11
H-03	4.18E+12	7.01E+11	2.10E+11	4.38E+08	3.79E+12	2.22E+12	2.38E+11
H-04	1.27E+12	5.36E+11	2.83E+11	3.29E+08	1.75E+12	1.33E+12	6.79E+10
H-05	3.04E+12	4.95E+11	1.83E+11	3.29E+08	4.96E+12	3.10E+12	1.70E+11
H-06	2.62E+13	4.21E+12	1.56E+12	2.30E+09	7.58E+12	4.43E+12	1.46E+12
H-07	3.72E+13	4.41E+12	1.78E+12	2.41E+09	1.68E+13	1.06E+13	2.04E+12
H-08	2.03E+12	3.30E+11	1.19E+11	2.19E+08	3.21E+12	2.22E+12	1.02E+11
H-09	1.65E+13	2.47E+12	1.18E+12	1.42E+09	6.70E+12	4.43E+12	9.17E+11
H-10	1.93E+13	3.63E+12	1.65E+12	2.08E+09	7.72E+12	4.87E+12	1.05E+12
H-11	2.39E+13	4.37E+12	2.06E+12	2.41E+09	2.17E+13	1.37E+13	1.36E+12
Total	**1.58E+14**	**2.44E+13**	**1.04E+13**	**1.38E+10**	**9.69E+13**	**6.12E+13**	**8.79E+12**

Table 4-20. Instream Direct Deposit Loading of Fecal Coliform (cfu/d) from Wildlife in the Hogue Creek Watershed.

Sub-watershed	Raccoon	Muskrat	Beaver	Geese-off season	Geese-in season	Wood Duck-off season	Wood Duck-in season
H-01	1.10E+07	1.31E+07	3.38E+05	2.20E+08	3.10E+08	1.37E+08	1.97E+08
H-02	1.13E+07	1.09E+07	3.00E+05	1.05E+08	1.45E+08	6.08E+07	9.11E+07
H-03	4.80E+06	3.59E+06	1.50E+05	5.49E+07	7.49E+07	3.04E+07	4.56E+07
H-04	3.67E+06	4.84E+06	1.13E+05	2.50E+07	3.50E+07	1.52E+07	3.04E+07
H-05	3.39E+06	3.13E+06	1.13E+05	6.99E+07	9.99E+07	4.56E+07	6.08E+07
H-06	2.88E+07	2.67E+07	7.88E+05	1.10E+08	1.50E+08	6.08E+07	9.11E+07
H-07	3.02E+07	3.05E+07	8.25E+05	2.40E+08	3.35E+08	1.52E+08	2.13E+08
H-08	2.26E+06	2.03E+06	7.50E+04	4.49E+07	6.49E+07	3.04E+07	4.56E+07
H-09	1.70E+07	2.02E+07	4.88E+05	9.49E+07	1.35E+08	6.08E+07	9.11E+07
H-10	2.49E+07	2.83E+07	7.13E+05	1.10E+08	1.55E+08	6.08E+07	1.06E+08
H-11	2.99E+07	3.53E+07	8.25E+05	3.10E+08	4.34E+08	1.82E+08	2.89E+08
Total	**1.67E+08**	**1.79E+08**	**4.73E+06**	**1.38E+09**	**1.94E+09**	**8.35E+08**	**1.26E+09**

4.6. SUMMARY: CONTRIBUTION FROM ALL SOURCES

Based on the inventory of sources discussed in this chapter, a summary of the relative contribution of fecal coliform from each different source is given in Table 4-21. Over 96% of the fecal coliform load deposited in the watershed is from livestock. Wildlife and pets account for less than 2% each, and human sources (from failing septic systems) account for less than 0.5%. Direct stream inputs from cattle, wildlife, and straight pipes account for a small proportion (<0.1%) of the total fecal coliform load deposited in the watershed, and permitted point sources contribute an insignificant proportion of the total fecal coliform load (<0.01%). While these direct deposits contribute a small fraction of the overall fecal coliform load deposited in the watershed, their impact on water quality is much more direct and can be quite large. Fecal coliform deposited on the land surface may die before it is transported to the stream by precipitation events. The amount of land-deposited fecal coliform that makes its way into the stream depends on such factors as precipitation amount, intensity, and frequency; die-off rates; land cover; best management

> **Interesting Fact:**
>
> One beef cow produces the same amount of fecal coliform each day as 23 people, 56 geese, 130 deer, 400 raccoons, 1800 muskrats, and 150,000 beaver.

practices; and proximity to the stream. The LSPC model considers these and other factors when estimating fecal coliform loads to the receiving waters, as described in Chapter 5.

Table 4-21. Summary of Annual Fecal Coliform Loads in the Hogue Creek Watershed by Source.

Source		Annual Fecal Coliform Load (cfu/yr)	Percentage of Annual Load (%)
Direct Loading to Streams	Permitted Point Sources	1.08E+11	0.00%
	Straight pipes	1.69E+12	0.01%
	Cattle in Stream	1.01E+13	0.05%
	Wildlife in Stream	1.12E+12	0.01%
Loading to Land Surface	Failing Septic Systems	8.36E+13	0.39%
	Pets	2.86E+14	1.34%
	Livestock	2.06E+16	96.53%
	Wildlife	3.59E+14	1.68%
Total		**2.13E+16**	**100.00%**

CHAPTER 5: WATERSHED MODELING

An important step in developing a TMDL is establishing the relationship between pollutant loadings (both point and nonpoint) and instream water quality conditions. This relationship must be representative of the watershed and stream being assessed and must be predictive of future water quality conditions given established source loads. Once this relationship is developed, management options for reducing pollutant loadings to the stream can be evaluated. The best way to establish this predictive linkage between loads and instream water quality is to develop a computer simulation model of the watershed. The watershed model considers the following key processes in establishing this linkage: the spatial and temporal distribution of source loads in the watershed, local climate and precipitation patterns, wash-off and runoff processes, stream hydrology, and the fate and transport of pollutants. This chapter describes the modeling approach used in the development of the Hogue Creek bacteria TMDL. A watershed model is a useful tool for evaluating various management options and scenarios, but should be used in concert with an instream monitoring program and adaptive management approach to successfully achieve targeted water quality goals (see Chapter 7).

5.1. MODEL DESCRIPTION

The Loading Simulation Program C++ (LSPC) model was used to simulate fecal coliform transport and fate in the Hogue Creek watershed. LSPC is a public domain watershed model developed by Tetra Tech, Inc. (Tetra Tech, 2005) and maintained as part of USEPA's TMDL Modeling Toolbox. LSPC is a dynamic watershed model that is used to simulate hydrologic processes, sediment, pollutant accumulation, transport, and general water quality. LSPC was developed by streamlining algorithms used in the Hydrologic Simulation Program Fortran (HSPF) model (Duda *et al.*, 2001) and rewriting those algorithms in a Microsoft Visual C++ programming architecture.

The LSPC model simulates point source and nonpoint source pollutant loadings, performs flow routing through streams, and simulates instream water quality processes. For nonpoint sources, LSPC simulates accumulation and die-off of the pollutant on the land surface according to the distribution of sources, land use, and management practices. LSPC simulates the runoff of water and accumulated pollutants from both pervious and impervious portions of the watershed, considering the individual characteristics of various land uses and soil types. LSPC then simulates the routing of water and pollutants through the stream channel network, considering die-off during transport. Fecal coliform bacteria was simulated as a dissolved pollutant using the general constituent pollutant model (GQUAL) in LSPC. Simulated fecal coliform concentrations were then translated to *E. coli* concentrations using VADEQ's translator equation (VADEQ, 2003).

The ArcGIS 9 geographical information system program was used to display and analyze watershed information for input into LSPC. Microsoft Access was used to store and manage model input parameters and data. Microsoft Excel was used to summarize model output.

5.2. INPUT DATA REQUIREMENTS

The LSPC model requires a wide variety of input data to describe hydrology, pollutant sources, and land use characteristics within the watershed. The different types and sources of input data used to develop the TMDL for the Hogue Creek watershed are discussed below.

5.2.1. Meteorological Data

Hourly precipitation and evapotranspiration data are needed for the LSPC watershed model to simulate flow and bacteria concentrations. Precipitation data for weather stations near the Hogue Creek watershed were obtained from the National Climatic Data Center (NCDC, 2006). Daily maximum and minimum temperatures were also obtained from NCDC, and used to calculate hourly evapotranspiration. For the Hogue Creek TMDL, data were obtained from a total of five weather stations ranging from 4 to 14 miles from the Hogue Creek watershed (Figure 5-1 and Table 5-1). Using data reported from these stations, an hourly precipitation and evapotranspiration data set for the Hogue Creek watershed was developed for the time period of 1/1/1993 through 1/1/2006.

The Star Tannery Weather Station (448046) was used as the primary station for generating Hogue Creek TMDL weather files. The Star Tannery station is only 6.64 miles outside of the

Hogue Creek watershed, and it represented the closest station with hourly data. As with most weather stations, there were occasional gaps in data at the Star Tannery Station from either station inactivity or equipment malfunction. These data gaps had to be patched with reliable data from other surrounding stations. Gaps in daily maximum and minimum temperature data at Star Tannery were patched with data from other stations in the following order of priority: Winchester (449181), then Winchester 7 SE (449186). If data from the first priority patching station was unavailable then the next priority station was consulted. Data from Gore (443468) was not used for patching because the limited Gore data set did not overlap with any periods of missing temperature at Star Tannery.

Gaps in hourly precipitation data at Star Tannery were patched with data from other stations in the following order of priority: Cacapon (461323) hourly data, Gore (443468) disaggregated daily data, and Winchester (449181) disaggregated daily data. While the Gore and Winchester stations are closer in proximity to the Hogue Creek watershed than the Cacapon Station, Cacapon was used as the first priority patching station because it contained hourly recorded data. This meant that the timing and time-specific intensities of rainfall events were not lost. Hourly precipitation data from the Gore and Winchester stations were computed by disaggregating daily accumulated rainfall amounts using the USEPA BASINS program WDMUtil. This disaggregation sometimes looses significant patterns in rainfall timing and intensity.

Patched weather files were then tested for representativeness by comparing precipitation and observed Hogue Creek flow. This test was conducted to determine if any time periods severely misrepresented precipitation in the watershed. Large flow peaks without large corresponding precipitation or large precipitation events without large corresponding flow peaks were signs that the patched weather files were not representative of the actual watershed conditions at that time. Based on this comparison, three periods were identified as not representative. These included 8/3/1995 – 8/6/1995, 7/18/1996 – 7/22/1996, and 5/1/2003 – 6/30/2003. For these time periods, precipitation was patched from an alternate station that better represented actual watershed conditions based on observed flow. Precipitation data from Cacapon was used to patch the weather file during the first two periods, and precipitation data from Winchester was used to patch the weather file during the final period in 2003. Overall, 32% of precipitation data was patched due to data gaps at the Star Tannery Station or to improve representativeness (Table

5-2). Twenty-one percent of the data set was patched with data from Cacapon, 6.1% was patched with data from Gore, and 5.1% was patched with data from Winchester. For daily minimum and maximum temperature data, only 14% of the data sets were patched. Twelve percent was patched with Winchester data, and 1.9% was patched with Winchester 7SE data.

Once complete maximum and minimum daily temperature data sets were compiled for the watershed, these data were used to develop an hourly potential evapotranspiration data set. Potential evapotranspiration was computed by the Hamon method (Hamon, 1961) from station latitude and daily minimum and maximum temperatures. This computation was conducted using the WDMUtil program available as part of USEPA's BASINS software.

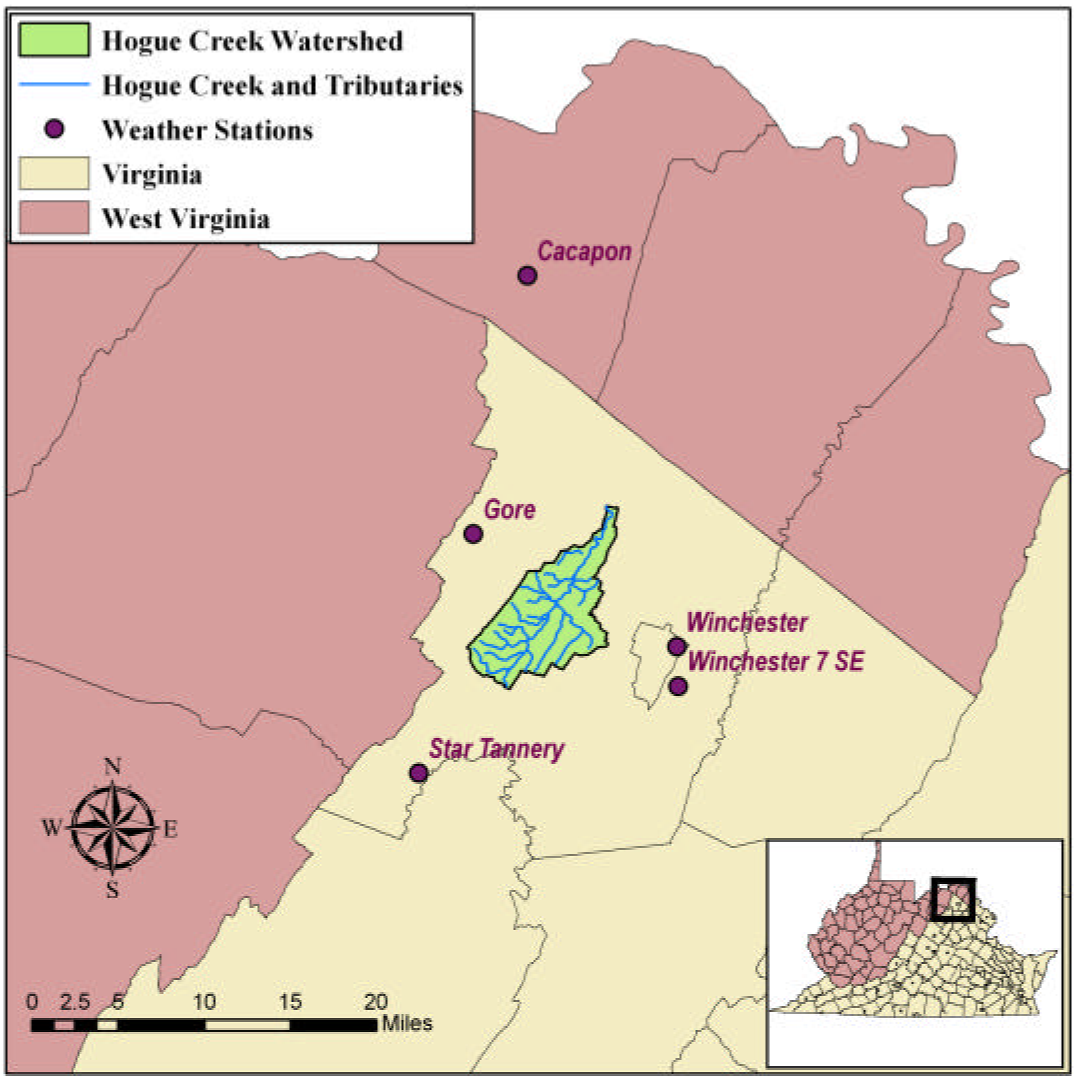


Figure 5-1. Weather Stations Used in Hogue Creek TMDL Development.

Table 5-1. Meteorological Datasets Compiled for the Hogue Creek LSPC Model.

Station Name	Station ID	Data Frequency	Data Type	Period of Record	Elevation (m)	Distance From Watershed (mi)
Star Tannery	448046	Hourly	Precipitation	1948-2006	289.6	6.64
			Min Temp.			
			Max Temp.			
Cacapon	461323	Hourly	Precipitation	1980-2006	289.6	14.27
Gore	443468	Daily	Precipitation	1997-2001	347.5	3.91
Winchester	449181	Daily	Precipitation	1982-2006	219.5	4.03
			Min Temp.			
			Max Temp.			
Winchester 7 SE	449186	Daily	Min Temp.	1979-2006	207.3	4.76
			Max Temp.			
			Max Temp.			

Table 5-2. Hogue Creek TMDL Weather File Patching Summary.

Source	Hourly Precipitation		Daily Min. Temp.		Daily Max. Temp.	
	# of Data Points	% of Record	# of Data Points	% of Record	# of Data Points	% of Record
Star Tannery	77,296	68%	4,103	86%	4,104	86%
Patched by Cacapon	23,869	21%				
Patched by Gore	6,975	6.1%				
Patched by Winchester	5,836	5.1%	583	12%	583	12%
Patched by Winchester 7SE			93	1.9%	92	1.9%
Total Patched	36,680	32%	676	14%	675	14%
Total Data Set	113,976	100%	4,779	100%	4,779	100%

5.2.2. Land Use

Section 3.5 describes the land cover within the Hogue Creek watershed. These data were obtained from the 1992 National Land Cover Dataset (NLCD) and based on satellite imagery of the land surface. For this reason, these data may not always be accurate as a land use dataset. For instance, transitional areas could incorrectly be classified as cropland, or residential areas with ample tree cover might be interpreted as forest, rather than low intensity residential. This distinction is important in the water quality modeling of bacteria, because bacterial sources such as failing septic systems and pets are distributed to residential land use areas. Based solely on land cover data, the residential land use in the watershed is underestimated, so those loads would be distributed to an erroneously small land area. To correct potential errors in the transfer from land cover to land use datasets, aerial photography and census data were used.

Large areas classified as cropland within the watershed were investigated using aerial photography. If these areas were found to not be crops, the land use acreages within that sub-watershed were modified to reflect the correct land use classifications. Crop acreage in sub-watersheds H-01, H-10, and H-11 were found to be incorrectly identified in the land cover dataset. In total, 9.4 acres of transitional land, 4.41 acres of forest, 20.9 acres of pasture, and 1.9 acres of residential land use was incorrectly classified as cropland.

The residential land use was then modified to more accurately represent forested and open residential areas. 2000 census data were used to determine the number of houses in each sub-watershed (Table 4-3). Because no sewer service exists in the watershed, a minimum lot size of 0.25 acres was assumed to allow for septic systems. Based on the number of homes in each sub-watershed, and a 0.25 acre lot size, a minimum residential acreage was calculated for each sub-watershed. If the low intensity residential acreage from the land cover data set was less than this minimum value, the acreage was increased to the minimum value. Any increase in low intensity residential acreage was offset by reductions in forest and pasture land uses based on the proportion of forest to pasture land in the sub-watershed.

After cropland and residential land use modifications were made, a robust land use data set was obtained for the Hogue Creek watershed. Table 5-3 shows the land use breakdown in each sub-watershed. These land use values were used to represent the watershed in the LSPC model, and they were used to calculate land use specific bacterial loadings for the watershed.

Table 5-3. Land Use in Hogue Creek Sub-watersheds.

Sub-watershed	Acres in Each Land Use						
	Forest	Pasture/ Hay	Row Crops	Commercial/ Transitional	Low Intensity Residential	High Intensity Residential	Total
H-01	1705	202	2	12	14	0	1935
H-02	1386	765	16	5	15	0	2187
H-03	200	479	17	6	10	0	712
H-04	204	14	2	0	2	0	222
H-05	341	161	7	1	5	0	515
H-06	3286	945	23	93	57	0	4404
H-07	4915	1050	69	86	136	0	6256
H-08	234	96	2	2	2	0	336
H-09	2317	385	2	29	28	0	2761
H-10	2570	515	11	7	138	0	3241
H-11	3571	386	10	16	29	0	4012
Total	**20729**	**4998**	**161**	**257**	**436**	**0**	**26581**

A portion of the commercial/transitional, low intensity residential, and high intensity residential land uses is considered impervious to precipitation. Imperviousness was estimated at 80%, 11%, and 30%, respectively, for these land uses. Based on these percentages, the impervious portion of each land use was modeled in LSPC as an impervious land segment, while the remaining acreage was modeled as a pervious land segment.

5.2.3. Hydrology Model Parameters

The LSPC model was constructed to simulate both hydrology and bacteria in Hogue Creek. Because the hydrology of the watershed is so important in controlling the loading and concentrations of pollutants in the stream, the model was first constructed and calibrated to accurately predict the flow of Hogue Creek as observed at the USGS flow gaging station. Once the model was accurately representing the hydrology of the watershed, then the bacteria loadings were included in the model and the water quality was calibrated to match observed bacteria data collected from the stream.

A number of different model parameters are required in the LSPC model to simulate hydrology. Table 5-4 shows the different hydrologic parameters used in the Hogue Creek LSPC model. This table describes how the value for each parameter was obtained and the variables by which the parameter was altered. Some of the parameters were constants used throughout the model. Parameters that depend on seasonal cycles were varied by month. Other parameters were given a separate value for each sub-watershed, land use, or soil type. Sub-watersheds used in the model are shown in Figure 3-1. Land uses considered in the model were the six aggregated land use categories tabulated in Table 3-2 (excluding open water). Soil types considered in the model were those hydrologic soil types identified in Table 3-1 for each of the different sub-watersheds.

Table 5-4. Hydrologic Model Parameters for the Hogue Creek LSPC Model.

Parameter	Parameter Description	Varied By	Source
DEPINIT_M	Initial water depth	Sub-watershed	Field measurement
LEN_M	Longitudinal length of the reach	Sub-watershed	GIS measurement
SLOPE	Longitudinal slope of the reach	Sub-watershed	GIS measurement
WID_M	Cross-sectional bankfull width	Sub-watershed	Field measurement
DEP_M	Cross-sectional bankfull depth	Sub-watershed	Field measurement
R1	Ratio of bottom width to bankfull width	Sub-watershed	Field measurement
R2	Upper bank slope	Sub-watershed	Field measurement
W1	Ratio of bank width to bankfull width	Sub-watershed	Field measurement
MANNING_N	Manning's roughness coefficient	Sub-watershed	Estimated from literature
CRRAT	Ratio of maximum velocity to mean velocity	Sub-watershed	Estimated from literature
SLSUR	Slope of overland flow	Sub-watershed and Land use	GIS measurement
LSUR	Length of overland flow	Sub-watershed and Land use	GIS measurement
MELEV	Mean watershed elevation	Sub-watershed	GIS measurement
RMELEV	Mean reach elevation	Sub-watershed	GIS measurement
LZSN	Lower zone nominal soil moisture storage	Soil type and Land use	Calibrated
INFILT	Index to infiltration capacity	Soil type and Land use	Calibrated
KVARY	Variable groundwater recession	Constant	Calibrated
AGWRC	Base groundwater recession	Constant	Calibrated
PETMAX	Temperature below which evapotranspiration is reduced	Constant	Estimated from literature
PETMIN	Temperature below which evapotranspiration is set to zero	Constant	Estimated from literature
INFEXP	Exponent in infiltration equation	Constant	Estimated from literature
INFILD	Ratio of max/mean infiltration capacities	Constant	Estimated from literature
DEEPFR	Fraction of groundwater inflow to deep recharge	Constant	Calibrated
BASETP	Fraction of remaining evapotranspiration from baseflow	Constant	Calibrated
AGWETP	Fraction of remaining evapotranspiration from active groundwater	Constant	Calibrated
CEPSC	Interception storage capacity	Land use and month	Calibrated
UZSN	Upper zone nominal soil moisture storage	Land use and month	Calibrated
NSUR	Manning's n for overland flow	Constant	Calibrated
INTWF	Interflow inflow parameter	Constant	Calibrated
IRC	Interflow recession parameter	Constant	Calibrated
LZETP	Lower zone evapotranspiration parameter	Land use and month	Calibrated

The source of parameter values used in the model varied depending upon the parameter. Some of the parameters, such as physical characteristics of the stream channel, were specifically measured in the field by VADEQ staff. Other parameters were obtained by analyzing GIS coverages of the watershed. For instance, the slopes of each reach were obtained by combining digital elevation data for the watershed and stream coverages. Other parameters were estimated from literature values, and some parameters were initially estimated and then used as calibration parameters. These calibration parameters were adjusted during the calibration process to optimize the agreement between simulated flows and measured flows. The resulting values for hydrologic parameters in the calibrated Hogue Creek LSPC model are listed in APPENDIX A.

5.2.4. Water Quality Model Parameters

Following successful calibration of Hogue Creek hydrology, the LSPC model was expanded to simulate fecal coliform concentrations. A number of different model parameters are required in the LSPC model to simulate fecal coliform. Table 5-5 shows the different water quality parameters used in the Hogue Creek LSPC model to simulate fecal coliform. The monthly accumulation rate (ACQOPM) and maximum storage (SQOLIM) were calculated from bacteria source information for each sub-watershed and land use on a monthly basis. All other water quality parameters were constants that were estimated from literature values and adjusted (if necessary) during the calibration process to optimize the agreement between simulated fecal coliform levels and measured concentrations. The resulting values for water quality parameters in the calibrated Hogue Creek LSPC model are listed in Table 5-5 and APPENDIX B.

Table 5-5. Water Quality Model Parameters for the Hogue Creek LSPC Model.

Parameter	Parameter Description	Varied By	Source	Calibrated Value
WSQOP	Rate of surface runoff which will remove 90% of stored pollutant	Constant	Calibrated	0.38
IOQC	Concentration of pollutant in interflow	Constant	Calibrated	50
AOQC	Concentration of pollutant in active groundwater	Constant	Calibrated	25
ACQOPM (MON-ACCUM)	Monthly parameter for rate of accumulation of pollutant	Sub-watershed, land use, and month	Calculated from source inventory	See APPENDIX B
SQOLIM	Monthly parameter for maximum storage of pollutant	Sub-watershed, land use, and month	Literature derived fraction of accumulation rate	See APPENDIX B
FSTDEC	First order decay rate for pollutant	Constant	Calibrated	0.76
THFST	Temperature correction coefficient for first order decay of pollutant	Constant	Estimated from literature	1.05

5.3. ACCOUNTING FOR POLLUTANT SOURCES

5.3.1. Modeling Permitted Point Sources

There are a total of 46 SFH general permits and 2 individual VPDES permits in the Hogue Creek watershed (Section 4.1). During TMDL allocation model runs, permitted point sources were modeled using maximum permitted design flows and bacteria concentrations. SFH permits were modeled at 1,000 gal/d and 200 cfu/100ml fecal coliform. Indian Hollow (VA0071927) and Gainesboro (VA0091898) Elementary Schools were modeled at 200 cfu/100ml fecal coliform and 7,000 and 10,000 gal/d, respectively.

During calibration and existing condition model runs, permitted point sources were modeling using more representative flows. Flow for the Gainesboro Elementary School (VA0091898) was set to zero, because this facility is not yet constructed and discharging. Flow for the Indian Hollow Elementary School (VA0071927) was based on monthly average flow reported by the facility on discharge monitoring reports (DMRs). Reported flow ranged from zero during summer months when school was not in session to 4,000 gal/d. SFH general permits that did not discharge to perennial streams were modeled with zero flow during calibration and existing condition model runs. This is because under normal conditions, flow from these discharges would percolate into the soil within dry ditches and not affect bacteria concentrations or flows in Hogue Creek. For SFH general permits that do discharge to perennial streams, the flows during calibration and existing condition model runs were based on the anticipated flow recorded on the permit application. Flows ranged from 20 to 1000 gal/d.

5.3.2. Modeling Direct Deposits

Fecal coliform loading from straight pipes was modeled as directly entering the stream with no die-off from source to stream. The daily fecal coliform loadings from straight pipes calculated in Table 4-7 were modeled as direct inputs within the respective sub-watersheds.

A portion of fecal coliform loadings from animals that live or wade in the stream was also modeled as a direct input. This includes loadings from cattle, raccoon, muskrat, beaver, geese, and ducks. For cattle, direct deposit loadings were determined from the number of cattle with stream access, the total loading from those cattle, and the percentage of time spent in the stream as described in Section 4.4.1. The calculated direct deposit loading from cattle by sub-watershed and month was presented in Table 4-13. These loads were modeled as continuous direct inputs varying by month within the respective sub-watersheds.

Direct deposit loadings from wildlife species were determined based on the total loading from those species and the percent of load deposited directly in the stream (see Section 4.5). The calculated direct deposit loading from wildlife by sub-watershed and season was presented in Table 4-20. These loads were modeled as continuous direct inputs varying by month within the respective sub-watersheds.

5.3.3. Modeling Land Applied Sources

Fecal coliform loads from failing septic systems and pets and fecal coliform loads from livestock and wildlife that were not deposited directly in the stream were modeled as land applied loads. Chapter 4 describes and quantifies the load from each source deposited onto the land surface in each sub-watershed. For modeling purposes, the land applied loads from each source within a sub-watershed were distributed among the land uses occupied by that source. The load was distributed evenly across the total acreage of land occupied by that source within the sub-watershed. Table 5-6 shows the land uses across which fecal coliform loads were distributed for each source. In the LSPC model, these loads were represented by a daily loading rate for each sub-watershed and land use combination. The daily loading rate was calculated as the total daily load from all sources to a particular land use in a particular sub-watershed divided by the area of that land use in the sub-watershed. Because loadings and some animal numbers varied by month, the daily loading rates also were varied by month. The daily loading rates were expressed in the LSPC model in the form of an Accumulation Table (ACCUM_TABLE). The Accumulation Table for the calibrated existing condition is presented in APPENDIX B.

Once fecal coliform is deposited on the land surface, precipitation and runoff is needed to transport the bacteria to surface waters. The LSPC model simulates precipitation events based on the weather data inputs, and simulates runoff from a variety of land use and hydrologic parameters (see Section 5.2.3).

Table 5-6. Summary of Land Uses Receiving Fecal Coliform Loads From Various Sources.

Source	Forest	Pasture	Crops	Commercial	Residential
Failing Septic Systems					x
Pets					x
Livestock		X			
Deer	x	X	x	x	x
Raccoon	x	X	x	x	x
Muskrat	x		x		
Beaver	x	X			
Geese	x	X	x	x	x
Duck	x	X	x	x	x
Wild Turkey	x	X	x		

5.3.4. Modeling fecal coliform die-off

The die-off of fecal coliform on the land surface and in the stream was modeled according to the following first order decay function:

$$C_t = C_0 10^{-Kt} \quad \textbf{[5-1]}$$

where: C_t = concentration or load at time t,

C_0 = starting concentration or load,

K = decay rate (day^{-1}),

and t = time in days.

Following successful water quality calibration, a resulting decay rate of 0.76 day^{-1} was used for fecal coliform die-off in the stream. On the land surface, fecal coliform die-off was estimated as 0.51 day^{-1} during warm months and 0.36 day^{-1} during cold months (USEPA, 2000b). This decay rate was represented in LSPC by specifying a maximum surface buildup of 1.5 times the daily buildup rate during April through September and 1.8 times the daily buildup rate during October through March.

5.3.5. *E. coli* Translator Equation

Output from the LSPC model was generated as an hourly timeseries and daily average time series of fecal coliform concentrations. *E. coli* concentrations were determined using the following translator equation:

$$\log_2 EC(cfu/100mL) = -0.0172 + 0.91905 * \log_2 FC(cfu/100mL) \quad \textbf{[5-2]}$$

This translator was implemented as a post-processing step in a spreadsheet after running the model.

Water quality calibration of the model was conducted using fecal coliform, since source information and observed monitoring data were in the form of fecal coliform measurements. For TMDL scenarios, however, fecal coliform concentrations were translated to *E. coli*. This allowed direct comparison of TMDL loadings to the *E. coli* water quality standards.

The TMDL was set to meet both the instantaneous *E. coli* standard of 235 cfu/100ml and the monthly geometric mean *E. coli* standard of 126 cfu/100ml. Instantaneous *E. coli* concentrations were translated from the daily average of hourly fecal coliform concentrations simulated for each day. Monthly geometric means were calculated by taking the geometric mean of translated daily average fecal coliform concentrations within each calendar month.

5.4. ACCOUNTING FOR BEST MANAGEMENT PRACTICES (BMPS)

The Virginia Department of Conservation and Recreation tracks all agricultural best management practices (BMPs) that are cost-shared in Virginia. Table 5-7 contains a summary of

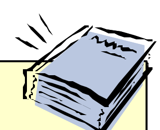
BMPs installed in the Hogue Creek watershed through Virginia's Agricultural Cost Share Program. Very few BMPs have been installed in the Hogue Creek watershed with state assistance. Neither of these two practices was included in the modeling of Hogue Creek. The first BMP was installed in 1997 and was given a five year design lifespan. The second BMP, integrated pest management, should not affect bacteria source loadings within the watershed.

Table 5-7. Agricultural Best Management Practices Installed in the Hogue Creek Watershed.

Best Management Practice	Extent Installed (acres)	Year Installed
Permanent vegetative cover on cropland (SL-1)	1	1997
Integrated pest management (WQ-10)	2037	2004

5.5. MODEL CALIBRATION AND VALIDATION

Model calibration is the process of selecting model parameters that provide an accurate representation of the watershed. Validation ensures that the calibrated parameters are appropriate for time periods other than the calibration period. In this section, the procedures followed for calibrating the hydrology and water quality components of the LSPC model are discussed. The calibration and validation results of the hydrology and water quality components are presented.



Definition:

<u>Calibration and Validation</u> – Calibration is the process of adjusting model parameters until the computer model produces the best possible fit with real-world data. Validation is then testing the fit of the model against a different set of real-world data than what was used to calibrate the model.

5.5.1. Hydrologic Calibration/Validation

The hydrology calibration period selected for the Hogue Creek LSPC model was 1995-1997. This time period represented both higher flow and lower flow periods. The Hogue Creek LSPC model was run for this time period and then the calibration parameters identified in Table 5-4 were adjusted until simulated stream flow matched observed stream flow during that time period. A reasonable match or fit between the simulated and observed flow was determined according to the hydrology calibration criteria shown in Table 5-8. These criteria are consistent with the criteria recommended in the HSPF Expert System (HSPEXP) developed by the USGS (Lumb et al., 1994) to assist in hydrologic calibration.

Table 5-8. Hydrology Calibration Criteria Used for the Hogue Creek LSPC Model.

Errors (Simulated-Observed)	Calibration Criteria
Error in total volume:	10%
Error in 50% lowest flows:	10%
Error in 10% highest flows:	15%
Seasonal volume error - Summer:	30%
Seasonal volume error - Fall:	30%
Seasonal volume error - Winter:	30%
Seasonal volume error - Spring:	30%
Error in storm volumes:	20%
Error in summer storm volumes:	50%

Most calibration parameters were adjusted within the typical ranges for those parameters as defined by USEPA BASINS Technical Note 6 (USEPA, 2000). Several parameters (IRC, CEPS, UZSN, and LZETP) were adjusted slightly outside of typical ranges but within the possible ranges for those parameters. Final calibrated values for all hydrologic parameters are shown in APPENDIX A.

In addition to adjusting calibration parameters, a small constant baseflow contribution was added to the model to account for sustained stream flows during extremely dry periods. During extreme dry periods, observed flows would stabilize or moderate whereas modeled flows would continue decreasing. Adjusting model parameters could not account for the moderated baseflow conditions during these extreme dry periods. To correct this discrepancy, a 0.3 cfs constant input was added to the model in sub-watershed H-11. During the 1994-2006 modeling period, observed stream flows only decreased below 0.3 cfs 0.5% of the time. The addition of this constant baseflow input represents stream recharge from deep aquifers or from outside of the basin. Such recharge or extra-basin transfer is possible and even likely in a karst geologic setting such as the Hogue Creek watershed.

A successful hydrologic calibration was obtained for the Hogue Creek LSPC model. Simulated flow during the calibration period (1995-1997) correlated nicely with observed flow during that time period. The error statistics for the successful hydrologic calibration are shown in Table 5-9. Figure 5-2 and Figure 5-3 compare the simulated and observed flows in Hogue Creek during the calibration period. Figure 5-4 compares the average monthly flows simulated by the model with observed average monthly flows. Figure 5-5 shows the simulated and observed flow frequency curves, and Figure 5-6 shows a representative storm. Each of these comparisons shows relatively good agreement between simulated and observed flows. This agreement indicates that the model developed for the Hogue Creek watershed represents the hydrologic conditions in the watershed and can be used to reasonably predict flows in Hogue Creek.

Table 5-9. Error Statistics for Hydrologic Calibration Period (1995-1997).

Statistics	Simulated (in/yr)	Observed (in/yr)	Error (%)	Criteria (%)	Criteria met
Total volume	6.56	6.43	1.93	10	Y
Volume of 50% lowest flows	0.63	0.66	-3.54	10	Y
Volume of 10% highest flows	3.24	3.52	-7.75	15	Y
Seasonal volume - Summer	1.40	1.12	24.58	30	Y
Seasonal volume - Fall	2.05	1.58	29.72	30	Y
Seasonal volume - Winter	1.85	2.51	-26.26	30	Y
Seasonal volume - Spring	1.26	1.22	3.08	30	Y
Total storm volume	3.21	3.22	-0.51	20	Y
Summer storm volume	0.79	0.75	4.90	50	Y
Coefficient of Determination (r^2)	0.6987				

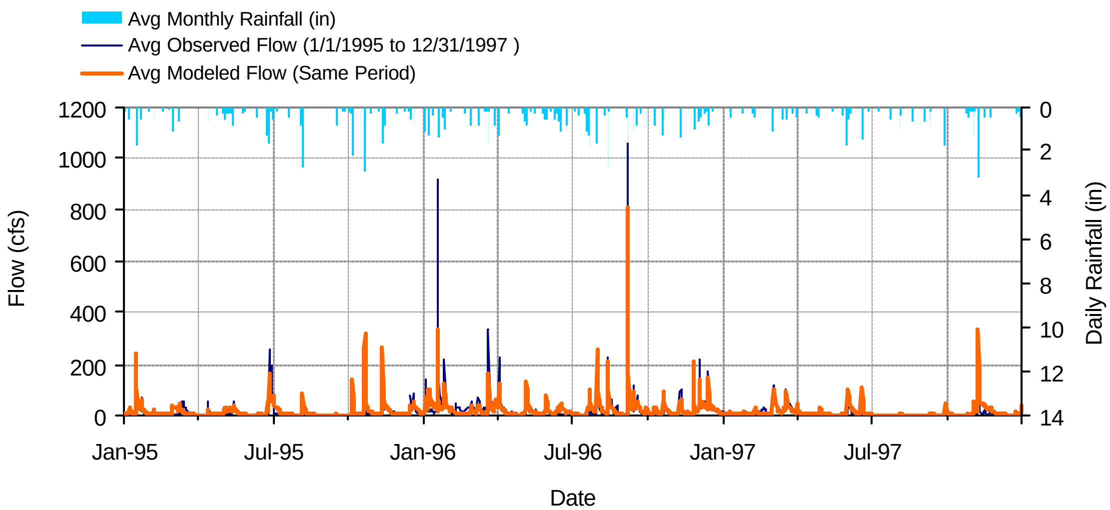


Figure 5-2. Simulated Versus Observed Flow in Hogue Creek During Calibration Period (1995-1997).

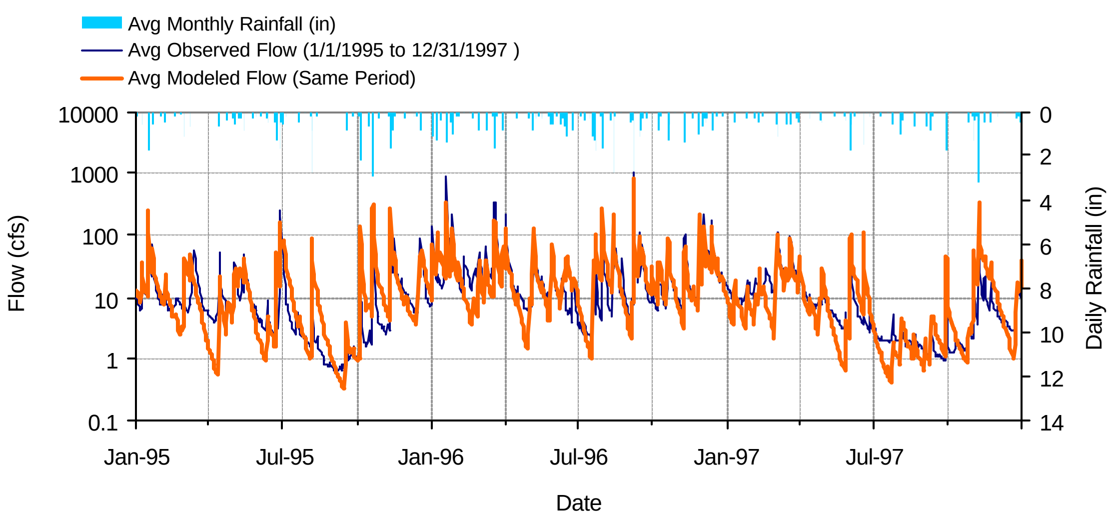


Figure 5-3. Simulated Versus Observed Flow in Hogue Creek During Calibration Period (1995-1997) – Log Scale.

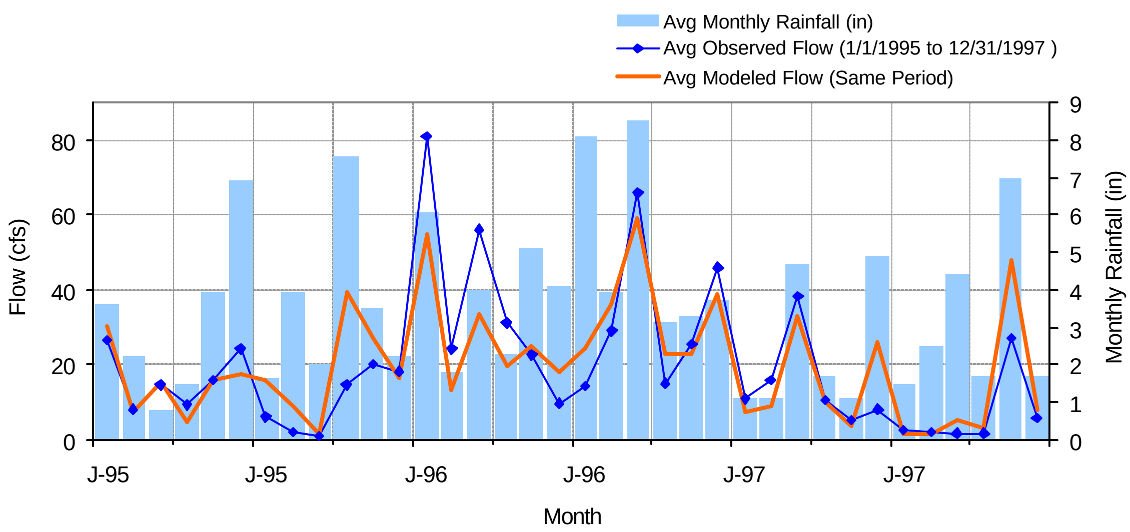


Figure 5-4. Simulated Versus Observed Average Monthly Flow in Hogue Creek During Calibration Period (1995-1997).

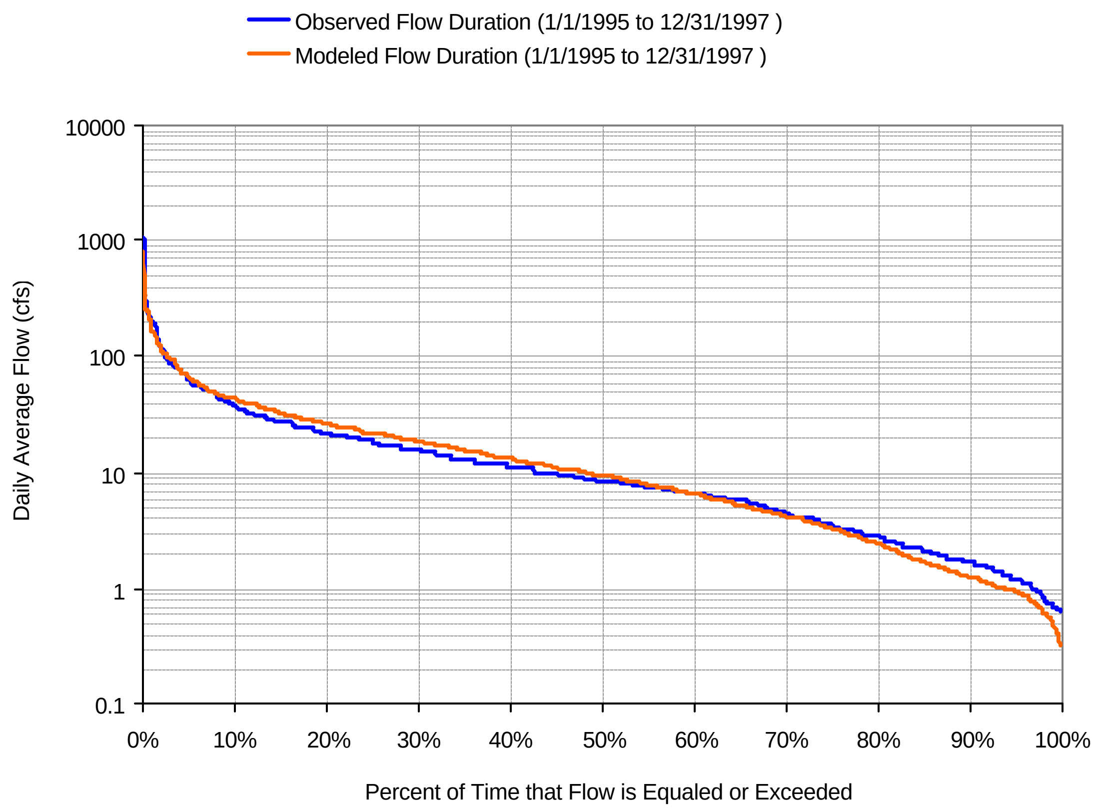


Figure 5-5. Simulated and Observed Flow Frequency Curves for Hogue Creek During the Calibration Period (1995-1997).

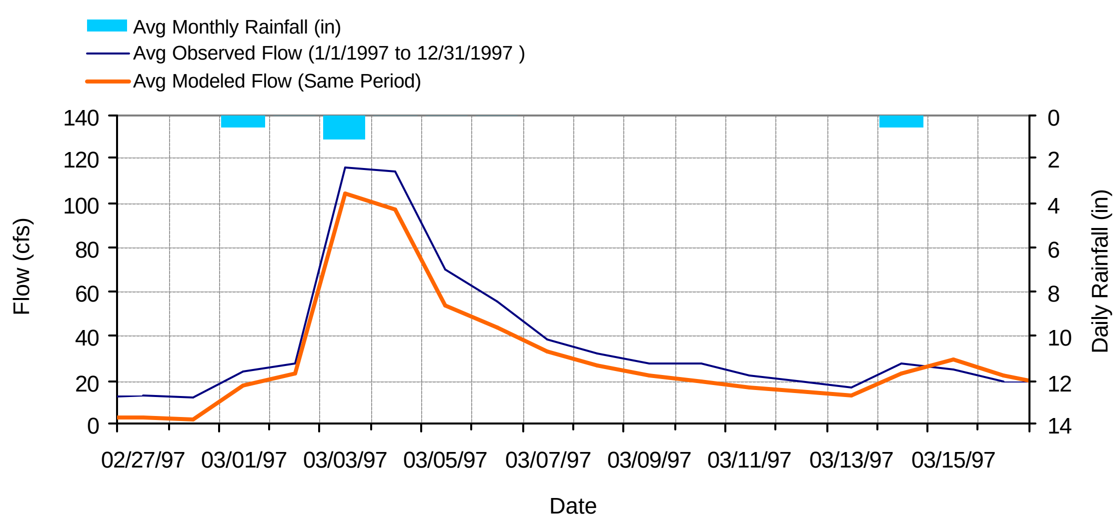


Figure 5-6. Representative Storm Event During Calibration Period (1995-1997).

The parameters that were used to calibrate the Hogue Creek LSPC model were tested during a separate validation period from 2003-2005. This time period also contained periods of high and low flows. All calibration criteria were met during the validation period (Table 5-10). Figure 5-7 through Figure 5-11 compare the simulated and observed flows in Hogue Creek during the validation period (2003-2005). Similarly to the calibration period, simulated flows during the validation period represented good agreement with observed flows.

Table 5-10. Error Statistics for Hydrologic Validation Period (2003-2005).

Statistics	Simulated (in/yr)	Observed (in/yr)	Error (%)	Criteria (%)	Criteria met
Total volume	6.17	6.65	-7.17	10	Y
Volume of 50% lowest flows	0.60	0.61	-2.17	10	Y
Volume of 10% highest flows	3.21	3.67	-12.38	15	Y
Seasonal volume - Summer	1.00	0.80	24.95	30	Y
Seasonal volume - Fall	1.62	1.32	22.67	30	Y
Seasonal volume - Winter	1.70	2.28	-25.76	30	Y
Seasonal volume - Spring	1.86	2.25	-17.25	30	Y
Total storm volume	3.08	3.25	-5.41	20	Y
Summer storm volume	0.67	0.58	17.15	50	Y
Coefficient of Determination (r^2)	0.611				

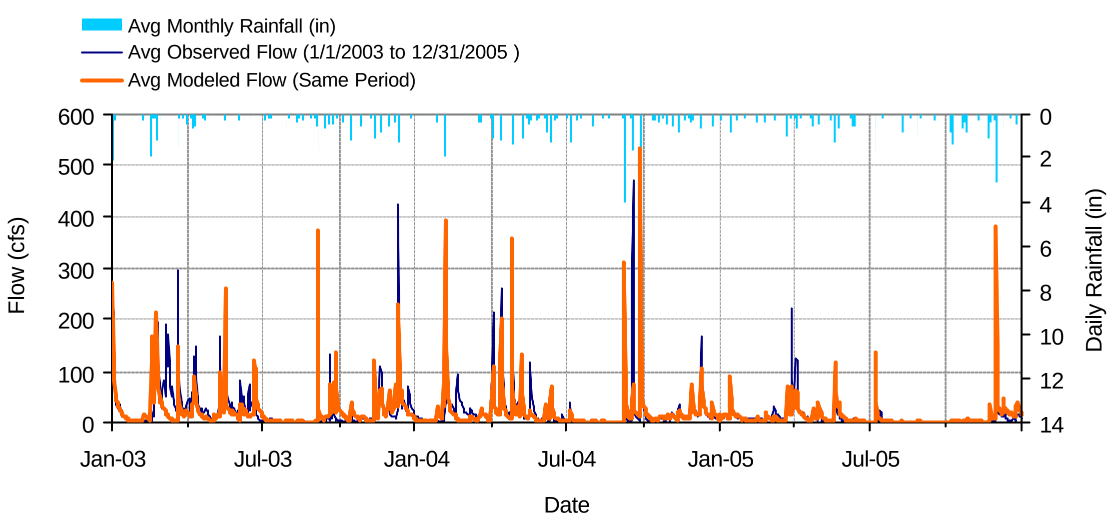


Figure 5-7. Simulated Versus Observed Flow in Hogue Creek During Validation Period (2003-2005).

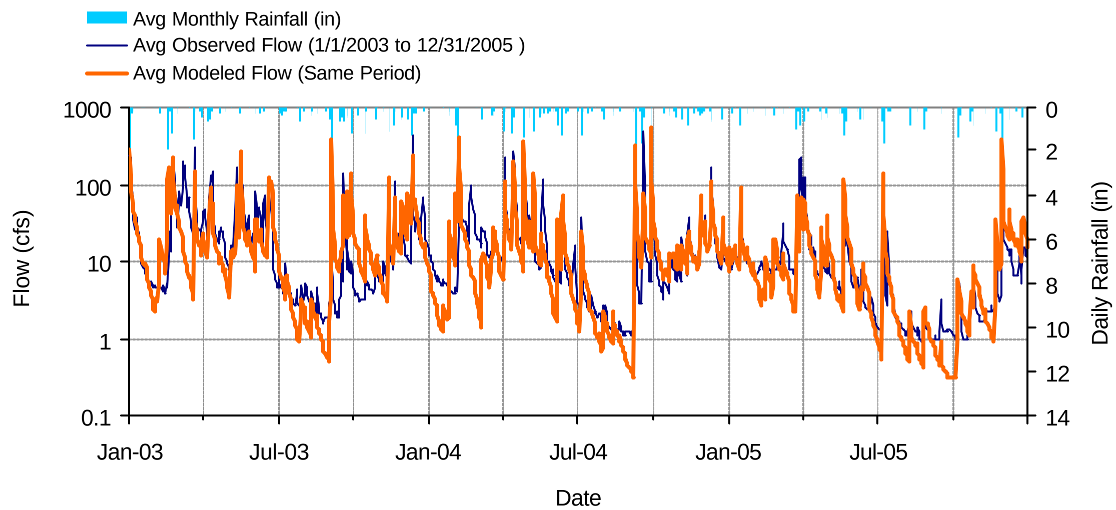


Figure 5-8. Simulated Versus Observed Flow in Hogue Creek During Validation Period (2003-2005) – Log Scale.

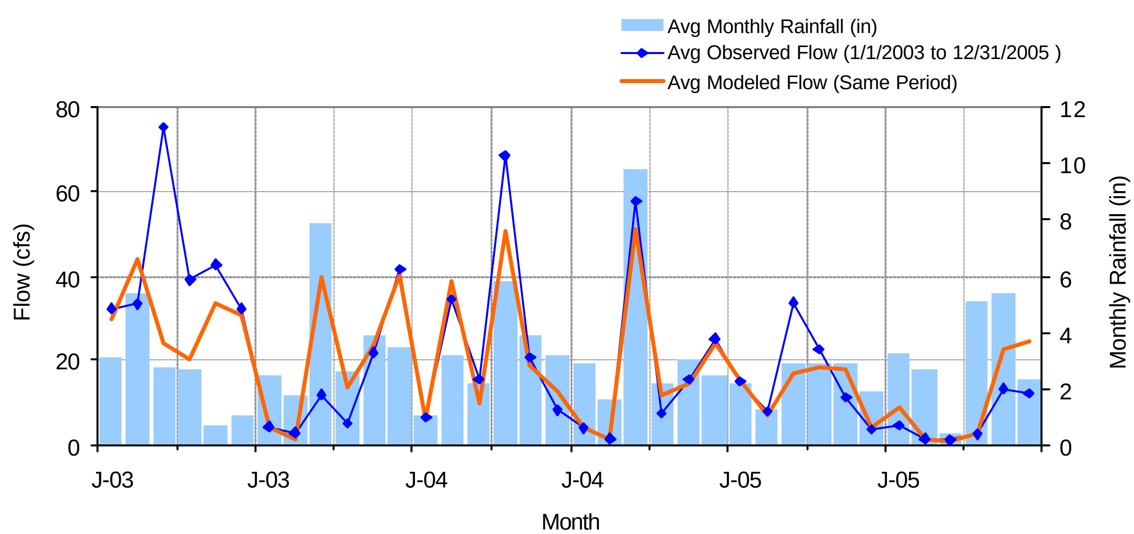


Figure 5-9. Simulated Versus Observed Average Monthly Flow in Hogue Creek During Validation Period (2003-2005).

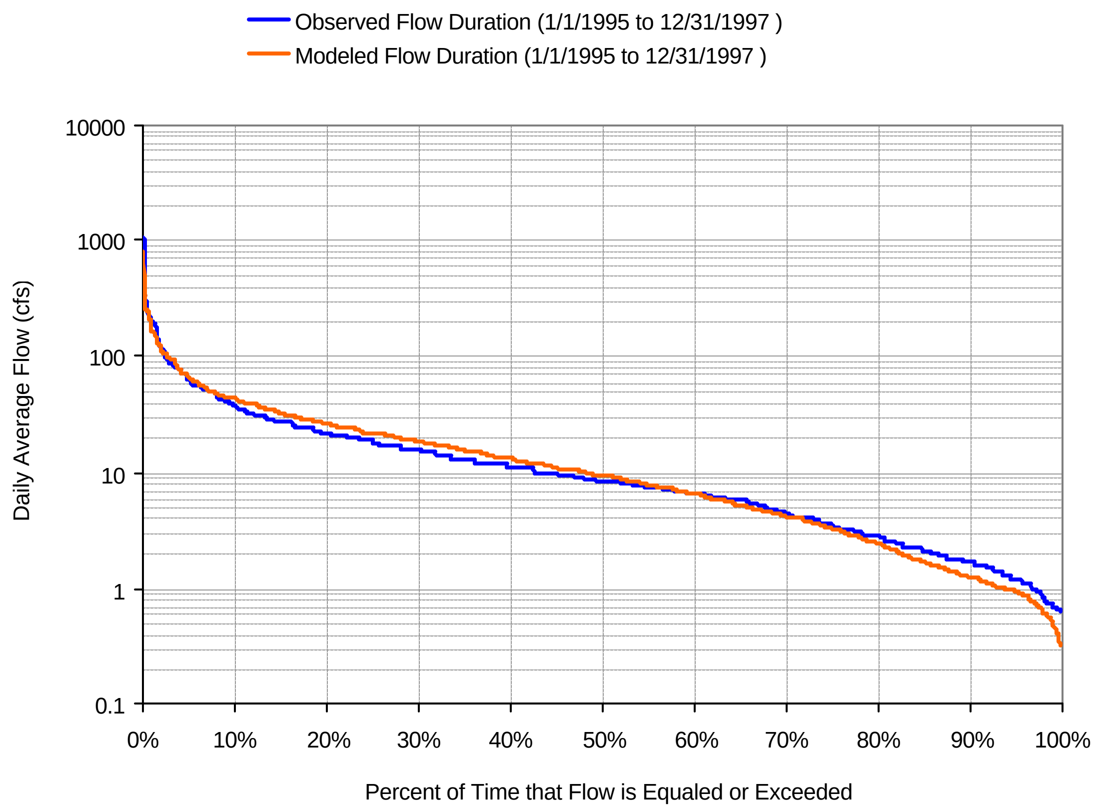


Figure 5-10. Simulated and Observed Flow Frequency Curves for Hogue Creek During Validation Period (2003-2005).

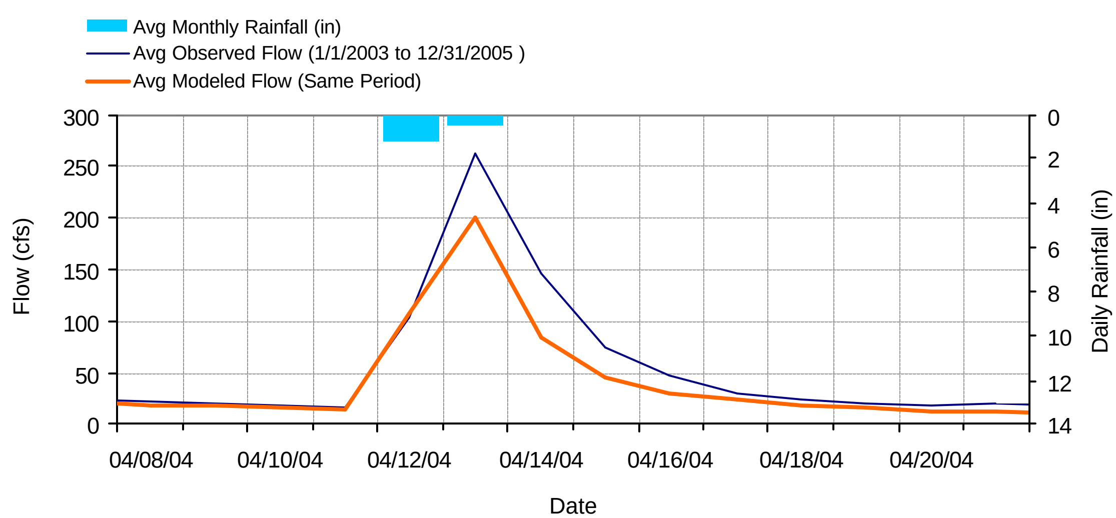


Figure 5-11. Representative Storm Event During Validation Period (2003-2005).

In addition to meeting the calibration criteria during the calibration and validation periods, these criteria were also met during the entire modeling period from 1994-2005. This indicates that the model adequately represents Hogue Creek hydrology under a variety of flow conditions and throughout the modeling period.

Simulated flows in Hogue Creek during the calibration and validation period were partitioned into surface runoff, interflow, and baseflow to examine the origins of surface water in Hogue Creek (Table 5-11). Flow partitioning was relatively consistent between the calibration and validation periods. The majority of flow (57-59%) was derived from baseflow. Approximately a quarter of average annual flow (24-25%) was from interflow, and surface runoff accounted for only 17-19% of average annual flow. These percent contributions are typical of a rural mostly-forested watershed such as Hogue Creek.

Table 5-11. Flow Partitioning for Hogue Creek During Calibration and Validation Periods.

Average Annual Flow	Calibration		Validation	
Surface Runoff (in)	0.81	17%	0.84	19%
Interflow (in)	1.15	24%	1.10	25%
Baseflow (in)	2.79	59%	2.53	57%
Total (in)	4.76	100%	4.47	100%
Baseflow Index	0.59		0.57	

5.5.2. Sensitivity Analysis

A sensitivity analysis was performed to determine the sensitivity of the calibrated Hogue Creek hydrologic model to various model parameters. To conduct this sensitivity analysis, various hydrologic parameters were individually modified and the resulting simulated flows were compared to the calibrated model flows. In this analysis, each model parameter was independently decreased by 50% compared to its calibrated value. The total flow volume, volume of 10% highest flows, volume of 50% lowest flows, and total storm volume were then compared between the calibrated model and modified parameter model. Table 5-12 and Figure 5-12 show the results of the sensitivity analysis. Those model parameters with the greatest influence on model results included: groundwater recession coefficient (AGWRC), the infiltration rate (INFILT), the lower zone nominal soil moisture storage (LZSN), and the lower zone evapotranspiration parameter (LZETP). For all of the remaining model parameters, a 50% reduction in the calibrated value resulted in less than a 10% change in simulated results.

Table 5-12. Sensitivity Analysis for Calibrated Hogue Creek Hydrologic Model - Percent Change Resulting from a 50% Decrease in Model Parameters.

Parameter	Percent Change in Simulated Flow Volumes			
	Total Flow Volume	Volume of 10% Highest Flows	Volume of 50% Lowest Flows	Total Storm Volume
LZSN	-0.26%	-4.98%	17.06%	-5.20%
INFILT	-2.15%	-24.38%	29.20%	-31.62%
KVARY	1.45%	2.93%	-6.21%	3.67%
AGWRC	0.48%	-41.81%	95.18%	-71.82%
DEEPFR	-3.76%	-2.96%	1.02%	-2.81%
BASETP	1.15%	2.08%	-0.67%	2.60%
AGWETP	1.41%	0.38%	6.76%	0.18%
INTFW	1.88%	-3.22%	6.37%	-0.16%
IRC	1.43%	-2.75%	8.20%	-3.46%
CEPS	0.73%	3.38%	-4.49%	3.94%
UZSN	0.89%	-0.97%	7.43%	-2.95%
LZETP	-9.64%	-13.36%	-7.94%	-15.56%

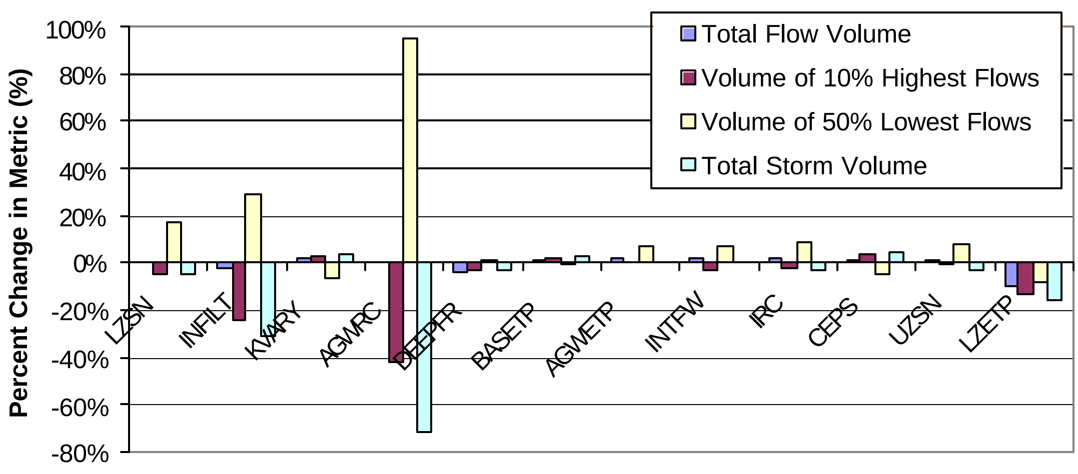


Figure 5-12. Sensitivity Analysis for Calibrated Hogue Creek Hydrologic Model - Percent Change Resulting from a 50% Decrease in Model Parameters.

5.5.3. Water Quality Calibration/Validation

To ensure that the LSPC model was accurately predicting bacteria concentrations in Hogue Creek, the water quality portion of the model was calibrated to observed fecal coliform monitoring data. Water quality was calibrated at the outlet of sub-watershed 6, which is the location of VADEQ monitoring station 1AHOC006.23. Since observed monitoring data spanned from 1994 to 2005, the 2000 to 2005 time period was used for water quality calibration and the 1994 to 1999 time period was used for validation of the water quality. During calibration, the water quality parameters identified in Table 5-5 were adjusted to obtain the best agreement between simulated fecal coliform concentrations and observed data. Final calibrated parameters are shown in APPENDIX B.

Table 5-13 compares statistics for simulated and observed fecal coliform concentrations during the calibration period. The calibrated model nicely fit observed fecal coliform data, matching the geometric mean and violation rate to within 5%. Calibration criteria were not set for minimum and maximum values, since the monitoring data set is censored at the low and high end of the measurement range. The time series of simulated fecal coliform data during the calibration period is shown in Figure 5-13. It should be noted that exact agreement with observed data is not expected, because monitoring data represents a single snap-shot in time and simulated data represents a daily average concentration. While exact agreement is not expected, simulated results should match the range and pattern of observed fecal coliform data. During the calibration period, the range and pattern of observed fecal coliform data are matched nicely. The simulated data show the same seasonal trend of higher bacteria concentrations in the summer months.

Table 5-13. Comparison of Simulated and Observed Fecal Coliform Statistics in Hogue Creek During the Calibration Period (2000-2005).

Statistic	Simulated	Observed	Error	Criteria	Criteria Met
min	27	25			
max	6298	1600			
geometric mean	171	180	-5.00%	10%	Y
violation rate	25.67%	20.69%	4.98%	10%	Y

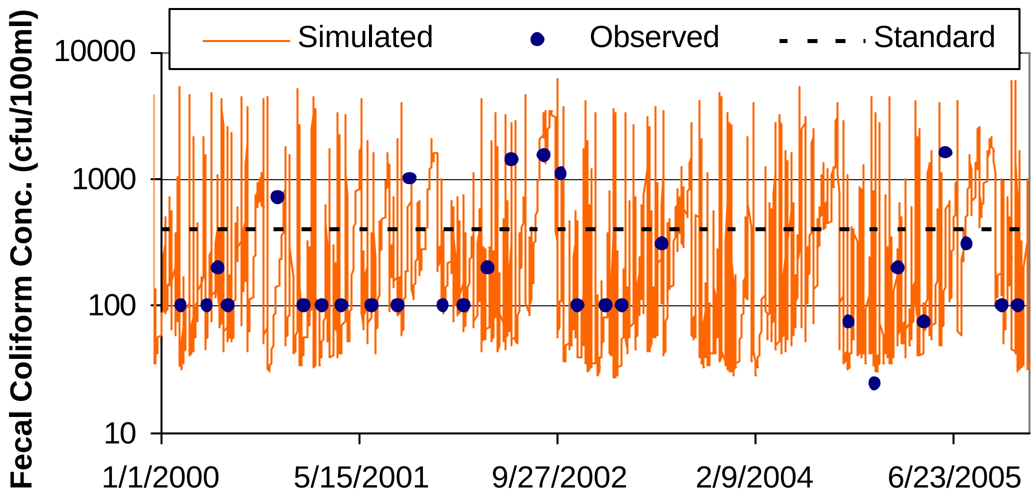


Figure 5-13. Simulated Versus Observed Fecal Coliform Concentrations in Hogue Creek During the Calibration Period (2000-2005).

After calibration of the water quality parameters, the model was validated using a different time period of observed data. The time period from 1994 to 1999 was selected for model validation. Table 5-14 compares the simulated and observed fecal coliform statistics during the validation period. While agreement with observed data was not as close as during the calibration period, the geometric mean and violation rate of simulated data were within 8% of observed data and met the calibration criteria. Figure 5-14 shows the time series of simulated results. Again, simulated results generally match observed data with relatively good agreement. The only deviations from this good agreement is one very high observed data point that is slightly above the range of daily average values and several low observed data points during the summer of 1998 and 1999. As discussed above, observed data represent snap-shots in time, while simulated data represent daily averages, so it is not surprising that observed data may at times be above or below the simulated average concentration for a day. During the summer of 1998 and 1999, flows were very low, and simulated bacteria concentrations were high due to direct deposit inputs. While the model represents these direct deposit inputs as being constant, they are actually very discrete (as individual organisms wading in the stream defecate). This difference most likely explains the disagreement between low observed and high simulated bacteria concentrations during these two summers. These time periods were also portions of the record where simulated hydrology differed the greatest from observed flows. For these reasons, this time period (1998 – 1999) was avoided in selecting a time period for TMDL allocations.

Table 5-14. Comparison of Simulated and Observed Fecal Coliform Statistics in Hogue Creek During the Validation Period (1994-1999).

Statistic	Simulated	Observed	Error	Criteria	Criteria Met
min	27	100			
max	7031	8000			
geometric mean	204	221	-7.91%	10%	Y
violation rate	31.90%	24.00%	7.90%	10%	Y

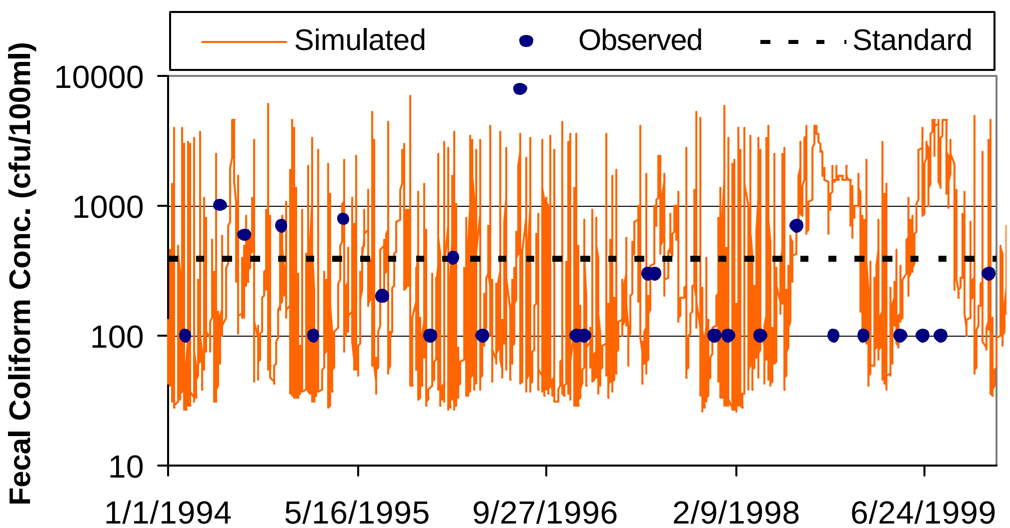


Figure 5-14. Simulated Versus Observed Fecal Coliform Concentrations in Hogue Creek During the Validation Period (1994-1999).

CHAPTER 6: TMDL ALLOCATIONS

The objective of a TMDL is to allocate allowable loads among different pollutant sources so that the appropriate control actions can be taken to achieve water quality standards (USEPA, 1991). To achieve this objective, existing conditions were first simulated and calibrated. Then future conditions were projected, and various reduction scenarios were adjusted until water quality standards were met.

6.1. EXISTING CONDITIONS

Following hydrologic and water quality calibration of the Hogue Creek LSPC model, the model was used to simulate existing conditions. Existing conditions were simulated using weather inputs for 2003 to 2005, source information described in Chapter 4, and calibrated model parameters. The relative contributions of bacteria from various sources under existing conditions were used to make informed decisions regarding appropriate and effective TMDL allocations.

Table 6-1 summarizes the relative contributions of bacteria from various sources to instream concentrations in Hogue Creek. When all sources are considered, the geometric mean *E. coli* standard of 126 cfu/100ml is violated 30.56% of the time. When sources are considered individually, only the direct deposit source from livestock is expected to cause violations of the geometric mean standard (16.67% of the time). This means that the livestock direct deposit source is the most important in controlling the *E. coli* geometric mean concentration. This observation is further illustrated in Figure 6-1. The largest peaks in monthly *E. coli* geometric mean concentrations occur during the summer months when flows are the lowest. At these times, the contributions from livestock direct deposit account for the majority of the concentration. During wetter periods, however, other sources such as runoff from agricultural or residential lands are the largest contributors, but concentrations do not exceed the monthly geometric mean standard at these times. This figure also shows that point sources and runoff from forest are the smallest contributors to monthly *E. coli* geometric mean concentrations.

Table 6-1 also shows the contributions of individual sources to violations of the instantaneous *E. coli* standard of 235 cfu/100ml. All sources combined cause a 27.01% violation rate of the instantaneous standard. Individually, livestock direct deposit causes the highest violation rate (11.95%), followed closely by agricultural runoff (with 9.58%). Residential runoff, wildlife direct deposit, and straight pipes by themselves also are predicted to cause violations of the instantaneous standard at times. Point sources and forest runoff individually are not predicted to cause any violations of the instantaneous standard.

While livestock direct deposits have the greatest impact on instream *E. coli* concentrations, agricultural runoff has the greatest impact when considering annual loads of *E. coli* to the stream (Table 6-1). Agricultural runoff accounts for more than 90% of the total annual load of *E. coli*, residential runoff accounts for 5.25%, livestock direct deposit accounts for 3.17%, forest runoff accounts for 1.65%, and all other sources account for less than 1% of total annual *E. coli* loads. There are several reasons that agricultural runoff accounts for such a high percentage of the total annual *E. coli* load but a much smaller proportion of the instream concentration. Flows are greatly increased during runoff events, so *E. coli* loads are large, but those loads only effect instream concentrations during precipitation events. During most of the year, it is not raining, so day-to-day instream concentrations are much more controlled by continuous sources, such as livestock direct deposit. Figure 6-2 shows this by displaying the relative contributions of each bacteria source under low flow and high flow conditions. Under high flow conditions (greater than median flow), 91% of the *E. coli* load is from agricultural runoff. Under low flow conditions (less than median flow), agricultural runoff only accounts for 11% of the *E. coli* load. During low flows, direct deposits from cattle contribute the majority of the load (50%), with residential/commercial runoff contributing the second most (23%).

Lastly, Table 6-1 shows the impact of individual sources on daily *E. coli* loads. Daily loads are much more variable than annual loads, and certain sources may account for almost the entire load on one day, but none of the load on another day. As a percentage of daily *E. coli* loads, livestock direct deposits, agricultural runoff, and residential runoff can each account for virtually none up to virtually the entire daily load. Straight pipes can account for up to 28.87% of daily loads, and wildlife direct deposits can account for up to 21.07% of daily loads. Forest runoff and point sources are not predicted to account for more than 5% of the load on any one day.

Table 6-1. Relative Contributions of Various Bacteria Sources Under Existing Conditions.

Statistic	Point Sources	Straight Pipes	Livestock DD	Wildlife DD	Ag Runoff	Res./Com. Runoff	Forest Runoff	All
Geo mean Violation Rate	0.00%	0.00%	16.67%	0.00%	0.00%	0.00%	0.00%	30.56%
Instantaneous Violation Rate	0.00%	1.46%	11.95%	0.82%	9.58%	1.55%	0.00%	27.01%
Average Annual Load	1.56E+11	1.43E+12	8.40E+12	9.82E+11	2.39E+14	1.39E+13	4.37E+12	2.65E+14
Percent of Total Annual Load	0.06%	0.54%	3.17%	0.37%	90.08%	5.25%	1.65%	100.00%
Daily Load Range	1.54E+08-1.19E+11	1.46E+09-1.11E+12	3.48E+09-8.06E+12	1.11E+09-7.66E+11	0.00E+00-4.49E+13	0.00E+00-2.83E+12	0.00E+00-7.70E+11	6.76E+09-4.70E+13
Percent of Daily Load Range	0.00%-3.32%	0.02%-28.87%	0.04%-94.46%	0.01%-21.07%	0.00%-96.54%	0.00%-84.06%	0.00%-3.35%	100.00%

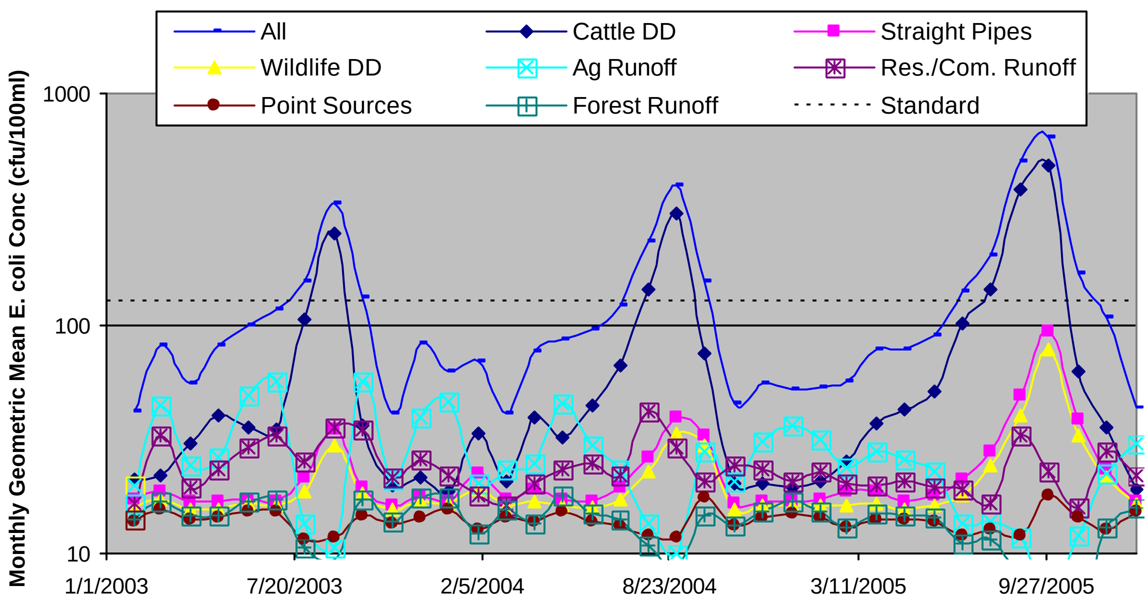


Figure 6-1. Relative Contributions of Various Sources to the Monthly Geometric Mean *E. coli* Concentration in Hogue Creek Under Existing Conditions.

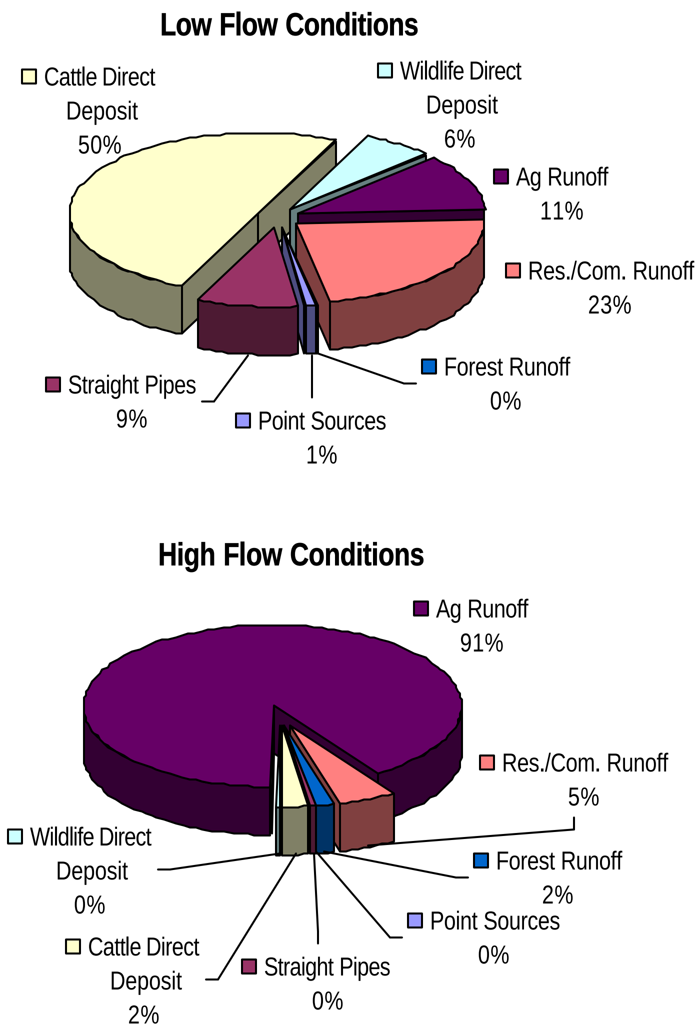


Figure 6-2. Relative Contributions of Various Bacteria Sources to Hogue Creek Under Low Flow and High Flow Conditions.

6.2. FUTURE CONDITIONS

The Hogue Creek TMDL was developed to consider further growth and future conditions in the watershed. TMDLs do impose caps on the amount of pollutants discharged in a watershed, however, the reductions called for in the TMDL may take several years to achieve. Changes in populations and land use are likely to continue as the TMDL is being implemented, so the TMDL considers those changes. For the Hogue Creek TMDL, a projection of future conditions in the year 2015 was used. 2015 represents a reasonable time frame for this TMDL to be implemented.

For future condition projections, human populations were estimated to grow. Based on U.S. Census data from 1990 and 2000, populations in the Hogue Creek watershed grew at an annual rate of 1.85%. This growth rate matches the medium projected growth rate in the Frederick County Comprehensive Plan (Frederick County, 2003), however, the plan estimates that future growth might be better represented by a higher projection of 2.75% annually. This high projection was used in the Hogue Creek TMDL to estimate human and pet populations in 2015. Based on these projections, human populations in the Hogue Creek watershed are estimated to reach 6015 by 2015 and pet populations are estimated to reach 2460 (Table 6-2). Members of the Local Steering Committee felt that this estimated growth rate was high, but agreed that it represents a conservative estimate regarding future bacteria loadings, which adds to the implicit margin of safety (see Section 6.4).

Table 6-2. Future Projections for Human and Pet Populations in 2015.

Sub-watershed	Population	Households	Pets
H-01	209	80	80
H-02	219	85	85
H-03	135	55	55
H-04	22	9	9
H-05	73	28	28
H-06	765	322	322
H-07	1887	769	769
H-08	27	12	12
H-09	453	157	157
H-10	1847	782	782
H-11	377	162	162
Total	**6015**	**2460**	**2460**

To accommodate projected population growth in the Hogue Creek watershed through 2015 there will need to be land use changes. The Frederick County Comprehensive Plan denotes the entire Hogue Creek watershed as a rural area with several pockets of rural community centers (Shawneeland/North Mountain, Gainesboro, and Round Hill). Based on planning guidelines for these rural areas and rural community centers, large scale land use changes are not expected in the watershed. Low intensity residential land uses are expected to increase throughout the watershed, and some commercial development may be expected in the rural community centers over the next 10 years. Land use acreages in the Hogue Creek LSPC model were modified to account for these expected changes. Low intensity residential land uses were increased by 0.25 acres per projected additional household. While most new homes will likely be developed on larger lot sizes, 0.25 acres represents the area typically impacted by development of a single family home with a septic system. If additional acreage is associated with a lot, that additional acreage is usually better characterized by the surrounding land cover (e.g., forest or hay) in terms of hydrology and bacteria sources. Commercial land uses within the watershed were also increased to account for some development in rural community centers. In each sub-watershed containing a rural community center (Gainesboro in H-01; Round Hill in H-07; and Shawneeland/North Mountain in H-10), commercial land uses were increased by 10 acres. Equivalent areas of low intensity residential and commercial land uses that were added to the watershed based on growth projections were subtracted from forest and pasture/hay lands. Decreases in forest and pasture/hay acreages were based on the percentages of forest and pasture in each sub-watershed. Table 6-3 summarizes the projected land use changes in the Hogue Creek watershed by 2015.

Table 6-3. Projected Future Growth Land Use Changes in the Hogue Creek Watershed.

Sub-watershed	Change in Land Use Acreage			
	Forest	Pasture/Hay	Low Intensity Residential	Commercial/ Transitional
H-01	-14	-2	+ 6	+ 10
H-02	-4	-3	+ 6	0
H-03	-1	-3	+ 4	0
H-04	0	0	0	0
H-05	-2	0	+ 2	0
H-06	-18	-6	+ 23	0
H-07	-53	-13	+ 56	+ 10
H-08	-1	-1	+ 1	0
H-09	-9	-1	+ 11	0
H-10	-56	-12	+ 58	+ 10
H-11	-11	-2	+ 12	0
Total	**-169**	**-43**	**+ 179**	**+ 30**

With the projected growth in human population in the Hogue Creek watershed, inputs from point sources are also expected to increase. Based on VADEQ policy, point source contributions within a TMDL watershed are estimated at five times the existing load to account for future growth. This future growth allocation allows for the expansion of existing point sources or the addition of new point sources. For the Hogue Creek watershed, the growth allocation for point sources was 5.48×10^{11} cfu/yr. While a five times expansion of existing point source loads seems large, this expansion will not cause violations of the bacteria standard since such discharges will be required to treat waste to below the water quality standard level. Existing conditions also show that point source contributions to overall bacteria loads are insignificant (see Section 6.1).

To account for future conditions in the Hogue Creek watershed, human populations and associated bacteria loads were projected to increase, pet populations and associated bacteria loads were projected to increase, and some land use was projected to change from forest or pasture/hay to low intensity residential or commercial/transitional. No changes to wildlife or livestock population estimates were made. While development and land use changes might suggest a decrease in these populations, the projected acreage converted is relatively small on a watershed scale (less than 1% loss of forest and pasture lands). Not decreasing these populations under the future condition scenarios also provides a more conservative TMDL estimate and adds to the implicit margin of safety (see Section 6.4).

6.3. ALLOCATION SCENARIOS

LSPC model simulations for 2003 to 2005 were used to develop TMDL allocations. This period was selected for allocation determination because simulated flow and water quality during this time period provided the best possible match to observed conditions, thus increasing the reliability of allocation results. This time period also represents a range of environmental conditions. It covers years with above and below average annual flow in Hogue Creek, and covers daily flows from 0.87 to 482 cfs, which represents the 6th percentile to the 99.9th percentile of historic flows.

A variety of allocation scenarios were evaluated to meet the *E. coli* TMDL goal of a calendar-month geometric mean of 126 cfu/100mL and the single sample limit of 235 cfu/100mL. Each scenario represents a different combination of bacteria load reductions from the various sources.

These load reductions are modeled by decreasing the amount of bacteria applied to the land surface or directly deposited in the stream. In the model, this has the effect of reducing the amount of bacteria that reaches the stream, the ultimate goal of the TMDL. Thus, the reductions called for in the various scenarios indicate the need to decrease the amount of bacteria reaching the stream in order to meet the applicable water quality standard. The reductions are not intended to infer that agricultural producers should reduce their herd size or limit the use of manure as fertilizer or soil conditioner. Rather, it is assumed that the required reductions from affected agricultural source categories (cattle direct deposit, cropland, etc.) will be accomplished by implementing BMPs like filter strips, stream fencing, and off-stream watering; and that required reductions from residential source categories will be accomplished by repairing aging septic systems, eliminating straight pipe discharges, and other appropriate measures included in the TMDL Implementation Plan.

Various allocation scenarios are summarized in Table 6-4. The first scenario represents the future condition described in Section 6.2. This scenario produces a 36% violation rate of the geometric mean standard and a 28% violation rate of the instantaneous standard. The second scenario evaluates the results of eliminating anthropogenic sources of bacteria. This scenario demonstrates that the TMDL can be met without reductions in wildlife direct deposit or forest runoff. Scenario 3 shows the results of eliminating straight pipes, which makes only small improvements in *E. coli* violation rates. Because straight pipes are illegal and must be corrected if identified, all remaining scenarios contain 100% reductions in straight pipes, even though those reductions have small impacts on overall violation rates.

The next several scenarios (4-6) show the results of eliminating bacteria from cattle direct deposit, agricultural runoff, and residential runoff, respectively. Of these three, elimination of cattle direct deposits had the largest impact on violation rates, but elimination of any of these sources independently would not be enough to meet the TMDL or a 10.5% violation rate. Scenario 7 shows the results of making modest reductions in each of these sources simultaneously. Once again, these reductions were not enough to reduce violation rates below 10.5%. Scenario 8 continued to make reductions in these sources until violation rates were less than 10.5%. This scenario shows that 67% reductions in cattle direct deposit, agricultural runoff, and residential runoff (in combination with the elimination of straight pipes) would be necessary to reduce bacteria violation rates below 10.5%. This level is significant, because current water quality assessment procedures evaluate streams as impaired when more than 10.5% of samples violate the *E. coli* standard. Reducing violation rates below 10.5% would mean that the impairment could be delisted (i.e., removed from the 303(d) Impaired Waters List). Scenarios 8, 9, and 10 provide three alternatives that would reduce bacteria violation rates to that level. These scenarios represent good options for Stage I Implementation targets in the Implementation Plan (see Section 7.4.2).

While reductions in bacteria violation rates to below 10.5% may result in delisting of the impairment, the water quality standard for *E. coli* is expressed as an instantaneous (never to exceed) limit. This means that the TMDL must be developed to meet a bacteria violation rate of 0.00%. Scenarios 11 and 12 provide two alternatives that meet the 0.00% violation rate and would be appropriate allocations for the TMDL. Scenario 11 presents equal reductions among cattle direct deposit, agricultural runoff, and residential runoff; while Scenario 12 presents greater reductions from the runoff sources. An additional scenario that presented greater reductions from cattle direct deposits than runoff sources was not shown, because even if cattle direct deposit reductions were increased, reductions from runoff sources could not be decreased and still meet the 0.00% violation requirement. Based on stakeholder input and the ability to more easily reduce direct deposits than runoff loads, Scenario 11 was selected as the TMDL allocation scenario.

Table 6-4. Bacteria Allocation Scenarios for Hogue Creek.

Scenario[1]	Fecal Coliform Loading Reductions (%)							% Violation of *E. coli* Standard		Average Annual *E. coli* Load (cfu/yr)
	Straight Pipes	Cattle DD	Wildlife DD	Permitted Point Sources	Agricultural Runoff	Residential Runoff	Forest Runoff	Geometric Mean	Instantane-ous	
Future Condition	0%	0%	0%	0%	0%	0%	0%	36.11%	28.19%	2.71E+14
2	100%	100%	0%	0%	100%	100%	0%	0.00%	0.00%	1.26E+13
3	100%	0%	0%	0%	0%	0%	0%	30.56%	27.28%	2.70E+14
4	100%	100%	0%	0%	0%	0%	0%	2.78%	14.78%	2.65E+14
5	100%	0%	0%	0%	100%	0%	0%	25.00%	17.79%	4.09E+13
6	100%	0%	0%	0%	0%	100%	0%	16.67%	21.35%	2.52E+14
7	100%	50%	0%	0%	50%	50%	0%	13.89%	14.96%	1.48E+14
8	100%	67%	0%	0%	67%	67%	0%	11.11%	10.49%	1.04E+14
9	100%	90%	0%	0%	46%	46%	0%	5.56%	10.40%	1.55E+14
10	100%	26%	0%	0%	90%	90%	0%	13.89%	10.49%	4.63E+13
11	100%	97%	0%	0%	97%	97%	0%	0.00%	0.00%	2.20E+13
12	100%	93%	0%	0%	99%	99%	0%	0.00%	0.00%	1.62E+13

[1] Scenarios highlighted in blue represent reduction levels that meet a 10.5% violation rate of the instantaneous *E. coli* standard. These scenarios would be reasonable Stage I Implementation targets. Scenarios highlighted in yellow represent reduction levels that meet the *E. coli* standard with no violations. These scenarios define the TMDL.

6.4. THE HOGUE CREEK TMDL

The objective of the bacteria TMDL for Hogue Creek is to determine what reductions in fecal coliform and *E. coli* loadings from point and nonpoint sources are required to meet state water quality standards. The state water quality standards for *E. coli* used in the development of this TMDL were 126 cfu/100mL (calendar-month geometric mean) and 235 cfu/100mL (single sample maximum). Allocation Scenario 11 successfully met both of these standards and was selected as the TMDL allocation scenario. This scenario calls for elimination of straight pipes and a 97% reduction in fecal coliform from cattle direct deposit, agricultural runoff, and residential runoff.

Table 6-5 shows these reductions for each land use and direct source, as well as fecal coliform loadings under existing conditions, future conditions, and the successful TMDL scenario. Loadings expressed in Table 6-5 are for fecal coliform deposited on the land surface and fecal coliform deposited in the stream. The LSPC model then simulates instream fecal coliform concentrations, which are translated to *E. coli* concentrations. Figure 6-3 shows the *E. coli* concentrations at the outlet of Hogue Creek under the successful TMDL allocation scenario. Both geometric mean and instantaneous *E. coli* standards are met at all times. Under this reduction scenario, the average annual *E. coli* load at the outlet of Hogue Creek is 2.20×10^{13} cfu/yr. This is the annual expression of the TMDL for Hogue Creek.

Table 6-5. Fecal Coliform Load Reductions in Hogue Creek Under TMDL Conditions.

Source	Annual Fecal Coliform Loading Under Existing Conditions (cfu/yr)	Annual Fecal Coliform Loading Under Future Conditions (cfu/yr)	Annual Fecal Coliform Loading Under TMDL Conditions (cfu/yr)	Percent Reduction (%)
Land Based				
Forest	3.79E+15	3.76E+15	3.76E+15	0%
Pasture	2.24E+17	2.22E+17	6.66E+15	97%
Cropland	2.95E+13	2.95E+13	8.84E+11	97%
Commercial	4.44E+13	4.95E+13	1.49E+12	97%
Residential	4.18E+15	7.80E+15	2.34E+14	97%
Direct				
Straight Pipes	1.69E+12	1.69E+12	0.00E+00	100%
Cattle DD	1.01E+13	1.01E+13	3.03E+11	97%
Wildlife DD	1.12E+12	1.12E+12	1.12E+12	0%
Permitted Point Sources	1.74E+11	1.04E+12	1.04E+12	0%

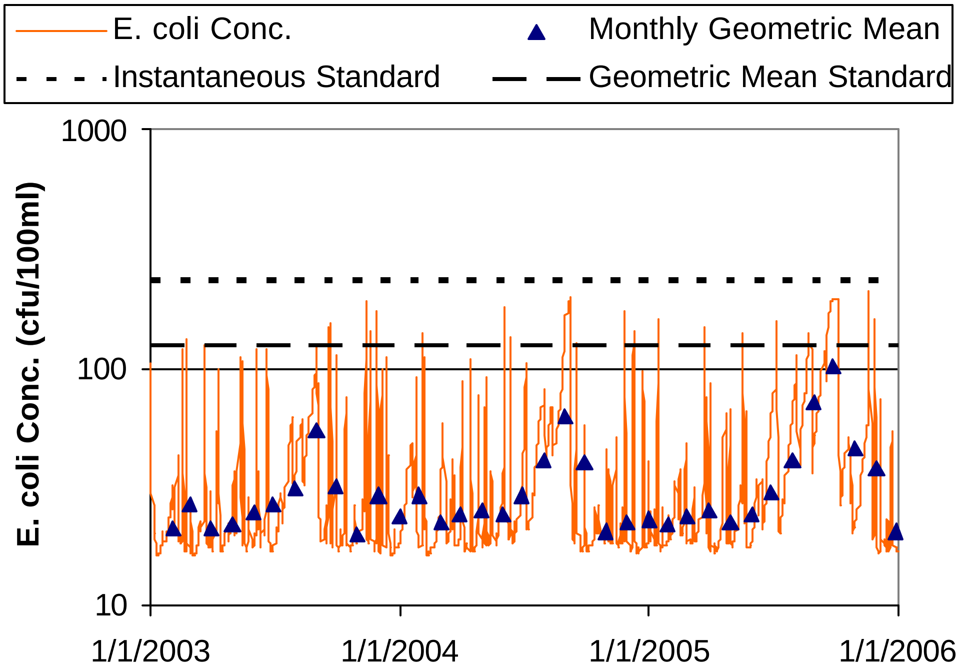


Figure 6-3. *E. coli* Concentrations in Hogue Creek Under Successful TMDL Conditions.

The TMDL considers all sources contributing fecal coliform and *E. coli* to Hogue Creek, including point (or direct) and nonpoint (or indirect) sources. The TMDL can be shown to represent these sources as defined in the following equation:

TMDL = WLA + LA + MOS **[6-1]**

where,

WLA = wasteload allocation (point source contributions);

LA = load allocation (nonpoint source contributions); and

MOS = margin of safety.

In the Hogue Creek TMDL, an implicit margin of safety (MOS) was included. Implicit margins of safety are implemented by using conservative estimates of model input parameters and by using a conservative calibration of water quality (bacteria) parameters. The calibrated LSPC model for Hogue Creek simulated a 25.67% fecal coliform violation rate, while a 20.69% violation rate was observed. Creating a TMDL target based on a conservative calibration provides a slightly higher target that includes an allowance for uncertainty.

The wasteload allocation (or WLA) portion of the TMDL includes the *E. coli* contributions from 46 single family home general permits, 2 individual VPDES permits, and an allowance for future growth of point sources. This future growth could be the addition of new point sources in the watershed or expansions of existing facilities. The total WLA for Hogue Creek is 6.58 x 10^{11} cfu/yr. Table 6-6 shows the dischargers contributing to this WLA.

Table 6-6. Wasteload Allocation Table for the Hogue Creek TMDL.

Facility	Permit #	Permitted Flow (MGD)	Permitted Fecal Conc. (cfu/100ml)	Permitted *E. coli* Conc. (cfu/100ml)	Permitted Fecal WLA	Permitted *E. coli* WLA
Indian Hollow Elementary School	VA0071927	0.007	200	126	1.93E+10	1.22E+10
Gainesboro Elementary School	VA0091898	0.01	200	126	2.76E+10	1.74E+10
46 Single Family Home General Permits		0.046	200	126	1.27E+11	8.01E+10
Future Growth		0.315	200	126	8.70E+11	5.48E+11
Total		**0.378**	**200**	**126**	**1.04E+12**	**6.58E+11**

The load allocation (LA) portion of the Hogue Creek TMDL represents the contributions from all nonpoint sources. This value is easily calculated as the difference of the TMDL and the WLA. For the Hogue Creek watershed, the LA is 2.13 x 10^{13} cfu/yr. Table 6-7 shows the TMDL for Hogue Creek expressed on an average annual basis, including the WLA, LA, and MOS. Table 6-8 shows the TMDL expressed as a daily load of *E. coli*. Because the TMDL is variable with flow conditions, this daily expression was developed using the 99th percentile flow condition at the numeric water quality criterion of 235 cfu/100ml.

Table 6-7. Total Maximum Daily Load of *E. coli* for Hogue Creek Expressed as an Average Annual Load.

Stream	WLA (cfu/yr)	LA (cfu/yr)	MOS	TMDL (cfu/yr)
Hogue Creek (VAV-B06R)	6.58E+11	2.13E+13	Implicit	2.20E+13

Table 6-8. Total Maximum Daily Load of *E. coli* for Hogue Creek Expressed as a Daily Load.

Stream	WLA[1] (cfu/d)	LA (cfu/d)	MOS	TMDL[2] (cfu/d)
Hogue Creek (VAV-B06R)	1.80E+09	2.95E+12	Implicit	2.95E+12

[1] The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.
[2] The TMDL is presented for the 99th percentile daily flow condition at the numeric water quality criterion of 235 cfu/100ml. The TMDL is variable depending on flow conditions. The numeric water quality criterion will be used to assess progress toward TMDL goals.

According to Federal regulations at 40 CFR Part 130.7, TMDLs must comply with eight specific requirements. These requirements are listed below with a description of how the Hogue TMDL complies with these requirements.

- Designed to implement applicable water quality standards – The applicable water quality standard is Virginia's water quality criteria for bacteria (9VAC25-260-170). These criteria are an *E. coli* monthly geometric mean of 126 cfu/100ml and an *E. coli* single sample maximum of 235 cfu/100ml. *E. coli* concentrations in Hogue Creek were modeled during a representative time period, and the selected TMDL condition was shown to not exceed either of these criteria (Figure 6-3).

- Include a total allowable load as well as individual waste load allocations and load allocations – The Hogue Creek TMDL was calculated as 2.20 x 10^{13} cfu/yr. This load was divided into an allocation for point sources (WLA) and an allocation for nonpoint sources (LA). The resulting WLA was 6.58 x 10^{11}, and the resulting LA was 2.13 x 10^{13} (Table 6-7).

- Consider background pollutant contributions – The Hogue Creek TMDL considered all sources of *E. coli* including background sources from wildlife.

- Consider critical environmental conditions – The Hogue Creek TMDL was modeled over a multi-year period that included a wide range of climatic conditions, including dry and wet periods. Flow conditions during the TMDL allocation period ranged from the historic 6th percentile to the 99.9th percentile.

- Consider seasonal environmental variations – The Hogue Creek TMDL was modeled over a multi-year period, and included seasonal variations in flow, bacterial loading rates, and animal behavior.

- Include a margin of safety – The Hogue Creek TMDL included an implicit margin of safety by using conservative modeling assumptions and a conservative water quality calibration.

- Provide reasonable assurance that the TMDL can be met – Chapter 7 discusses the reasonable assurance for the Hogue Creek TMDL. In short, the TMDL WLA will be met through ensuring that all issued VPDES permits are in conformance with the TMDL. The LA will be met through the development of a TMDL Implementation Plan and nonpoint source programs that provide cost share for best management practices.

- Be subject to public participation – Public participation was included throughout the development of the Hogue Creek TMDL (Chapter 8). An initial public meeting was held to inform the public of the TMDL effort. A Local Steering Committee was then developed to assist and guide VADEQ with local knowledge as the TMDL was being developed. Once a draft of the TMDL was available, a second public meeting was held to solicit public comment on the draft.

CHAPTER 7: TMDL IMPLEMENTATION AND REASONABLE ASSURANCE

Once a TMDL has been approved by USEPA, measures must be taken to reduce pollution levels from both point and nonpoint sources. The following sections outline the framework used in Virginia to provide reasonable assurance that the required pollutant reductions can be achieved.

7.1. CONTINUING PLANNING PROCESS AND WATER QUALITY MANAGEMENT PLANNING

As part of the Continuing Planning Process, VADEQ staff will present both USEPA-approved TMDLs and TMDL implementation plans to the State Water Control Board (SWCB) for inclusion in the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act's Section 303(e) and Virginia's Public Participation Guidelines for Water Quality Management Planning.

VADEQ staff will also request that the SWCB adopt TMDL WLAs as part of the Water Quality Management Planning Regulation (9VAC 25-720), except in those cases when permit limitations are equivalent to numeric criteria contained in the Virginia Water Quality Standards, such as in the case for bacteria. This regulatory action is in accordance with §2.2-4006A.4.c and §2.2-4006B of the Code of Virginia. SWCB actions relating to water quality management planning are described in VADEQ's public participation guidelines (VADEQ, 2004c), which can be found on VADEQ's web site at: http://www.deq.state.va.us/tmdl/pdf/ppp.pdf.

> Frequently Asked Question:
>
> *What happens after the TMDL Study is complete?*
> The TMDL will be submitted to EPA for approval. The next step is then to develop a TMDL Implementation Plan. This plan lays out the actions and costs necessary to implement the pollutant reductions called for in the TMDL.

7.2. STAGED IMPLEMENTATION

In general, Virginia intends for the required control actions, including Best Management Practices (BMPs), to be implemented in an iterative process that first addresses those sources with the largest impact on water quality. The iterative implementation of pollution control actions in the watershed has several benefits:

1. It enables tracking of water quality improvements following implementation through follow-up stream monitoring;

2. It provides a measure of quality control, given the uncertainties inherent in computer simulation modeling;

3. It provides a mechanism for developing public support through periodic updates on implementation levels and water quality improvements;

4. It helps ensure that the most cost effective practices are implemented first; and

5. It allows for the evaluation of the adequacy of the TMDL in achieving water quality standards.

7.3. IMPLEMENTATION OF WASTE LOAD ALLOCATIONS

Federal regulations 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)). All such permits should be submitted to USEPA for review.

For the implementation of the WLA component of the TMDL, the Commonwealth utilizes the Virginia NPDES program. Requirements of the permit process should not be duplicated in the TMDL process, and permitted sources are not usually addressed through the development of any TMDL implementation plans.

7.3.1. Stormwater

VADEQ and VADCR coordinate separate state permitting programs that regulate the management of pollutants carried by stormwater runoff. VADEQ regulates stormwater discharges associated with industrial activities through its VPDES program, while VADCR regulates stormwater discharges from construction sites, and from municipal separate storm sewer systems (MS4s) through the VSMP program. Stormwater discharges from coal mining operations are permitted through NPDES permits by the Department of Mines, Minerals and Energy (DMME). As with non-stormwater permits, all new or revised stormwater permits must be consistent with the assumptions and requirements of any applicable TMDL WLA. If a WLA is based on conditions specified in existing permits, and the permit conditions are being met, no additional actions may be needed. If a WLA is based on reduced pollutant loads, additional pollutant control actions will need to be implemented.

7.3.2. TMDL Modifications for New or Expanding Dischargers

Permits issued for facilities with wasteload allocations developed as part of a TMDL must be consistent with the assumptions and requirements of these wasteload allocations (WLA), as per USEPA regulations. In cases where a proposed permit modification is affected by a TMDL WLA, permit and TMDL staff must coordinate to ensure that new or expanding discharges meet this requirement. In 2005, VADEQ issued guidance memorandum 05-2011 describing the available options and the process that should be followed under those circumstances, including public participation, USEPA approval, State Water Control Board actions, and coordination between permit and TMDL staff (VADEQ, 2005b). The guidance memorandum is available on VADEQ's web site at http://www.deq.virginia.gov/waterguidance/.

7.4. IMPLEMENTATION OF LOAD ALLOCATIONS

The TMDL program does not impart new implementation authorities. Therefore, the Commonwealth intends to use existing programs to the fullest extent in order to attain its water quality goals. The measures for nonpoint source reductions, which can include the use of better treatment technology and the installation of best management practices (BMPs), are implemented in an iterative process that is described along with specific BMPs in the TMDL implementation plan.

7.4.1. Implementation Plan Development

For the implementation of the TMDL's LA component, a TMDL implementation plan will be developed that addresses at a minimum the requirements specified in the Code of Virginia, Section 62.1-44.19.7. State law directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters". 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". USEPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process" (USEPA, 1999). The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans and milestones for attaining water quality standards.

In order to qualify for other funding sources, such as USEPA's Section 319 grants, additional plan requirements may need to be met. The detailed process for developing an implementation plan has been described in the "TMDL Implementation Plan Guidance Manual", published in July 2003 (VADCR, 2003) and available upon request from the VADEQ and VADCR TMDL project staff or at http://www.deq.virginia.gov/tmdl/implans/ipguide.pdf

Watershed stakeholders will have opportunities to provide input and to participate in the development of the TMDL implementation plan. Regional and local offices of VADEQ, VADCR, and other cooperating agencies are technical resources to assist in this endeavor.

With successful completion of implementation plans, local stakeholders will have a blueprint to restore impaired waters and enhance the value of their land and water resources. Additionally, development of an approved implementation plan may enhance opportunities for obtaining financial and technical assistance during implementation.

7.4.2. Staged Implementation Scenarios

The purpose of the staged implementation scenarios is to identify one or more combinations of implementation actions that result in the reduction of controllable sources to the maximum extent practicable using cost-effective, reasonable BMPs for nonpoint source control. Among the most efficient sediment BMPs for both urban and rural watersheds are infiltration and retention basins, riparian buffer zones, grassed waterways, streambank protection and stabilization, and wetland development or enhancement.

Actions identified during TMDL implementation plan development that go beyond what can be considered cost-effective and reasonable will only be included as implementation actions if there are reasonable grounds for assuming that these actions will in fact be implemented.

If water quality standards are not met upon implementation of all cost-effectivce and reasonable BMPs, a Use Attainability Analysis may need to be initiated since Virginia's water quality standards allow for changes to use designations if existing water quality standards cannot be attained by implementing effluent limits required under §301b and §306 of Clean Water Act, and cost effective and reasonable BMPs for nonpoint source control. Additional information on UAAs is presented in Section 7.6, Attainability of Designated Uses.

One of the important milestones in the staged implementation of this TMDL will be the point where violations of the instantaneous water quality standard are less than 10.5% and Hogue Creek can be delisted. Table 6-4 shows 3 distinct scenarios that can meet this level of compliance. Any of these scenarios would be an appropriate Stage I Implementation Scenario. The Hogue Creek Local Steering Committee preferred the equitable distribution of Scenario 8, so this scenario is presented here as a possible Stage I Implementation Scenario. This scenario calls for elimination of straight pipes, 67% reduction in cattle direct deposits, and 67% reduction in agricultural, residential, and commercial runoff (Table 7-1). This scenario meets the 10.5% violation rate and represents a reasonable milestone in the implementation of the Hogue Creek TMDL. During the development of the TMDL Implementation Plan, however, other appropriate Stage I Scenarios or additional interim steps could be included in the plan.

Table 7-1. Fecal Coliform Load Reductions in Hogue Creek Under Stage I Implementation Scenario.

Source	Annual Fecal Coliform Loading Under Existing Conditions (cfu/yr)	Annual Fecal Coliform Loading Under Future Conditions (cfu/yr)	Annual Fecal Coliform Loading Under Stage I Conditions (cfu/yr)	Percent Reduction (%)
Land Based				
Forest	3.79E+15	3.76E+15	3.76E+15	0%
Pasture	2.24E+17	2.22E+17	7.33E+16	67%
Cropland	2.95E+13	2.95E+13	9.73E+12	67%
Commercial	4.44E+13	4.95E+13	1.63E+13	67%
Residential	4.18E+15	7.80E+15	2.57E+15	67%
Direct				
Straight Pipes	1.69E+12	1.69E+12	0.00E+00	100%
Cattle DD	1.01E+13	1.01E+13	3.33E+12	67%
Wildlife DD	1.12E+12	1.12E+12	1.12E+12	0%
Permitted Point Sources	1.74E+11	1.04E+12	1.04E+12	0%

7.4.3. Link to Ongoing Restoration Efforts

Implementation of this TMDL will contribute to on-going water quality improvement efforts aimed at restoring water quality in the Chesapeake Bay. In 2005, the Secretary of Natural Resources developed tributary strategies for the major basins discharging to the Chesapeake Bay (VASNR, 2005). These strategies set nutrient and sediment reductions for the basins and highlight practices to achieve those reductions. Many of the BMPs that will be used to reduce bacteria in Hogue Creek will also be effective in reducing nutrients and sediment contributions as part of the Potomac River Basin Tributary Strategy. For example, livestock fencing and riparian buffers will be essential components of the Hogue Creek Implementation Plan. These same BMPs are elements of the Potomac Tributary Strategy to reduce nutrient and sediment inputs to the Chesapeake Bay. More information on the Potomac Basin Tributary Strategy can be found at:

http://www.naturalresources.virginia.gov/Initiatives/WaterQuality/FinalizedTribStrats/shenandoah.pdf.

7.4.4. Implementation Funding Sources

The implementation of pollutant reductions from non-regulated nonpoint sources relies heavily on incentive-based programs. Therefore, the identification of funding sources for non-regulated implementation activities is a key to success. Cooperating agencies, organizations and stakeholders must identify potential funding sources available for implementation during the development of the implementation plan in accordance with the "Virginia Guidance Manual for Total Maximum Daily Load Implementation Plans" (VADCR, 2003). The TMDL Implementation Plan Guidance Manual 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.

Some of the major potential sources of funding for non-regulated implementation actions may include the U.S. Department of Agriculture's Conservation Reserve Enhancement and Environmental Quality Incentive Programs, USEPA Section 319 funds, the Virginia State Revolving Loan Program (also available for permitted activities), Virginia Agricultural Best Management Practices Cost-Share Programs, the Virginia Water Quality Improvement Fund (available for both point and nonpoint source pollution), tax credits and landowner contributions.

With additional appropriations for the Water Quality Improvement Fund during the last two legislative sessions, the Fund has become a significant funding stream for agricultural BMPs and wastewater treatment plants. Additionally, funding is being made available to address urban and residential water quality problems. Information on WQIF projects and allocations can be found at http://www.deq.virginia.gov/bay/wqif.html and at

http://www.dcr.virginia.gov/soil_&_water/wqia.shtml.

7.5. FOLLOW-UP MONITORING

Following the development of the TMDL, VADEQ will make every effort to continue to monitor the impaired stream in accordance with its ambient and biological monitoring programs. VADEQ's Ambient Watershed Monitoring Plan for conventional pollutants calls for watershed monitoring to take place on a rotating basis, bi-monthly for two consecutive years of a six-year cycle. In accordance with VADEQ Guidance Memo No. 03-2004 (VADEQ, 2004d), during periods of reduced resources, monitoring can temporarily discontinue until the TMDL staff determines that implementation measures to address the source(s) of impairments are being installed. Monitoring can resume at the start of the following fiscal year, next scheduled monitoring station rotation, or where deemed necessary by the regional office or TMDL staff, as a new special study. Since there may be a lag time of one-to-several years before any improvement in the benthic community will be evident, follow-up biological monitoring may not have to occur in the fiscal year immediately following the implementation of control measures.

The purpose, location, parameters, frequency, and duration of the monitoring will be determined by the VADEQ staff, in cooperation with VADCR staff, the Implementation Plan Steering Committee and local stakeholders. Whenever possible, the location of the follow-up monitoring station(s) will be the same as the listing station. At a minimum, the monitoring station must be representative of the original impaired segment. The details of the follow-up monitoring will be outlined in the Annual Water Monitoring Plan prepared by each VADEQ Regional Office. Other agency personnel, watershed stakeholders, etc. may provide input on the Annual Water Monitoring Plan. These recommendations must be made to the VADEQ regional TMDL coordinator by September 30 of each year.

VADEQ will continue to monitor bacteria in Hogue Creek at station 1AHOC006.23 according to its ambient monitoring program. When an Implementation Plan is developed for Hogue Creek and implementation of that plan begins, VADEQ will increase the frequency of monitoring at this site to assess water quality progress as BMPs are implemented.

VADEQ staff, in cooperation with VADCR staff, the Implementation Plan Steering Committee and local stakeholders, will continue to use data from the ambient monitoring stations to evaluate reductions in pollutants ("water quality milestones" as established in the IP), the effectiveness of the TMDL in attaining and maintaining water quality standards, and the success of implementation efforts. Recommendations may then be made, when necessary, to target implementation efforts in specific areas and continue or discontinue monitoring at follow-up stations.

In some cases, watersheds will require monitoring above and beyond what is included in VADEQ's standard monitoring plan. Ancillary monitoring by citizens' or watershed groups, local government, or universities is an option that may be used in such cases. An effort should be made to ensure that ancillary monitoring follows established QA/QC guidelines in order to maximize compatibility with VADEQ monitoring data. In instances where citizens' monitoring data is not available and additional monitoring is needed to assess the effectiveness of targeting efforts, TMDL staff may request of the monitoring managers in each regional office an increase in the number of stations or monitor existing stations at a higher frequency in the watershed. The additional monitoring beyond the original bimonthly single station monitoring will be contingent on staff resources and available laboratory budget. More information on citizen monitoring in Virginia and QA/QC guidelines is available at http://www.deq.virginia.gov/cmonitor/.

To demonstrate that the watershed is meeting water quality standards in watersheds where corrective actions have taken place (whether or not a TMDL or Implementation plan has been completed), VADEQ must meet the minimum data requirements from the original listing station or a station representative of the originally listed segment. The minimum data requirement for conventional pollutants (bacteria, dissolved oxygen, etc) is bimonthly monitoring for two consecutive years. For biological monitoring, the minimum requirement is two consecutive samples (one in the spring and one in the fall) in a one year period.

7.6. ATTAINABILITY OF DESIGNATED USES

In some streams for which TMDLs have been developed, factors may prevent the stream from attaining its designated use.

In order for a stream to be assigned a new designated use, or a subcategory of a use, the current designated use must be removed. To remove a designated use, the state must demonstrate that the use is not an existing use, and that downstream uses are protected. Such uses will be attained by implementing effluent limits required under §301b and §306 of Clean Water Act and by implementing cost-effective and reasonable best management practices for nonpoint source control (9 VAC 25-260-10 paragraph I).

The state must also demonstrate that attaining the designated use is not feasible because:

1. Naturally occurring pollutant concentration prevents the attainment of the use;
2. Natural, ephemeral, intermittent or low flow conditions prevent the attainment of the use unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating state water conservation;

3. Human-caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place;

4. Dams, diversions or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the waterbody to its original condition or to operate the modification in such a way that would result in the attainment of the use;

5. Physical conditions related to natural features of the water body, such as the lack of proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude attainment of aquatic life use protection; or

6. Controls more stringent than those required by §301b and §306 of the Clean Water Act would result in substantial and widespread economic and social impact.

This and other information is collected through a special study called a UAA. All site-specific criteria or designated use changes must be adopted by the SWCB as amendments to the water quality standards regulations. During the regulatory process, watershed stakeholders and other interested citizens, as well as the USEPA, will be able to provide comment during this process. Additional information can be obtained at http://www.deq.virginia.gov/wqs/.

The process to address potentially unattainable reductions based on the above is as follows: As a first step, measures targeted at the controllable, anthropogenic sources identified in the TMDL's staged implementation scenarios will be implemented. The expectation would be for the reductions of all controllable sources to the maximum extent practicable using the implementation approaches described above. VADEQ will continue to monitor biological health and water quality in the stream during and subsequent to the implementation of these measures to determine if water quality standards are attained. This effort will also help to evaluate if the modeling assumptions were correct. In the best-case scenario, water quality goals will be met and the stream's uses fully restored using effluent controls and BMPs. If, however, water quality standards are not being met, and no additional effluent controls and BMPs can be identified, a UAA would then be initiated with the goal of re-designating the stream for a more appropriate use or subcategory of a use.

A 2006 amendment to the Code of Virginia under 62.1-44.19:7E provides an opportunity for aggrieved parties in the TMDL process to present to the State Water Control Board reasonable grounds indicating that the attainment of the designated use for a water is not feasible. The Board may then allow the aggrieved party to conduct a use attainability analysis according to the criteria listed above and a schedule established by the Board. The amendment further states that "If applicable, the schedule shall also address whether TMDL development or implementation for the water shall be delayed."

CHAPTER 8: PUBLIC PARTICIPATION

Public participation was elicited at every stage of the TMDL development in order to receive input from stakeholders and to apprise the stakeholders of the progress made. Public participation was encouraged through holding public meetings in the watershed and by forming a Hogue Creek TMDL Local Steering Committee. The Local Steering Committee was a group of local citizens, landowners, organizations, and government entities that could provide local input and assistance to VADEQ during the TMDL Study. The goal of the Local Steering Committee was to make sure that the technical aspects of the study (including model inputs and assumptions) were accurate as well as acceptable to the community.

On January 25, 2007, VADEQ held a public meeting at the Indian Hollow Elementary School to explain the Hogue Creek impairment to local citizens and describe the TMDL Study that would take place. The meeting was advertised through signs and posters throughout the watershed, e-mail announcements to 65 local contacts, letters to VPDES permit holders, notice publication in the Virginia Register, and announcement through the Lord Fairfax Soil and Water Conservation District. Approximately 19 people attended the meeting. At the meeting, VADEQ explained the bacterial impairment in Hogue Creek, described the TMDL process, and provided an open invitation to participate on the Local Steering Committee. Handouts of the presentation were made available to attendees of the meeting and were distributed electronically upon request to those that were not able to attend the meeting.

The Local Steering Committee met on February 21, 2007 and again on May 30, 2007. At the first meeting, the committee reviewed land use and bacteria source data. Comments from the meeting were used to refine estimates of animal populations and bacteria source input data. At the second meeting, the committee reviewed model calibration and TMDL allocations. Comments from the stakeholders were used to select appropriate Stage I and TMDL allocation options. In addition to input from the Local Steering Committee, VADEQ contacted members of the Lord Fairfax Soil and Water Conservation District, Virginia Department of Game and Inland Fisheries, Virginia Department of Health, and Virginia Department of Agriculture and Consumer

Services to receive input regarding specific aspects of the watershed characterization and model inputs.

On July 11, 2007, a second public meeting was held in the Hogue Creek watershed. This meeting was once again advertised through signs and posters throughout the watershed, e-mail announcements, notice publication in the Virginia Register, and through personal contacts of the Local Steering Committee members. Approximately 11 people attended this final public meeting. At the meeting, VADEQ presented the draft TMDL report to the public and explained its development and conclusions. Handouts of the presentation and the executive summary of the draft report were made available to the public at the meeting. The full report was made available on the VADEQ website at:

http://gisweb.deq.virginia.gov/tmdlapp/tmdl_draft_reports.cfm. Following the meeting, a 30-day public comment period on the draft was initiated. No comments were received on the draft during the comment period.

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APPENDIX A:
Hydrologic Model Parameters

Table A-1. Hydrologic Reach Parameters for Calibrated Hogue Creek LSPC Model.

Sub-watershed	DEPINIT_M	LEN_M	SLOPE	WID_M	DEP_M	R1	R2	W1	MANNING_N	CRRAT
H-01	1	6320	0.0047	17.4	0.6	0.71	0.37	0.55	0.04	1.5
H-02	0.7	3105	0.00016	17.4	0.6	0.71	0.37	0.55	0.04	1.5
H-03	0.3	1686	0.00030	1.5	0.5	0.67	0.1	67	0.04	1.5
H-04	0.7	922	0.00054	9.3	0.6	0.95	0.1	11	0.04	1.5
H-05	0.3	2025	0.030	1.5	0.5	0.67	0.1	67	0.04	1.5
H-06	0.7	3069	0.00016	9.3	0.6	0.95	0.1	11	0.04	1.5
H-07	0.3	6289	0.0097	8.6	0.4	0.77	0.13	0.35	0.04	1.5
H-08	0.5	1465	0.00034	6.8	0.65	0.82	0.19	0.32	0.04	1.5
H-09	0.3	2761	0.011	6.8	0.65	0.82	0.19	0.32	0.04	1.5
H-10	0.3	1811	0.0022	5.5	0.6	0.82	0.37	0.3	0.04	1.5
H-11	0.3	8626	0.037	5.5	0.6	0.82	0.37	0.3	0.04	1.5

Table A-2. Hydrologic Watershed Parameters for Sub-watershed H-01 in Calibrated Hogue Creek LSPC Model.

Sub-watershed	Land use	Acres	LSUR	MELEV	RMELEV
H-01	Low Intensity Residential	0.89	470	756	638
H-01	High Intensity Residential	0.00	470	756	638
H-01	Transitional/Commercial	11.56	470	756	638
H-01	Row Crops	14.46	470	756	638
H-01	Pasture/Hay	192.59	470	756	638
H-01	Forest	1714.66	470	756	638

Table A-3. Hydrologic Watershed Parameters for Sub-watershed H-02 in Calibrated Hogue Creek LSPC Model.

Sub-watershed	Land use	Acres	LSUR	MELEV	RMELEV
H-02	Low Intensity Residential	0.00	457	802	707
H-02	High Intensity Residential	0.00	457	802	707
H-02	Transitional/Commercial	5.34	457	802	707
H-02	Row Crops	15.79	457	802	707
H-02	Pasture/Hay	770.60	457	802	707
H-02	Forest	1395.30	457	802	707

Table A-4. Hydrologic Watershed Parameters for Sub-watershed H-03 in Calibrated Hogue Creek LSPC Model.

Sub-watershed	Land use	Acres	LSUR	MELEV	RMELEV
H-03	Low Intensity Residential	1.56	200	774	699
H-03	High Intensity Residential	0.00	200	774	699
H-03	Transitional/Commercial	6.45	200	774	699
H-03	Row Crops	16.68	200	774	699
H-03	Pasture/Hay	485.04	200	774	699
H-03	Forest	202.16	200	774	699

Table A-5. Hydrologic Watershed Parameters for Sub-watershed H-04 in Calibrated Hogue Creek LSPC Model.

Sub-watershed	Land use	Acres	LSUR	MELEV	RMELEV
H-04	Low Intensity Residential	0.00	200	838	699
H-04	High Intensity Residential	0.00	200	838	699
H-04	Transitional/Commercial	0.22	200	838	699
H-04	Row Crops	2.22	200	838	699
H-04	Pasture/Hay	14.01	200	838	699
H-04	Forest	205.71	200	838	699

Table A-6. Hydrologic Watershed Parameters for Sub-watershed H-05 in Calibrated Hogue Creek LSPC Model.

Sub-watershed	Land use	Acres	LSUR	MELEV	RMELEV
H-05	Low Intensity Residential	0.67	200	867	790
H-05	High Intensity Residential	0.00	200	867	790
H-05	Transitional/Commercial	0.89	200	867	790
H-05	Row Crops	7.12	200	867	790
H-05	Pasture/Hay	162.79	200	867	790
H-05	Forest	343.60	200	867	790

Table A-7. Hydrologic Watershed Parameters for Sub-watershed H-06 in Calibrated Hogue Creek LSPC Model.

Sub-watershed	Land use	Acres	LSUR	MELEV	RMELEV
H-06	Low Intensity Residential	8.23	397	984	707
H-06	High Intensity Residential	0.00	397	984	707
H-06	Transitional/Commercial	93.41	397	984	707
H-06	Row Crops	23.13	397	984	707
H-06	Pasture/Hay	957.19	397	984	707
H-06	Forest	3322.35	397	984	707

Table A-8. Hydrologic Watershed Parameters for Sub-watershed H-07 in Calibrated Hogue Creek LSPC Model.

Sub-watershed	Land use	Acres	LSUR	MELEV	RMELEV
H-07	Low Intensity Residential	59.16	483	968	814
H-07	High Intensity Residential	0.00	483	968	814
H-07	Transitional/Commercial	85.62	483	968	814
H-07	Row Crops	69.39	483	968	814
H-07	Pasture/Hay	1065.49	483	968	814
H-07	Forest	4976.74	483	968	814

Table A-9. Hydrologic Watershed Parameters for Sub-watershed H-08 in Calibrated Hogue Creek LSPC Model.

Sub-watershed	Land use	Acres	LSUR	MELEV	RMELEV
H-08	Low Intensity Residential	0.67	200	751	700
H-08	High Intensity Residential	0.00	200	751	700
H-08	Transitional/Commercial	2.45	200	751	700
H-08	Row Crops	2.00	200	751	700
H-08	Pasture/Hay	96.07	200	751	700
H-08	Forest	234.85	200	751	700

Table A-10. Hydrologic Watershed Parameters for Sub-watershed H-09 in Calibrated Hogue Creek LSPC Model.

Sub-watershed	Land use	Acres	LSUR	MELEV	RMELEV
H-09	Low Intensity Residential	0.89	366	1061	765
H-09	High Intensity Residential	0.00	366	1061	765
H-09	Transitional/Commercial	28.69	366	1061	765
H-09	Row Crops	2.45	366	1061	765
H-09	Pasture/Hay	389.64	366	1061	765
H-09	Forest	2340.03	366	1061	765

Table A-11. Hydrologic Watershed Parameters for Sub-watershed H-10 in Calibrated Hogue Creek LSPC Model.

Sub-watershed	Land use	Acres	LSUR	MELEV	RMELEV
H-10	Low Intensity Residential	19.79	321	1247	808
H-10	High Intensity Residential	0.00	321	1247	808
H-10	Transitional/Commercial	5.12	321	1247	808
H-10	Row Crops	18.24	321	1247	808
H-10	Pasture/Hay	529.97	321	1247	808
H-10	Forest	2667.18	321	1247	808

Table A-12. Hydrologic Watershed Parameters for Sub-watershed H-11 in Calibrated Hogue Creek LSPC Model.

Sub-watershed	Land use	Acres	LSUR	MELEV	RMELEV
H-11	Low Intensity Residential	1.11	389	1199	1202
H-11	High Intensity Residential	0.00	389	1199	1202
H-11	Transitional/Commercial	8.01	389	1199	1202
H-11	Row Crops	26.91	389	1199	1202
H-11	Pasture/Hay	384.30	389	1199	1202
H-11	Forest	3590.78	389	1199	1202

Table A-13. Hydrologic Parameter Group 1 for Calibrated Hogue Creek LSPC Model.

Hydrologic Soil Type	Sub-watershed	Land use	LZSN	INFILT	KVARY	AGWRC
B	H-05	Low Intensity Residential (pervious)	5.6	0.099	0.35	0.9215
		High Intensity Residential (pervious)	5.6	0.099	0.35	0.9215
		Transitional/Commercial (pervious)	5.6	0.099	0.35	0.9215
		Row Crops	5.6	0.1485	0.35	0.9215
		Pasture/Hay	5.6	0.1485	0.35	0.9215
		Forest	5.6	0.20075	0.35	0.9215
		Low Intensity Residential (impervious)	5.6	0	0.35	0.9215
		High Intensity Residential (impervious)	5.6	0	0.35	0.9215
		Transitional/Commercial (impervious)	5.6	0	0.35	0.9215
C	H-01 – H-04, H-07 – H-08	Low Intensity Residential (pervious)	7.2	0.066	0.35	0.9215
		High Intensity Residential (pervious)	7.2	0.066	0.35	0.9215
		Transitional/Commercial (pervious)	7.2	0.066	0.35	0.9215
		Row Crops	7.2	0.1045	0.35	0.9215
		Pasture/Hay	7.2	0.1045	0.35	0.9215
		Forest	7.2	0.1375	0.35	0.9215
		Low Intensity Residential (impervious)	7.2	0	0.35	0.9215
		High Intensity Residential (impervious)	7.2	0	0.35	0.9215
		Transitional/Commercial (impervious)	7.2	0	0.35	0.9215
B/C	H-06, H-09 – H-11	Low Intensity Residential (pervious)	6.4	0.0825	0.35	0.9215
		High Intensity Residential (pervious)	6.4	0.0825	0.35	0.9215
		Transitional/Commercial (pervious)	6.4	0.0825	0.35	0.9215
		Row Crops	6.4	0.1265	0.35	0.9215
		Pasture/Hay	6.4	0.1265	0.35	0.9215
		Forest	6.4	0.165	0.35	0.9215
		Low Intensity Residential (impervious)	6.4	0	0.35	0.9215
		High Intensity Residential (impervious)	6.4	0	0.35	0.9215
		Transitional/Commercial (impervious)	6.4	0	0.35	0.9215

Table A-14. Hydrologic Parameter Group 2 for Calibrated Hogue Creek LSPC Model.

Hydrologic Soil Type	Sub-watershed	Land use	PETMAX	PETMIN	INFEXP	INFILD	DEEPFR	BASETP	AGWETP
B	H-05	Low Intensity Residential (pervious)	45	35	2	2	0.14	0.05	0.01
		High Intensity Residential (pervious)	45	35	2	2	0.14	0.05	0.01
		Transitional/Commercial (pervious)	45	35	2	2	0.14	0.05	0.01
		Row Crops	45	35	2	2	0.14	0.05	0.01
		Pasture/Hay	45	35	2	2	0.14	0.05	0.01
		Forest	45	35	2	2	0.14	0.05	0.01
		Low Intensity Residential (impervious)	45	35	2	2	0.14	0.05	0.01
		High Intensity Residential (impervious)	45	35	2	2	0.14	0.05	0.01
		Transitional/Commercial (impervious)	45	35	2	2	0.14	0.05	0.01
C	H-01 - H-04, H-07 - H-08	Low Intensity Residential (pervious)	45	35	2	2	0.14	0.05	0.01
		High Intensity Residential (pervious)	45	35	2	2	0.14	0.05	0.01
		Transitional/Commercial (pervious)	45	35	2	2	0.14	0.05	0.01
		Row Crops	45	35	2	2	0.14	0.05	0.01
		Pasture/Hay	45	35	2	2	0.14	0.05	0.01
		Forest	45	35	2	2	0.14	0.05	0.01
		Low Intensity Residential (impervious)	45	35	2	2	0.14	0.05	0.01
		High Intensity Residential (impervious)	45	35	2	2	0.14	0.05	0.01
		Transitional/Commercial (impervious)	45	35	2	2	0.14	0.05	0.01
B/C	H-06, H-09 - H-11	Low Intensity Residential (pervious)	45	35	2	2	0.14	0.05	0.01
		High Intensity Residential (pervious)	45	35	2	2	0.14	0.05	0.01
		Transitional/Commercial (pervious)	45	35	2	2	0.14	0.05	0.01
		Row Crops	45	35	2	2	0.14	0.05	0.01
		Pasture/Hay	45	35	2	2	0.14	0.05	0.01
		Forest	45	35	2	2	0.14	0.05	0.01
		Low Intensity Residential (impervious)	45	35	2	2	0.14	0.05	0.01
		High Intensity Residential (impervious)	45	35	2	2	0.14	0.05	0.01
		Transitional/Commercial (impervious)	45	35	2	2	0.14	0.05	0.01

Table A-15. Hydrologic Parameter Group 3 for Calibrated Hogue Creek LSPC Model.

Hydrologic Soil Type	Sub-watershed	Land use	CEPS	UZSN	NSUR	INTFW	IRC	LZETP
B	H-05	Low Intensity Residential (pervious)	Monthly	Monthly	0.15	1	0.32	Monthly
		High Intensity Residential (pervious)	Monthly	Monthly	0.15	1	0.32	Monthly
		Transitional/Commercial (pervious)	Monthly	Monthly	0.15	1	0.32	Monthly
		Row Crops	Monthly	Monthly	0.15	1	0.32	Monthly
		Pasture/Hay	Monthly	Monthly	0.15	1	0.32	Monthly
		Forest	Monthly	Monthly	0.15	1	0.32	Monthly
		Low Intensity Residential (impervious)	Monthly	Monthly	0.15	1	0.32	Monthly
		High Intensity Residential (impervious)	Monthly	Monthly	0.15	1	0.32	Monthly
		Transitional/Commercial (impervious)	Monthly	Monthly	0.15	1	0.32	Monthly
C	H-01 - H-04, H-07 - H-08	Low Intensity Residential (pervious)	Monthly	Monthly	0.15	1	0.32	Monthly
		High Intensity Residential (pervious)	Monthly	Monthly	0.15	1	0.32	Monthly
		Transitional/Commercial (pervious)	Monthly	Monthly	0.15	1	0.32	Monthly
		Row Crops	Monthly	Monthly	0.15	1	0.32	Monthly
		Pasture/Hay	Monthly	Monthly	0.15	1	0.32	Monthly
		Forest	Monthly	Monthly	0.15	1	0.32	Monthly
		Low Intensity Residential (impervious)	Monthly	Monthly	0.15	1	0.32	Monthly
		High Intensity Residential (impervious)	Monthly	Monthly	0.15	1	0.32	Monthly
		Transitional/Commercial (impervious)	Monthly	Monthly	0.15	1	0.32	Monthly
B/C	H-06, H-09 - H-11	Low Intensity Residential (pervious)	Monthly	Monthly	0.15	1	0.32	Monthly
		High Intensity Residential (pervious)	Monthly	Monthly	0.15	1	0.32	Monthly
		Transitional/Commercial (pervious)	Monthly	Monthly	0.15	1	0.32	Monthly
		Row Crops	Monthly	Monthly	0.15	1	0.32	Monthly
		Pasture/Hay	Monthly	Monthly	0.15	1	0.32	Monthly
		Forest	Monthly	Monthly	0.15	1	0.32	Monthly
		Low Intensity Residential (impervious)	Monthly	Monthly	0.15	1	0.32	Monthly
		High Intensity Residential (impervious)	Monthly	Monthly	0.15	1	0.32	Monthly
		Transitional/Commercial (impervious)	Monthly	Monthly	0.15	1	0.32	Monthly

Table A-16. Monthly Interception Storage (CEPS) Parameters for Calibrated Hogue Creek Model.

Hydrologic Soil Type	Sub-watershed	Land use	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
B	H-05	Low Intensity Residential (pervious)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		High Intensity Residential (pervious)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		Transitional/Commercial (pervious)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		Row Crops	0.1	0.1	0.1	0.1	0.1	0.3	0.4	0.4	0.4	0.4	0.4	0.3
		Pasture/Hay	0.1	0.1	0.1	0.1	0.1	0.3	0.4	0.4	0.4	0.4	0.4	0.3
		Forest	0.1	0.1	0.1	0.1	0.1	0.3	0.4	0.4	0.4	0.4	0.4	0.3
		Low Intensity Residential (impervious)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		High Intensity Residential (impervious)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		Transitional/Commercial (impervious)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
C	H-01 - H-04, H-07 - H-08	Low Intensity Residential (pervious)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		High Intensity Residential (pervious)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		Transitional/Commercial (pervious)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		Row Crops	0.1	0.1	0.1	0.1	0.1	0.3	0.4	0.4	0.4	0.4	0.4	0.3
		Pasture/Hay	0.1	0.1	0.1	0.1	0.1	0.3	0.4	0.4	0.4	0.4	0.4	0.3
		Forest	0.1	0.1	0.1	0.1	0.1	0.3	0.4	0.4	0.4	0.4	0.4	0.3
		Low Intensity Residential (impervious)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		High Intensity Residential (impervious)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		Transitional/Commercial (impervious)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
B/C	H-06, H-09 - H-11	Low Intensity Residential (pervious)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		High Intensity Residential (pervious)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		Transitional/Commercial (pervious)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		Row Crops	0.1	0.1	0.1	0.1	0.1	0.3	0.4	0.4	0.4	0.4	0.4	0.3
		Pasture/Hay	0.1	0.1	0.1	0.1	0.1	0.3	0.4	0.4	0.4	0.4	0.4	0.3
		Forest	0.1	0.1	0.1	0.1	0.1	0.3	0.4	0.4	0.4	0.4	0.4	0.3
		Low Intensity Residential (impervious)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		High Intensity Residential (impervious)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		Transitional/Commercial (impervious)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Table A-17. Monthly Upper Zone Nominal Storage (UZSN) Parameters for Calibrated Hogue Creek LSPC Model.

Hydrologic Soil Type	Sub-watershed	Land use	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
B	H-05	Low Intensity Residential (pervious)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
		High Intensity Residential (pervious)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
		Transitional/Commercial (pervious)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
		Row Crops	0.05	0.05	0.05	0.05	0.05	0.06	0.12	0.12	0.12	0.05	0.05	0.05
		Pasture/Hay	0.05	0.05	0.05	0.05	0.05	0.06	0.12	0.12	0.12	0.05	0.05	0.05
		Forest	0.05	0.05	0.05	0.05	0.05	0.06	0.12	0.12	0.12	0.05	0.05	0.05
		Low Intensity Residential (impervious)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
		High Intensity Residential (impervious)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
		Transitional/Commercial (impervious)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
C	H-01 - H-04, H-07 - H-08	Low Intensity Residential (pervious)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
		High Intensity Residential (pervious)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
		Transitional/Commercial (pervious)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
		Row Crops	0.05	0.05	0.05	0.05	0.05	0.06	0.12	0.12	0.12	0.05	0.05	0.05
		Pasture/Hay	0.05	0.05	0.05	0.05	0.05	0.06	0.12	0.12	0.12	0.05	0.05	0.05
		Forest	0.05	0.05	0.05	0.05	0.05	0.06	0.12	0.12	0.12	0.05	0.05	0.05
		Low Intensity Residential (impervious)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
		High Intensity Residential (impervious)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
		Transitional/Commercial (impervious)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
B/C	H-06, H-09 - H-11	Low Intensity Residential (pervious)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
		High Intensity Residential (pervious)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
		Transitional/Commercial (pervious)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
		Row Crops	0.05	0.05	0.05	0.05	0.05	0.06	0.12	0.12	0.12	0.05	0.05	0.05
		Pasture/Hay	0.05	0.05	0.05	0.05	0.05	0.06	0.12	0.12	0.12	0.05	0.05	0.05
		Forest	0.05	0.05	0.05	0.05	0.05	0.06	0.12	0.12	0.12	0.05	0.05	0.05
		Low Intensity Residential (impervious)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
		High Intensity Residential (impervious)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
		Transitional/Commercial (impervious)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05

Table A-18. Monthly Lower Zone Evapotranspiration (LZEPT) Parameters for Calibrated Hogue Creek LSPC Model.

Hydrologic Soil Type	Sub-watershed	Land use	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
B	H-05	Low Intensity Residential (pervious)	0.2	0.2	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.2
		High Intensity Residential (pervious)	0.2	0.2	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.2
		Transitional/Commercial (pervious)	0.2	0.2	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.3
		Row Crops	0.2	0.2	0.2	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.7	0.5
		Pasture/Hay	0.2	0.2	0.2	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.7	0.5
		Forest	0.2	0.2	0.2	0.85	0.9	0.9	0.9	0.9	0.9	0.9	0.85	0.5
		Low Intensity Residential (impervious)	0.2	0.2	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.2
		High Intensity Residential (impervious)	0.2	0.2	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.2
		Transitional/Commercial (impervious)	0.2	0.2	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.2
C	H-01 - H-04, H-07 - H-08	Low Intensity Residential (pervious)	0.2	0.2	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.2
		High Intensity Residential (pervious)	0.2	0.2	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.2
		Transitional/Commercial (pervious)	0.2	0.2	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.2
		Row Crops	0.2	0.2	0.2	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.7	0.5
		Pasture/Hay	0.2	0.2	0.2	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.7	0.5
		Forest	0.2	0.2	0.2	0.85	0.9	0.9	0.9	0.9	0.9	0.9	0.85	0.5
		Low Intensity Residential (impervious)	0.2	0.2	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.2
		High Intensity Residential (impervious)	0.2	0.2	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.2
		Transitional/Commercial (impervious)	0.2	0.2	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.2
B/C	H-06, H-09 - H-11	Low Intensity Residential (pervious)	0.2	0.2	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.2
		High Intensity Residential (pervious)	0.2	0.2	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.2
		Transitional/Commercial (pervious)	0.2	0.2	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.2
		Row Crops	0.2	0.2	0.2	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.7	0.5
		Pasture/Hay	0.2	0.2	0.2	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.7	0.5
		Forest	0.2	0.2	0.2	0.85	0.9	0.9	0.9	0.9	0.9	0.9	0.85	0.5
		Low Intensity Residential (impervious)	0.2	0.2	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.2
		High Intensity Residential (impervious)	0.2	0.2	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.2
		Transitional/Commercial (impervious)	0.2	0.2	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.2

APPENDIX B:
Water Quality Model Parameters

Table B-1. Final Calibrated Water Quality Parameters for Hogue Creek LSPC Model.

Parameter	Parameter Description	Calibrated Value
WSQOP	Rate of surface runoff which will remove 90% of stored pollutant	0.38
IOQC	Concentration of pollutant in interflow	50
AOQC	Concentration of pollutant in active groundwater	25
ACQOPM (MON-ACCUM)	Monthly parameter for rate of accumulation of pollutant	See Table B-2
SQOLIM	Monthly parameter for maximum storage of pollutant	See Table B-3
FSTDEC	First order decay rate for pollutant	0.76
THFST	Temperature correction coefficient for first order decay of pollutant	1.05

Table B-2. Monthly Accumulation Table for Fecal Coliform Loading to Hogue Creek Watershed Under Existing Conditions (cfu/acre/d).

Sub-watershed	Land use ID	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
H-01	Low Intensity Residential (pervious)	2.51E+09	2.51E+09	2.51E+09	2.49E+09	2.49E+09	2.49E+09	2.49E+09	2.49E+09	2.49E+09	2.51E+09	2.51E+09	2.51E+09
	High Intensity Residential (pervious)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Transitional/Commercial (pervious)	6.03E+07	6.03E+07	6.03E+07	4.79E+07	4.79E+07	4.79E+07	4.79E+07	4.79E+07	4.79E+07	6.03E+07	6.03E+07	6.03E+07
	Row Crops	6.24E+07	6.24E+07	6.24E+07	5.00E+07	5.00E+07	5.00E+07	5.00E+07	5.00E+07	5.00E+07	6.24E+07	6.24E+07	6.24E+07
	Pasture/Hay	1.11E+10	1.11E+10	1.11E+10	1.11E+10	1.11E+10	1.11E+10	1.11E+10	1.11E+10	1.11E+10	1.11E+10	1.11E+10	1.11E+10
	Forest	6.24E+07	6.24E+07	6.24E+07	5.00E+07	5.00E+07	5.00E+07	5.00E+07	5.00E+07	5.00E+07	6.24E+07	6.24E+07	6.24E+07
	Low Intensity Residential (impervious)	2.51E+09	2.51E+09	2.51E+09	2.49E+09	2.49E+09	2.49E+09	2.49E+09	2.49E+09	2.49E+09	2.51E+09	2.51E+09	2.51E+09
	High Intensity Residential (impervious)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Low Intensity Residential (pervious)	6.03E+07	6.03E+07	6.03E+07	4.79E+07	4.79E+07	4.79E+07	4.79E+07	4.79E+07	4.79E+07	6.03E+07	6.03E+07	6.03E+07
H-02	Low Intensity Residential (pervious)	2.42E+09	2.42E+09	2.42E+09	2.42E+09	2.42E+09	2.42E+09	2.42E+09	2.42E+09	2.42E+09	2.42E+09	2.42E+09	2.42E+09
	High Intensity Residential (pervious)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Transitional/Commercial (pervious)	3.56E+07	3.56E+07	3.56E+07	3.04E+07	3.04E+07	3.04E+07	3.04E+07	3.04E+07	3.04E+07	3.56E+07	3.56E+07	3.56E+07
	Row Crops	3.77E+07	3.77E+07	3.77E+07	3.26E+07	3.26E+07	3.26E+07	3.26E+07	3.26E+07	3.26E+07	3.77E+07	3.77E+07	3.77E+07
	Pasture/Hay	1.13E+10	1.13E+10	1.13E+10	1.13E+10	1.13E+10	1.13E+10	1.13E+10	1.13E+10	1.13E+10	1.13E+10	1.13E+10	1.13E+10
	Forest	3.77E+07	3.77E+07	3.77E+07	3.26E+07	3.26E+07	3.26E+07	3.26E+07	3.26E+07	3.26E+07	3.77E+07	3.77E+07	3.77E+07
	Low Intensity Residential (impervious)	2.42E+09	2.42E+09	2.42E+09	2.42E+09	2.42E+09	2.42E+09	2.42E+09	2.42E+09	2.42E+09	2.42E+09	2.42E+09	2.42E+09
	High Intensity Residential (impervious)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Low Intensity Residential (pervious)	3.56E+07	3.56E+07	3.56E+07	3.04E+07	3.04E+07	3.04E+07	3.04E+07	3.04E+07	3.04E+07	3.56E+07	3.56E+07	3.56E+07
H-03	Low Intensity Residential (pervious)	2.37E+09	2.37E+09	2.37E+09	2.37E+09	2.37E+09	2.37E+09	2.37E+09	2.37E+09	2.37E+09	2.37E+09	2.37E+09	2.37E+09
	High Intensity Residential (pervious)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Transitional/Commercial (pervious)	4.57E+07	4.57E+07	4.57E+07	3.78E+07	3.78E+07	3.78E+07	3.78E+07	3.78E+07	3.78E+07	4.57E+07	4.57E+07	4.57E+07
	Row Crops	4.93E+07	4.93E+07	4.93E+07	4.14E+07	4.14E+07	4.14E+07	4.14E+07	4.14E+07	4.14E+07	4.93E+07	4.93E+07	4.93E+07
	Pasture/Hay	1.13E+10	1.13E+10	1.13E+10	1.13E+10	1.13E+10	1.13E+10	1.13E+10	1.13E+10	1.13E+10	1.13E+10	1.13E+10	1.13E+10
	Forest	4.93E+07	4.93E+07	4.93E+07	4.14E+07	4.14E+07	4.14E+07	4.14E+07	4.14E+07	4.14E+07	4.93E+07	4.93E+07	4.93E+07
	Low Intensity Residential (impervious)	2.37E+09	2.37E+09	2.37E+09	2.37E+09	2.37E+09	2.37E+09	2.37E+09	2.37E+09	2.37E+09	2.37E+09	2.37E+09	2.37E+09
	High Intensity Residential (impervious)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Low Intensity Residential (pervious)	4.57E+07	4.57E+07	4.57E+07	3.78E+07	3.78E+07	3.78E+07	3.78E+07	3.78E+07	3.78E+07	4.57E+07	4.57E+07	4.57E+07
H-04	Low Intensity Residential (pervious)	2.28E+09	2.28E+09	2.28E+09	2.26E+09	2.26E+09	2.26E+09	2.26E+09	2.26E+09	2.26E+09	2.28E+09	2.28E+09	2.28E+09
	High Intensity Residential (pervious)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Transitional/Commercial (pervious)	6.90E+07	6.90E+07	6.90E+07	5.10E+07	5.10E+07	5.10E+07	5.10E+07	5.10E+07	5.10E+07	6.90E+07	6.90E+07	6.90E+07
	Row Crops	7.35E+07	7.35E+07	7.35E+07	5.55E+07	5.55E+07	5.55E+07	5.55E+07	5.55E+07	5.55E+07	7.35E+07	7.35E+07	7.35E+07
	Pasture/Hay	9.68E+09	9.68E+09	9.68E+09	9.63E+09	9.63E+09	9.63E+09	9.63E+09	9.63E+09	9.63E+09	9.68E+09	9.68E+09	9.68E+09

	Forest	7.35E+07	7.35E+07	7.35E+07	5.55E+07	5.55E+07	5.55E+07	5.55E+07	5.55E+07	5.55E+07	7.35E+07	7.35E+07	7.35E+07
	Low Intensity Residential (impervious)	2.28E+09	2.28E+09	2.28E+09	2.26E+09	2.26E+09	2.26E+09	2.26E+09	2.26E+09	2.26E+09	2.28E+09	2.28E+09	2.28E+09
	High Intensity Residential (impervious)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Low Intensity Residential (pervious)	6.90E+07	6.90E+07	6.90E+07	5.10E+07	5.10E+07	5.10E+07	5.10E+07	5.10E+07	5.10E+07	6.90E+07	6.90E+07	6.90E+07
	Low Intensity Residential (pervious)	2.42E+09	2.42E+09	2.42E+09	2.40E+09	2.40E+09	2.40E+09	2.40E+09	2.40E+09	2.40E+09	2.42E+09	2.42E+09	2.42E+09
	High Intensity Residential (pervious)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Transitional/Commercial (pervious)	6.84E+07	6.84E+07	6.84E+07	5.44E+07	5.44E+07	5.44E+07	5.44E+07	5.44E+07	5.44E+07	6.84E+07	6.84E+07	6.84E+07
	Row Crops	7.07E+07	7.07E+07	7.07E+07	5.68E+07	5.68E+07	5.68E+07	5.68E+07	5.68E+07	5.68E+07	7.07E+07	7.07E+07	7.07E+07
H-05	Pasture/Hay	1.13E+10	1.13E+10	1.13E+10	1.12E+10	1.12E+10	1.12E+10	1.12E+10	1.12E+10	1.12E+10	1.13E+10	1.13E+10	1.13E+10
	Forest	7.07E+07	7.07E+07	7.07E+07	5.68E+07	5.68E+07	5.68E+07	5.68E+07	5.68E+07	5.68E+07	7.07E+07	7.07E+07	7.07E+07
	Low Intensity Residential (impervious)	2.42E+09	2.42E+09	2.42E+09	2.40E+09	2.40E+09	2.40E+09	2.40E+09	2.40E+09	2.40E+09	2.42E+09	2.42E+09	2.42E+09
	High Intensity Residential (impervious)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Low Intensity Residential (pervious)	6.84E+07	6.84E+07	6.84E+07	5.44E+07	5.44E+07	5.44E+07	5.44E+07	5.44E+07	5.44E+07	6.84E+07	6.84E+07	6.84E+07
	Low Intensity Residential (pervious)	2.39E+09	2.39E+09	2.39E+09	2.39E+09	2.39E+09	2.39E+09	2.39E+09	2.39E+09	2.39E+09	2.39E+09	2.39E+09	2.39E+09
	High Intensity Residential (pervious)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Transitional/Commercial (pervious)	2.76E+07	2.76E+07	2.76E+07	2.51E+07	2.51E+07	2.51E+07	2.51E+07	2.51E+07	2.51E+07	2.76E+07	2.76E+07	2.76E+07
	Row Crops	2.98E+07	2.98E+07	2.98E+07	2.73E+07	2.73E+07	2.73E+07	2.73E+07	2.73E+07	2.73E+07	2.98E+07	2.98E+07	2.98E+07
H-06	Pasture/Hay	1.14E+10	1.14E+10	1.14E+10	1.14E+10	1.14E+10	1.14E+10	1.14E+10	1.14E+10	1.14E+10	1.14E+10	1.14E+10	1.14E+10
	Forest	2.98E+07	2.98E+07	2.98E+07	2.73E+07	2.73E+07	2.73E+07	2.73E+07	2.73E+07	2.73E+07	2.98E+07	2.98E+07	2.98E+07
	Low Intensity Residential (impervious)	2.39E+09	2.39E+09	2.39E+09	2.39E+09	2.39E+09	2.39E+09	2.39E+09	2.39E+09	2.39E+09	2.39E+09	2.39E+09	2.39E+09
	High Intensity Residential (impervious)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Low Intensity Residential (pervious)	2.76E+07	2.76E+07	2.76E+07	2.51E+07	2.51E+07	2.51E+07	2.51E+07	2.51E+07	2.51E+07	2.76E+07	2.76E+07	2.76E+07
	Low Intensity Residential (pervious)	2.39E+09	2.39E+09	2.39E+09	2.39E+09	2.39E+09	2.39E+09	2.39E+09	2.39E+09	2.39E+09	2.39E+09	2.39E+09	2.39E+09
	High Intensity Residential (pervious)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Transitional/Commercial (pervious)	3.21E+07	3.21E+07	3.21E+07	2.82E+07	2.82E+07	2.82E+07	2.82E+07	2.82E+07	2.82E+07	3.21E+07	3.21E+07	3.21E+07
	Row Crops	3.40E+07	3.40E+07	3.40E+07	3.01E+07	3.01E+07	3.01E+07	3.01E+07	3.01E+07	3.01E+07	3.40E+07	3.40E+07	3.40E+07
H-07	Pasture/Hay	1.13E+10	1.13E+10	1.13E+10	1.13E+10	1.13E+10	1.13E+10	1.13E+10	1.13E+10	1.13E+10	1.13E+10	1.13E+10	1.13E+10
	Forest	3.40E+07	3.40E+07	3.40E+07	3.01E+07	3.01E+07	3.01E+07	3.01E+07	3.01E+07	3.01E+07	3.40E+07	3.40E+07	3.40E+07
	Low Intensity Residential (impervious)	2.39E+09	2.39E+09	2.39E+09	2.39E+09	2.39E+09	2.39E+09	2.39E+09	2.39E+09	2.39E+09	2.39E+09	2.39E+09	2.39E+09
	High Intensity Residential (impervious)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Low Intensity Residential (pervious)	3.21E+07	3.21E+07	3.21E+07	2.82E+07	2.82E+07	2.82E+07	2.82E+07	2.82E+07	2.82E+07	3.21E+07	3.21E+07	3.21E+07
H-08	Low Intensity Residential (pervious)	2.48E+09	2.48E+09	2.48E+09	2.47E+09	2.47E+09	2.47E+09	2.47E+09	2.47E+09	2.47E+09	2.48E+09	2.48E+09	2.48E+09
	High Intensity Residential (pervious)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Transitional/Commercial (pervious)	7.15E+07	7.15E+07	7.15E+07	5.48E+07	5.48E+07	5.48E+07	5.48E+07	5.48E+07	5.48E+07	7.15E+07	7.15E+07	7.15E+07
	Row Crops	7.37E+07	7.37E+07	7.37E+07	5.71E+07	5.71E+07	5.71E+07	5.71E+07	5.71E+07	5.71E+07	7.37E+07	7.37E+07	7.37E+07

	Pasture/Hay	1.13E+10	1.13E+10	1.13E+10	1.13E+10	1.13E+10	1.13E+10	1.13E+10	1.13E+10	1.13E+10	1.13E+10	1.13E+10	1.13E+10
	Forest	7.37E+07	7.37E+07	7.37E+07	5.71E+07	5.71E+07	5.71E+07	5.71E+07	5.71E+07	5.71E+07	7.37E+07	7.37E+07	7.37E+07
	Low Intensity Residential (impervious)	2.48E+09	2.48E+09	2.48E+09	2.47E+09	2.47E+09	2.47E+09	2.47E+09	2.47E+09	2.47E+09	2.48E+09	2.48E+09	2.48E+09
	High Intensity Residential (impervious)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Low Intensity Residential (pervious)	7.15E+07	7.15E+07	7.15E+07	5.48E+07	5.48E+07	5.48E+07	5.48E+07	5.48E+07	5.48E+07	7.15E+07	7.15E+07	7.15E+07
H-09	Low Intensity Residential (pervious)	2.44E+09	2.44E+09	2.44E+09	2.44E+09	2.44E+09	2.44E+09	2.44E+09	2.44E+09	2.44E+09	2.44E+09	2.44E+09	2.44E+09
	High Intensity Residential (pervious)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Transitional/Commercial (pervious)	3.18E+07	3.18E+07	3.18E+07	2.77E+07	2.77E+07	2.77E+07	2.77E+07	2.77E+07	2.77E+07	3.18E+07	3.18E+07	3.18E+07
	Row Crops	3.41E+07	3.41E+07	3.41E+07	3.01E+07	3.01E+07	3.01E+07	3.01E+07	3.01E+07	3.01E+07	3.41E+07	3.41E+07	3.41E+07
	Pasture/Hay	1.14E+10	1.14E+10	1.14E+10	1.14E+10	1.14E+10	1.14E+10	1.14E+10	1.14E+10	1.14E+10	1.14E+10	1.14E+10	1.14E+10
	Forest	3.41E+07	3.41E+07	3.41E+07	3.01E+07	3.01E+07	3.01E+07	3.01E+07	3.01E+07	3.01E+07	3.41E+07	3.41E+07	3.41E+07
	Low Intensity Residential (impervious)	2.44E+09	2.44E+09	2.44E+09	2.44E+09	2.44E+09	2.44E+09	2.44E+09	2.44E+09	2.44E+09	2.44E+09	2.44E+09	2.44E+09
	High Intensity Residential (impervious)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Low Intensity Residential (pervious)	3.18E+07	3.18E+07	3.18E+07	2.77E+07	2.77E+07	2.77E+07	2.77E+07	2.77E+07	2.77E+07	3.18E+07	3.18E+07	3.18E+07
H-10	Low Intensity Residential (pervious)	2.28E+09	2.28E+09	2.28E+09	2.28E+09	2.28E+09	2.28E+09	2.28E+09	2.28E+09	2.28E+09	2.28E+09	2.28E+09	2.28E+09
	High Intensity Residential (pervious)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Transitional/Commercial (pervious)	3.22E+07	3.22E+07	3.22E+07	2.77E+07	2.77E+07	2.77E+07	2.77E+07	2.77E+07	2.77E+07	3.22E+07	3.22E+07	3.22E+07
	Row Crops	3.48E+07	3.48E+07	3.48E+07	3.04E+07	3.04E+07	3.04E+07	3.04E+07	3.04E+07	3.04E+07	3.48E+07	3.48E+07	3.48E+07
	Pasture/Hay	1.14E+10	1.14E+10	1.14E+10	1.13E+10	1.13E+10	1.13E+10	1.13E+10	1.13E+10	1.13E+10	1.14E+10	1.14E+10	1.14E+10
	Forest	3.48E+07	3.48E+07	3.48E+07	3.04E+07	3.04E+07	3.04E+07	3.04E+07	3.04E+07	3.04E+07	3.48E+07	3.48E+07	3.48E+07
	Low Intensity Residential (impervious)	2.28E+09	2.28E+09	2.28E+09	2.28E+09	2.28E+09	2.28E+09	2.28E+09	2.28E+09	2.28E+09	2.28E+09	2.28E+09	2.28E+09
	High Intensity Residential (impervious)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Low Intensity Residential (pervious)	3.22E+07	3.22E+07	3.22E+07	2.77E+07	2.77E+07	2.77E+07	2.77E+07	2.77E+07	2.77E+07	3.22E+07	3.22E+07	3.22E+07
H-11	Low Intensity Residential (pervious)	2.32E+09	2.32E+09	2.32E+09	2.31E+09	2.31E+09	2.31E+09	2.31E+09	2.31E+09	2.31E+09	2.32E+09	2.32E+09	2.32E+09
	High Intensity Residential (pervious)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Transitional/Commercial (pervious)	4.80E+07	4.80E+07	4.80E+07	3.88E+07	3.88E+07	3.88E+07	3.88E+07	3.88E+07	3.88E+07	4.80E+07	4.80E+07	4.80E+07
	Row Crops	5.05E+07	5.05E+07	5.05E+07	4.13E+07	4.13E+07	4.13E+07	4.13E+07	4.13E+07	4.13E+07	5.05E+07	5.05E+07	5.05E+07
	Pasture/Hay	1.14E+10	1.14E+10	1.14E+10	1.14E+10	1.14E+10	1.14E+10	1.14E+10	1.14E+10	1.14E+10	1.14E+10	1.14E+10	1.14E+10
	Forest	5.05E+07	5.05E+07	5.05E+07	4.13E+07	4.13E+07	4.13E+07	4.13E+07	4.13E+07	4.13E+07	5.05E+07	5.05E+07	5.05E+07
	Low Intensity Residential (impervious)	2.32E+09	2.32E+09	2.32E+09	2.31E+09	2.31E+09	2.31E+09	2.31E+09	2.31E+09	2.31E+09	2.32E+09	2.32E+09	2.32E+09
	High Intensity Residential (impervious)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Low Intensity Residential (pervious)	4.80E+07	4.80E+07	4.80E+07	3.88E+07	3.88E+07	3.88E+07	3.88E+07	3.88E+07	3.88E+07	4.80E+07	4.80E+07	4.80E+07

Table B-3. Monthly Maximum Storage (SQOLIM) Table for Fecal Coliform Loading to Hogue Creek Watershed Under Existing Conditions (cfu/acre).

Sub-watershed	Land use ID	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
H-01	Low Intensity Residential (pervious)	4.51E+09	4.51E+09	4.51E+09	3.74E+09	3.74E+09	3.74E+09	3.74E+09	3.74E+09	3.74E+09	4.51E+09	4.51E+09	4.51E+09
	High Intensity Residential (pervious)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Transitional/Commercial (pervious)	1.09E+08	1.09E+08	1.09E+08	7.18E+07	7.18E+07	7.18E+07	7.18E+07	7.18E+07	7.18E+07	1.09E+08	1.09E+08	1.09E+08
	Row Crops	1.12E+08	1.12E+08	1.12E+08	7.51E+07	7.51E+07	7.51E+07	7.51E+07	7.51E+07	7.51E+07	1.12E+08	1.12E+08	1.12E+08
	Pasture/Hay	2.00E+10	2.00E+10	2.00E+10	1.66E+10	1.66E+10	1.66E+10	1.66E+10	1.66E+10	1.66E+10	2.00E+10	2.00E+10	2.00E+10
	Forest	1.12E+08	1.12E+08	1.12E+08	7.51E+07	7.51E+07	7.51E+07	7.51E+07	7.51E+07	7.51E+07	1.12E+08	1.12E+08	1.12E+08
	Low Intensity Residential (impervious)	4.51E+09	4.51E+09	4.51E+09	3.74E+09	3.74E+09	3.74E+09	3.74E+09	3.74E+09	3.74E+09	4.51E+09	4.51E+09	4.51E+09
	High Intensity Residential (impervious)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Low Intensity Residential (pervious)	1.09E+08	1.09E+08	1.09E+08	7.18E+07	7.18E+07	7.18E+07	7.18E+07	7.18E+07	7.18E+07	1.09E+08	1.09E+08	1.09E+08
H-02	Low Intensity Residential (pervious)	4.36E+09	4.36E+09	4.36E+09	3.62E+09	3.62E+09	3.62E+09	3.62E+09	3.62E+09	3.62E+09	4.36E+09	4.36E+09	4.36E+09
	High Intensity Residential (pervious)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Transitional/Commercial (pervious)	6.40E+07	6.40E+07	6.40E+07	4.57E+07	4.57E+07	4.57E+07	4.57E+07	4.57E+07	4.57E+07	6.40E+07	6.40E+07	6.40E+07
	Row Crops	6.79E+07	6.79E+07	6.79E+07	4.89E+07	4.89E+07	4.89E+07	4.89E+07	4.89E+07	4.89E+07	6.79E+07	6.79E+07	6.79E+07
	Pasture/Hay	2.03E+10	2.03E+10	2.03E+10	1.69E+10	1.69E+10	1.69E+10	1.69E+10	1.69E+10	1.69E+10	2.03E+10	2.03E+10	2.03E+10
	Forest	6.79E+07	6.79E+07	6.79E+07	4.89E+07	4.89E+07	4.89E+07	4.89E+07	4.89E+07	4.89E+07	6.79E+07	6.79E+07	6.79E+07
	Low Intensity Residential (impervious)	4.36E+09	4.36E+09	4.36E+09	3.62E+09	3.62E+09	3.62E+09	3.62E+09	3.62E+09	3.62E+09	4.36E+09	4.36E+09	4.36E+09
	High Intensity Residential (impervious)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Low Intensity Residential (pervious)	6.40E+07	6.40E+07	6.40E+07	4.57E+07	4.57E+07	4.57E+07	4.57E+07	4.57E+07	4.57E+07	6.40E+07	6.40E+07	6.40E+07
H-03	Low Intensity Residential (pervious)	4.27E+09	4.27E+09	4.27E+09	3.55E+09	3.55E+09	3.55E+09	3.55E+09	3.55E+09	3.55E+09	4.27E+09	4.27E+09	4.27E+09
	High Intensity Residential (pervious)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Transitional/Commercial (pervious)	8.22E+07	8.22E+07	8.22E+07	5.67E+07	5.67E+07	5.67E+07	5.67E+07	5.67E+07	5.67E+07	8.22E+07	8.22E+07	8.22E+07
	Row Crops	8.87E+07	8.87E+07	8.87E+07	6.21E+07	6.21E+07	6.21E+07	6.21E+07	6.21E+07	6.21E+07	8.87E+07	8.87E+07	8.87E+07
	Pasture/Hay	2.03E+10	2.03E+10	2.03E+10	1.69E+10	1.69E+10	1.69E+10	1.69E+10	1.69E+10	1.69E+10	2.03E+10	2.03E+10	2.03E+10
	Forest	8.87E+07	8.87E+07	8.87E+07	6.21E+07	6.21E+07	6.21E+07	6.21E+07	6.21E+07	6.21E+07	8.87E+07	8.87E+07	8.87E+07
	Low Intensity Residential (impervious)	4.27E+09	4.27E+09	4.27E+09	3.55E+09	3.55E+09	3.55E+09	3.55E+09	3.55E+09	3.55E+09	4.27E+09	4.27E+09	4.27E+09
	High Intensity Residential (impervious)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Low Intensity Residential (pervious)	8.22E+07	8.22E+07	8.22E+07	5.67E+07	5.67E+07	5.67E+07	5.67E+07	5.67E+07	5.67E+07	8.22E+07	8.22E+07	8.22E+07
H-04	Low Intensity Residential (pervious)	4.10E+09	4.10E+09	4.10E+09	3.39E+09	3.39E+09	3.39E+09	3.39E+09	3.39E+09	3.39E+09	4.10E+09	4.10E+09	4.10E+09
	High Intensity Residential (pervious)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Transitional/Commercial (pervious)	1.24E+08	1.24E+08	1.24E+08	7.64E+07	7.64E+07	7.64E+07	7.64E+07	7.64E+07	7.64E+07	1.24E+08	1.24E+08	1.24E+08

	Row Crops	1.32E+08	1.32E+08	1.32E+08	8.33E+07	8.33E+07	8.33E+07	8.33E+07	8.33E+07	8.33E+07	1.32E+08	1.32E+08	1.32E+08
	Pasture/Hay	1.74E+10	1.74E+10	1.74E+10	1.44E+10	1.44E+10	1.44E+10	1.44E+10	1.44E+10	1.44E+10	1.74E+10	1.74E+10	1.74E+10
	Forest	1.32E+08	1.32E+08	1.32E+08	8.33E+07	8.33E+07	8.33E+07	8.33E+07	8.33E+07	8.33E+07	1.32E+08	1.32E+08	1.32E+08
	Low Intensity Residential (impervious)	4.10E+09	4.10E+09	4.10E+09	3.39E+09	3.39E+09	3.39E+09	3.39E+09	3.39E+09	3.39E+09	4.10E+09	4.10E+09	4.10E+09
	High Intensity Residential (impervious)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Low Intensity Residential (pervious)	1.24E+08	1.24E+08	1.24E+08	7.64E+07	7.64E+07	7.64E+07	7.64E+07	7.64E+07	7.64E+07	1.24E+08	1.24E+08	1.24E+08
H-05	Low Intensity Residential (pervious)	4.35E+09	4.35E+09	4.35E+09	3.60E+09	3.60E+09	3.60E+09	3.60E+09	3.60E+09	3.60E+09	4.35E+09	4.35E+09	4.35E+09
	High Intensity Res idential (pervious)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Transitional/Commercial (pervious)	1.23E+08	1.23E+08	1.23E+08	8.17E+07	8.17E+07	8.17E+07	8.17E+07	8.17E+07	8.17E+07	1.23E+08	1.23E+08	1.23E+08
	Row Crops	1.27E+08	1.27E+08	1.27E+08	8.52E+07	8.52E+07	8.52E+07	8.52E+07	8.52E+07	8.52E+07	1.27E+08	1.27E+08	1.27E+08
	Pasture/Hay	2.03E+10	2.03E+10	2.03E+10	1.68E+10	1.68E+10	1.68E+10	1.68E+10	1.68E+10	1.68E+10	2.03E+10	2.03E+10	2.03E+10
	Forest	1.27E+08	1.27E+08	1.27E+08	8.52E+07	8.52E+07	8.52E+07	8.52E+07	8.52E+07	8.52E+07	1.27E+08	1.27E+08	1.27E+08
	Low Intensity Residential (impervious)	4.35E+09	4.35E+09	4.35E+09	3.60E+09	3.60E+09	3.60E+09	3.60E+09	3.60E+09	3.60E+09	4.35E+09	4.35E+09	4.35E+09
	High Intensity Residential (impervious)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Low Intensity Residential (pervious)	1.23E+08	1.23E+08	1.23E+08	8.17E+07	8.17E+07	8.17E+07	8.17E+07	8.17E+07	8.17E+07	1.23E+08	1.23E+08	1.23E+08
H-06	Low Intensity Residential (pervious)	4.31E+09	4.31E+09	4.31E+09	3.58E+09	3.58E+09	3.58E+09	3.58E+09	3.58E+09	3.58E+09	4.31E+09	4.31E+09	4.31E+09
	High Intensity Residential (pervious)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Transitional/Commercial (pervious)	4.97E+07	4.97E+07	4.97E+07	3.76E+07	3.76E+07	3.76E+07	3.76E+07	3.76E+07	3.76E+07	4.97E+07	4.97E+07	4.97E+07
	Row Crops	5.37E+07	5.37E+07	5.37E+07	4.10E+07	4.10E+07	4.10E+07	4.10E+07	4.10E+07	4.10E+07	5.37E+07	5.37E+07	5.37E+07
	Pasture/Hay	2.05E+10	2.05E+10	2.05E+10	1.70E+10	1.70E+10	1.70E+10	1.70E+10	1.70E+10	1.70E+10	2.05E+10	2.05E+10	2.05E+10
	Forest	5.37E+07	5.37E+07	5.37E+07	4.10E+07	4.10E+07	4.10E+07	4.10E+07	4.10E+07	4.10E+07	5.37E+07	5.37E+07	5.37E+07
	Low Intensity Residential (impervious)	4.31E+09	4.31E+09	4.31E+09	3.58E+09	3.58E+09	3.58E+09	3.58E+09	3.58E+09	3.58E+09	4.31E+09	4.31E+09	4.31E+09
	High Intensity Residential (impervious)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Low Intensity Residential (pervious)	4.97E+07	4.97E+07	4.97E+07	3.76E+07	3.76E+07	3.76E+07	3.76E+07	3.76E+07	3.76E+07	4.97E+07	4.97E+07	4.97E+07
H-07	Low Intensity Residential (pervious)	4.30E+09	4.30E+09	4.30E+09	3.58E+09	3.58E+09	3.58E+09	3.58E+09	3.58E+09	3.58E+09	4.30E+09	4.30E+09	4.30E+09
	High Intensity Residential (pervious)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Transitional/Commercial (pervious)	5.79E+07	5.79E+07	5.79E+07	4.23E+07	4.23E+07	4.23E+07	4.23E+07	4.23E+07	4.23E+07	5.79E+07	5.79E+07	5.79E+07
	Row Crops	6.13E+07	6.13E+07	6.13E+07	4.51E+07	4.51E+07	4.51E+07	4.51E+07	4.51E+07	4.51E+07	6.13E+07	6.13E+07	6.13E+07
	Pasture/Hay	2.04E+10	2.04E+10	2.04E+10	1.70E+10	1.70E+10	1.70E+10	1.70E+10	1.70E+10	1.70E+10	2.04E+10	2.04E+10	2.04E+10
	Forest	6.13E+07	6.13E+07	6.13E+07	4.51E+07	4.51E+07	4.51E+07	4.51E+07	4.51E+07	4.51E+07	6.13E+07	6.13E+07	6.13E+07
	Low Intensity Residential (impervious)	4.30E+09	4.30E+09	4.30E+09	3.58E+09	3.58E+09	3.58E+09	3.58E+09	3.58E+09	3.58E+09	4.30E+09	4.30E+09	4.30E+09
	High Intensity Residential (impervious)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Low Intensity Residential (pervious)	5.79E+07	5.79E+07	5.79E+07	4.23E+07	4.23E+07	4.23E+07	4.23E+07	4.23E+07	4.23E+07	5.79E+07	5.79E+07	5.79E+07
H-08	Low Intensity Residential (pervious)	4.47E+09	4.47E+09	4.47E+09	3.70E+09	3.70E+09	3.70E+09	3.70E+09	3.70E+09	3.70E+09	4.47E+09	4.47E+09	4.47E+09
	High Intensity Residential (pervious)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

	Transitional/Commercial (pervious)	1.29E+08	1.29E+08	1.29E+08	8.23E+07	8.23E+07	8.23E+07	8.23E+07	8.23E+07	8.23E+07	1.29E+08	1.29E+08	1.29E+08
	Row Crops	1.33E+08	1.33E+08	1.33E+08	8.56E+07	8.56E+07	8.56E+07	8.56E+07	8.56E+07	8.56E+07	1.33E+08	1.33E+08	1.33E+08
	Pasture/Hay	2.04E+10	2.04E+10	2.04E+10	1.70E+10	1.70E+10	1.70E+10	1.70E+10	1.70E+10	1.70E+10	2.04E+10	2.04E+10	2.04E+10
	Forest	1.33E+08	1.33E+08	1.33E+08	8.56E+07	8.56E+07	8.56E+07	8.56E+07	8.56E+07	8.56E+07	1.33E+08	1.33E+08	1.33E+08
	Low Intensity Residential (impervious)	4.47E+09	4.47E+09	4.47E+09	3.70E+09	3.70E+09	3.70E+09	3.70E+09	3.70E+09	3.70E+09	4.47E+09	4.47E+09	4.47E+09
	High Intensity Residential (impervious)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Low Intensity Residential (pervious)	1.29E+08	1.29E+08	1.29E+08	8.23E+07	8.23E+07	8.23E+07	8.23E+07	8.23E+07	8.23E+07	1.29E+08	1.29E+08	1.29E+08
	Low Intensity Residential (pervious)	4.39E+09	4.39E+09	4.39E+09	3.65E+09	3.65E+09	3.65E+09	3.65E+09	3.65E+09	3.65E+09	4.39E+09	4.39E+09	4.39E+09
	High Intensity Residential (pervious)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Transitional/Commercial (pervious)	5.72E+07	5.72E+07	5.72E+07	4.16E+07	4.16E+07	4.16E+07	4.16E+07	4.16E+07	4.16E+07	5.72E+07	5.72E+07	5.72E+07
	Row Crops	6.14E+07	6.14E+07	6.14E+07	4.51E+07	4.51E+07	4.51E+07	4.51E+07	4.51E+07	4.51E+07	6.14E+07	6.14E+07	6.14E+07
H-09	Pasture/Hay	2.05E+10	2.05E+10	2.05E+10	1.71E+10	1.71E+10	1.71E+10	1.71E+10	1.71E+10	1.71E+10	2.05E+10	2.05E+10	2.05E+10
	Forest	6.14E+07	6.14E+07	6.14E+07	4.51E+07	4.51E+07	4.51E+07	4.51E+07	4.51E+07	4.51E+07	6.14E+07	6.14E+07	6.14E+07
	Low Intensity Residential (impervious)	4.39E+09	4.39E+09	4.39E+09	3.65E+09	3.65E+09	3.65E+09	3.65E+09	3.65E+09	3.65E+09	4.39E+09	4.39E+09	4.39E+09
	High Intensity Residential (impervious)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Low Intensity Residential (pervious)	5.72E+07	5.72E+07	5.72E+07	4.16E+07	4.16E+07	4.16E+07	4.16E+07	4.16E+07	4.16E+07	5.72E+07	5.72E+07	5.72E+07
	Low Intensity Residential (pervious)	4.11E+09	4.11E+09	4.11E+09	3.42E+09	3.42E+09	3.42E+09	3.42E+09	3.42E+09	3.42E+09	4.11E+09	4.11E+09	4.11E+09
	High Intensity Residential (pervious)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Transitional/Commercial (pervious)	5.79E+07	5.79E+07	5.79E+07	4.16E+07	4.16E+07	4.16E+07	4.16E+07	4.16E+07	4.16E+07	5.79E+07	5.79E+07	5.79E+07
	Row Crops	6.27E+07	6.27E+07	6.27E+07	4.56E+07	4.56E+07	4.56E+07	4.56E+07	4.56E+07	4.56E+07	6.27E+07	6.27E+07	6.27E+07
H-10	Pasture/Hay	2.04E+10	2.04E+10	2.04E+10	1.70E+10	1.70E+10	1.70E+10	1.70E+10	1.70E+10	1.70E+10	2.04E+10	2.04E+10	2.04E+10
	Forest	6.27E+07	6.27E+07	6.27E+07	4.56E+07	4.56E+07	4.56E+07	4.56E+07	4.56E+07	4.56E+07	6.27E+07	6.27E+07	6.27E+07
	Low Intensity Residential (impervious)	4.11E+09	4.11E+09	4.11E+09	3.42E+09	3.42E+09	3.42E+09	3.42E+09	3.42E+09	3.42E+09	4.11E+09	4.11E+09	4.11E+09
	High Intensity Residential (impervious)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Low Intensity Residential (pervious)	5.79E+07	5.79E+07	5.79E+07	4.16E+07	4.16E+07	4.16E+07	4.16E+07	4.16E+07	4.16E+07	5.79E+07	5.79E+07	5.79E+07
	Low Intensity Residential (pervious)	4.18E+09	4.18E+09	4.18E+09	3.47E+09	3.47E+09	3.47E+09	3.47E+09	3.47E+09	3.47E+09	4.18E+09	4.18E+09	4.18E+09
	High Intensity Residential (pervious)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Transitional/Commercial (pervious)	8.64E+07	8.64E+07	8.64E+07	5.82E+07	5.82E+07	5.82E+07	5.82E+07	5.82E+07	5.82E+07	8.64E+07	8.64E+07	8.64E+07
	Row Crops	9.09E+07	9.09E+07	9.09E+07	6.20E+07	6.20E+07	6.20E+07	6.20E+07	6.20E+07	6.20E+07	9.09E+07	9.09E+07	9.09E+07
H-11	Pasture/Hay	2.06E+10	2.06E+10	2.06E+10	1.71E+10	1.71E+10	1.71E+10	1.71E+10	1.71E+10	1.71E+10	2.06E+10	2.06E+10	2.06E+10
	Forest	9.09E+07	9.09E+07	9.09E+07	6.20E+07	6.20E+07	6.20E+07	6.20E+07	6.20E+07	6.20E+07	9.09E+07	9.09E+07	9.09E+07
	Low Intensity Residential (impervious)	4.18E+09	4.18E+09	4.18E+09	3.47E+09	3.47E+09	3.47E+09	3.47E+09	3.47E+09	3.47E+09	4.18E+09	4.18E+09	4.18E+09
	High Intensity Residential (impervious)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Low Intensity Residential (pervious)	8.64E+07	8.64E+07	8.64E+07	5.82E+07	5.82E+07	5.82E+07	5.82E+07	5.82E+07	5.82E+07	8.64E+07	8.64E+07	8.64E+07