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Bacteria TMDL Development for the Banister River, Bearskin Creek, Cherrystone Creek, Polecat Creek, Stinking River, Sandy Creek, and Whitehorn Creek Watersheds

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Executive Summary

This report presents the development of bacteria TMDLs for the Banister River, Bearskin Creek, Cherrystone Creek, Polecat Creek, Stinking River, Sandy Creek, and Whitehorn Creek watersheds. These water bodies were listed as impaired on Virginia's 303(d) Total Maximum Daily Load Priority List and Reports (DEQ, 1998, 2002, 2004, 2006) because of violations of the state's water quality standards for *E. coli* and fecal coliform bacteria.

Description of the Study Area

The Banister River watershed is located within the borders of Halifax and Pittsylvania counties. Within the watershed's boundaries there are two county seats, Chatham and Halifax, as well as the cities of Dry Fork, Mount Airy, Gretna, and Spring Garden. All impaired streams are located in the Banister River watershed (USGS Cataloging Unit 0301010). The entire Banister watershed is approximately 353,319 acres. Approximately 70 percent of the entire drainage basin is located in Pittsylvania County and 30 percent in Halifax County.

Impairment Description

Segments of the Banister River, Bearskin Creek, Cherrystone Creek, Polecat Creek, Stinking River, Sandy Creek, and Whitehorn Creek watersheds were listed as impaired for bacteria on Virginia's 1996, 1998, 2002, 2004, and/or 2006 303(d) Total Maximum Daily Load Priority List and Reports (DEQ, 1996) due to violations of the state's water quality standard for fecal coliform bacteria and/ or *E. coli*.

Two segments of the Banister River were identified as impaired for bacteria on VA DEQ's 2004 and 2006 305(b)/303(d) Water Quality Assessment Integrated Report. First listed as impaired in the 2004 305(b)/303(d) Water Quality Assessment Integrated Report, the upstream impaired segment (VAC-L65R-01) of the Banister River is 11.67 miles long and includes the Banister River from Bearskin Creek to its headwaters. Between January 1, 2000 and December 31, 2004, 2 of 18 fecal coliform samples (11%) collected at the listing station (4ABAN070.20) exceeded the bacteria instantaneous criterion of 400 cfu/100 mL. The second segment for the Banister River (VAC-L67-01) is 13.18 miles and runs from Elkhorn Creek to Banister Lake. Between January 1, 2000 and December 31, 2004, 4 out of 16 *E. coli* (25%) samples collected at the listing station (4ABAN023.38) exceeded the *E. coli* standard of 235 cfu/100 ml.

The impaired segment of Bearskin Creek (VAC-L65R-02), which is 9.31 miles and includes the entire creek from its headwaters to the mouth of the Banister River, was first listed on the 2006 305(b)/303(d) Water Quality Assessment Integrated Report for exceedances of the *E. coli* standard of 235 cfu/100 ml. Between January 1, 2000 and December 31, 2004, 2 out of 7 samples (29%) collected at the listing station (4ABKN000.52) exceeded the *E. coli* criterion of 235 cfu/100 ml.

The impaired segment of Cherrystone Creek (VAC-L66R-01) which extends for 8.44 miles includes the Cherrystone Creek mainstem from the Cherrystone Creek dam to the Banister River confluence. This segment was first listed on the 1996 305(b)/303(d) Water Quality Assessment Integrated Report. Between January 1, 2000 and December 31, 2004 at the listing station (4ACRR003.56), 1 out of 9 *E. coli* samples (13%) exceeded the *E. coli* standard instantaneous of 235 cfu/100 ml and 1 out of 8 samples (11%) exceeded the fecal coliform instantaneous standard of 400cfu/ml.

The impaired segment of the Stinking River (VAC-L69R-01) was first listed on the 2004 305(b)/303(d) Water Quality Assessment Integrated Report. This segment of Stinking River is impaired for fecal coliform for 8.99 miles, from the mouth of the Stinking River to the mouth of the North Fork of the Stinking River. Between January 1, 2000 and December 31, 2004, 3 out of 20 samples (15%) collected exceeded the instantaneous fecal coliform bacteria standard of 400 (cfu/100mL).

The impaired segment of Sandy Creek (VAC-L70R-01) extends for 11.78 miles from the confluence of Johns Run to the mouth of Sandy Creek. This segment was first listed on the 2002 305(b)/303(d) Water Quality Assessment Integrated Report. Between January 1, 2000 and December 31, 2004, 3 out of 19 samples (16%) collected at station 4ASNA000.20 were recorded as exceeding the instantaneous fecal coliform bacteria criterion of 400 (cfu/100mL).

The impaired segment of Whitehorn Creek (VAC-L68R-01) extends 24.73 miles and was first listed on the 2002 305(b)/303(d) Water Quality Assessment Integrated Report and extends from the mouth to the headwaters of Whitehorn Creek. 1 out of 8 samples (12.5%) collected at listing station (4AWRN0005.50) between January 1, 2000 and December 31, 2004 exceeded the instantaneous fecal coliform bacteria standard of 400 (cfu/100mL). Also, at this station, 2 out of 8 (25%) of the samples collected within this same time frame exceeded the *E. coli* standard instantaneous of 235 cfu/100 ml.

Applicable Water Quality Standards

At the time of the initial listing of the Banister River, Bearskin Creek, Cherrystone Creek, Polecat Creek, Stinking River, Sandy Creek, and Whitehorn Creek segments, the Virginia Bacteria Water Quality Standard was expressed in fecal coliform bacteria; however, the bacteria water quality standard has been recently changed and is now expressed in *E. coli*. Virginia's bacteria water quality standard currently states that *E. coli* bacteria shall not exceed a geometric mean of 126 *E. coli* counts per 100 mL of water for two or more samples over within a calendar month or an *E. coli* concentration of 235 counts per 100 mL of water at anytime. However, the loading rates for watershed-based modeling are available only in terms of the previous standard, fecal coliform bacteria. Therefore, the TMDL was expressed in *E. coli* by converting modeled daily fecal coliform concentrations to daily *E. coli* concentrations using an in-stream translator. This TMDL was required to meet both the geometric mean and instantaneous *E. coli* water quality standard.

Watershed Characterization

The land use characterization for the Banister River watershed was based on land cover data from the National Land Use Land cover data set (NLCD) using 2001 reference data. Dominant land uses in the watershed are forest (60%) and agriculture (27%) account for a combined 87% of the total land area in the watershed.

The potential sources of fecal coliform include run-off from livestock grazing, manure applications, industrial processes, residential, and domestic pets waste. Some of these sources are driven by dry weather and others are driven by wet weather. The potential sources of fecal coliform in the watershed were identified and characterized. These sources include permitted point sources, failed septic systems and straight pipes, livestock, wildlife, and pets.

Data obtained from the DEQ's South Central Regional Office indicate that there are 8 individually permitted facilities and 18 general permits located in the watershed. For TMDL development, mean flow values were considered representative of flow conditions at each permitted facility, and were used in the model set-up and calibration. For TMDL allocation development, permitted facilities were represented as constant sources discharging at their design flow and permitted fecal coliform concentrations.

Bacteria Source Tracking

For the Banister River Watershed TMDLs, the Antibiotic Resistance Analysis (ARA) method of Bacteria Source Tracking (BST) was used. ARA has been the most widely used and published BST method to date and has been employed in Virginia, Florida, Kansas, Oregon, South Carolina, Tennessee, and Texas. Advantages of ARA include low cost per sample, and fast turnaround times for analyzing samples. The method can also be performed on large numbers of isolates; typically 48 isolates per unknown source such as an in-stream water quality sample.

BST was conducted monthly from June 2005 to July 2006 at stations 4ABAN023.28, 4ABAN070.20, 4ACRR000.80, 4ASNA000.20, 4AWRN005.50, and 4ASNE005.30. Results indicate that bacteria from human, livestock, wildlife, and pet sources are present in the Banister River.

TMDL Technical Approach

The Hydrologic Simulation Program-Fortran (HSPF) model was selected and used as a tool to predict the in-stream water quality conditions of delineated watershed under varying scenarios of rainfall and fecal coliform loading. HSPF is a hydrologic, watershed-based water quality model. The results from the model were used to develop the TMDL allocations based on the existing fecal coliform load. Basically, this means that HSPF can explicitly account for the specific watershed conditions, the seasonal variations in rainfall and climate conditions, and activities and uses related to fecal coliform loading.

The modeling process in HSPF starts with the following steps:

- delineating the watershed into smaller subwatersheds
- entering the physical data that describe each subwatershed and stream segment
- entering values for the rates and constants that describe the sources and the activities related to the fecal coliform loading in the watershed

The Banister River watershed was delineated into 63 smaller subwatersheds to represent the watershed characteristics and to improve the accuracy of the HSPF model. This delineation was based on topographic characteristics, and was created using a Digital Elevation Model (DEM), stream reaches obtained from the RF3 dataset and the National Hydrography Dataset (NHD), and stream flow and in-stream water quality data.

Stream flow data were available from the U.S. Geological Survey (USGS). Weather data were obtained from the National Climatic Data Center (NCDC). The data used in the model include meteorological data (hourly precipitation) and surface airways data (including wind speed/direction, ceiling height, dry bulb temperature, dew point temperature, and solar radiation).

The period of January 1992 to December 1993 was used for HSPF hydraulic calibration and January 1994 to December 1994 was used to validate the HSPF model. The hydrologic calibration parameters were adjusted until there was a good agreement between the observed and simulated stream flow, thereby indicating that the model parameterization is representative of the hydrologic characteristics of the study areas. The model results closely matched the observed flows during low flow conditions, base flow recession and storm peaks.

Instream water quality data for the calibration was retrieved from DEQ, and was evaluated for potential use in the set-up, calibration, and validation of the water quality model. The existing fecal coliform loading was calculated based on current watershed conditions. Since Virginia has recently changed its bacteria standard from fecal coliform to *E. coli* the modeled fecal coliform concentrations were changed to *E. coli* concentrations using a translator.

TMDL Calculations

The TMDL represents the maximum amount of a pollutant that the stream can receive without exceeding the water quality standard. The load allocation for the selected scenarios was calculated using the following equation:

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

Where,

WLA = wasteload allocation (point source contributions);

LA = load allocation (non-point source allocation); and

MOS = margin of safety.

The margin of safety (MOS) is a required component of the TMDL to account for any lack of knowledge concerning the relationship between effluent limitations and water quality. The MOS was implicitly incorporated in this TMDL. Implicitly incorporating the MOS required that allocation scenarios be designed to meet a 30-day geometric mean *E. coli* standard of 126 cfu/100 mL and the instantaneous *E. coli* standard of 235 cfu/100 mL with 0% exceedance.

Typically, there are several potential allocation strategies that would achieve the TMDL endpoint and water quality standards. A number of load allocation scenarios were developed to determine the final TMDL load allocation scenario.

For the hydrologic period from January 1996 to December 2003, fecal coliform loading and instream fecal coliform concentrations were estimated for the various scenarios using the developed HSPF model of for Banister River, Bearskin Creek, Cherrystone Creek, Polecat Creek, Stinking River, Sandy Creek, and Whitehorn Creek. After using the instream translator, the TMDL allocation plan was developed to meet geometric mean and instantaneous *E. coli* standards. Based on the load-allocation scenario analyses, the TMDL allocation plans that will meet the 30-day *E. coli* geometric mean water quality standard of 126 cfu/100 mL and the instantaneous *E. coli* water quality standard of 235 cfu/100 mL are presented in **Table E-1**.

Table E-1: Allocation Plan Loads for E. coli (% reduction) for the Banister River, Bearskin Creek, Cherrystone Creek, Polecat Creek, Stinking River, Sandy Creek, and Whitehorn Creek

Watershed	Human Sources (failed septic systems and straight pipes)	Livestock (Direct Instream Loading)	Agricultural and urban non point sources	Wildlife (Direct Instream Loading)
Banister River (VAC-L65R-01)	100.0%	100.0%	81.0%	35.0%
Banister River (VAC-L67R-01)	100.0%	100.0%	92.0%	35.0%
Bearskin Creek (VAC-L65R-02)	100.0%	100.0%	83.0%	40.0%
Cherrystone Creek (VAC-L66R-01)	100.0%	100.0%	94.0%	25.0%
Polecat Creek (VAC-L71R-05)	100.0%	100.0%	74.0%	40.0%
Stinking River (VAC-L69R-01)	100.0%	100.0%	83.0%	35.0%
Sandy Creek (VAC-L70R-01)	100.0%	100.0%	85.0%	40.0%
Whitehorn Creek (VAC-L68R-01)	100.0%	100.0%	94.0%	30.0%

The summaries of the bacteria TMDL allocation plan loads for Banister River, Bearskin Creek, Cherrystone Creek, Polecat Creek, Stinking River, Sandy Creek, and Whitehorn Creek are presented in **Table E-2**.

Table E-2: Banister River, Bearskin Creek, Cherrystone Creek, Polecat Creek, Stinking River, Sandy Creek, and Whitehorn Creek TMDL Allocation Plan Loads for E. coli (cfu/year)

Watershed	WLA (Point Sources)	LA (Nonpoint sources)	MOS (Margin of safety)	TMDL
Banister River (VAC-L65R-01)	1.52E+11	1.52E+13	IMPLICT	1.54E+13
Banister River (VAC-L67R-01)	2.78E+10	1.06E+14	IMPLICT	1.06E+14
Bearskin Creek (VAC-L65R-02)	9.18E+10	9.18E+12	IMPLICT	9.27E+12
Cherrystone Creek (VAC-L66R-01)	5.86E+12	1.85E+13	IMPLICT	2.43E+13
Polecat Creek (VAC-L71R-05)	8.40E+10	8.40E+12	IMPLICT	8.48E+12
Stinking River (VAC-L69R-01)	1.50E+11	1.50E+13	IMPLICT	1.52E+13
Sandy Creek (VAC-L70R-01)	3.94E+11	3.94E+13	IMPLICT	3.98E+13
Whitehorn Creek (VAC-L68R-01)	3.06E+12	2.52E+13	IMPLICT	2.82E+13

TMDL Implementation

The Commonwealth intends for this TMDL to be implemented through best management practices (BMPs) in the watershed. Implementation will occur in stages. The benefits of staged implementation are: 1) as stream monitoring continues to occur, it allows for water quality improvements to be recorded as they are being achieved; 2) it provides a measure of quality control, given the uncertainties that exist in any model; 3) it provides a mechanism for developing public support; 4) it helps to ensure the most cost effective practices are implemented initially, and 5) it allows for the evaluation of the TMDL's adequacy in achieving the water quality standard.

While section 303(d) of the Clean Water Act and current EPA regulations do not require the development of TMDL implementation plans as part of the TMDL process, they do require reasonable assurance that the load and wasteload allocations can and will be implemented. Additionally, Virginia's 1997 Water Quality Monitoring Information and Restoration Act (the "Act") directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters" (Section 62.1-44.19.7). The Act also establishes that the implementation plan shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments. EPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process." 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.

Once developed, DEQ intends to incorporate the TMDL implementation plan into the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act's Section 303(e). In response to a Memorandum of Understanding (MOU) between EPA and DEQ, DEQ also submitted a draft Continuous Planning Process to EPA in which DEQ commits to regularly updating the WQMPs. Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

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1.0 Introduction

1.1 Regulatory Guidance

Section 303(d) of the Clean Water Act and the Environmental Protection Agency's (EPA's) Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for water bodies that are exceeding water quality standards. TMDLs represent the total pollutant loading that a water body can receive without violating water quality standards. The TMDL process establishes the allowable loadings of pollutants for a water body based on the relationship between pollution sources and in-stream water quality conditions. By following the TMDL process, states can establish water quality based controls to reduce pollution from both point and non-point sources to restore and maintain the quality of their water resources (EPA, 2001).

The state regulatory agency for Virginia is the Department of Environmental Quality (DEQ). DEQ works in coordination with the Virginia Department of Conservation and Recreation (DCR), the Department of Mines, Minerals, and Energy (DMME), and the Virginia Department of Health (VDH) to develop and regulate a more effective TMDL process. DEQ is the lead agency for the development of TMDLs statewide and focuses its efforts on all aspects of reduction and prevention of pollution to state waters. DEQ ensures compliance with the Federal Clean Water Act and the Water Quality Planning Regulations, as well as with the Virginia Water Quality Monitoring, Information, and Restoration Act (WQMIRA), passed by the Virginia General Assembly in 1997, and coordinates public participation throughout the TMDL development process. The role of DCR is to initiate non-point source pollution control programs statewide through the use of federal grant money. DMME focuses its efforts on issuing surface mining permits and National Pollution Discharge Elimination System (NPDES) permits for industrial and mining operations. Lastly, VDH monitors waters for fecal coliform, classifies waters for shellfish growth and harvesting, and conducts surveys to determine sources of bacterial contamination (DEQ, 2001).

As required by the Clean Water Act and WQMIRA, DEQ develops and maintains a listing of all impaired waters in the state that details the pollutant(s) causing each impairment and the potential source(s) of each pollutant. This list is referred to as the 303(d) List of Impaired Waters. In addition to 303(d) List development, WQMIRA directs DEQ to develop and implement TMDLs for listed waters (DEQ, 2001a). Once TMDLs have been developed, they are distributed for public comment and then submitted to the EPA for approval.

1.2 Impairment Listing

Segments of the Banister River, Bearskin Creek, Cherrystone Creek, Polecat Creek, Stinking River, Sandy Creek, and Whitehorn Creek watersheds were listed as impaired for bacteria on Virginia's 1996, 1998, 2002, 2004, and/or 2006 303(d) Total Maximum Daily Load Priority List and Reports (DEQ, 1996) due to violations of the state's water quality standard for fecal coliform bacteria and/or *E. coli*. The impaired segments are located the Banister River Basin in Virginia (**Figure 1-1**). The watershed is located in the hydrologic unit (HUC) 0301010. The impaired watersheds include portions of Pittsylvania and Halifax Counties.

Two segments of the Banister River were identified as impaired for bacteria on VA DEQ's 2004 and 2006 305(b)/303(d) Water Quality Assessment Integrated Report. First listed as impaired in the 2004 305(b)/303(d) Water Quality Assessment Integrated Report, the upstream impaired segment (VAC-L65R-01) of the Banister River is 11.67 miles long and includes the Banister River from Bearskin Creek to its headwaters. Between January 1, 2000 and December 31, 2004, 2 of 18 fecal coliform samples (11%) collected at the listing station (4ABAN070.20) exceeded the bacteria instantaneous criterion of 400 cfu/100 mL. The second segment for the Banister River (VAC-L67-01) is 13.18 miles and runs from Elkhorn Creek to Banister Lake. Between January 1, 2000 and December 31, 2004, 4 out of 16 *E. coli* (25%) samples collected at the listing station (4ABAN023.38) exceeded the *E. coli* standard of 235 cfu/100 ml.

The impaired segment of Bearskin Creek (VAC-L65R-02), which is 9.31 miles and includes the entire creek from its headwaters to the mouth of the Banister River, was first listed on the 2006 305(b)/303(d) Water Quality Assessment Integrated Report for exceedances of the *E. coli* standard of 235 cfu/100 ml. Between January 1, 2000 and

December 31, 2004, 2 out of 7 samples (29%) collected at the listing station (4ABKN000.52) exceeded the *E. coli* criterion of 235 cfu/100 ml.

The impaired segment of Cherrystone Creek (VAC-L66R-01) which extends for 8.44 miles includes the Cherrystone Creek mainstem from the Cherrystone Creek dam to the Banister River confluence. This segment was first listed on the 1996 305(b)/303(d) Water Quality Assessment Integrated Report. Between January 1, 2000 and December 31, 2004 at the listing station (4ACRR003.56), 1 out of 9 *E. coli* samples (13%) exceeded the *E. coli* standard instantaneous of 235 cfu/100 ml and 1 out of 8 samples (11%) exceeded the fecal coliform instantaneous standard of 400cfu/ml.

The impaired segment of the Stinking River (VAC-L69R-01) was first listed on the 2004 305(b)/303(d) Water Quality Assessment Integrated Report. This segment of Stinking River is impaired for fecal coliform for 8.99 miles, from the mouth of the Stinking River to the mouth of the North Fork of the Stinking River. Between January 1, 2000 and December 31, 2004, 3 out of 20 samples (15%) collected exceeded the instantaneous fecal coliform bacteria standard of 400 (cfu/100mL).

The impaired segment of Sandy Creek (VAC-L70R-01) extends for 11.78 miles from the confluence of Johns Run to the mouth of Sandy Creek. This segment was first listed on the 2002 305(b)/303(d) Water Quality Assessment Integrated Report. Between January 1, 2000 and December 31, 2004, 3 out of 19 samples (16%) collected at station 4ASNA000.20 were recorded as exceeding the instantaneous fecal coliform bacteria criterion of 400 (cfu/100mL).

The impaired segment of Whitehorn Creek (VAC-L68R-01) extends 24.73 miles and was first listed on the 2002 305(b)/303(d) Water Quality Assessment Integrated Report and extends from the mouth to the headwaters of Whitehorn Creek. 1 out of 8 samples (12.5%) collected at listing station (4AWRN0005.50) between January 1, 2000 and December 31, 2004 exceeded the instantaneous fecal coliform bacteria standard of 400 (cfu/100mL). Also, at this station, 2 out of 8 (25%) of the samples collected within this same time frame exceeded the *E. coli* standard instantaneous of 235 cfu/100 ml.

The total length of these eight segments is approximately 110 miles. **Table 1-1** summarizes the details of the impaired segments and **Figure 1-1** presents their location.

Table 1-1: 2006 303(d) Impaired Segments within the Banister River, Bearskin Creek, Cherrystone Creek, Polecat Creek, Stinking River, Sandy Creek and Whitehorn Creek Watersheds.

TMDL ID	Stream Name	Miles	Boundaries	Station ID:	Impairment for	Violation Rate
VAC-L65R-01	Banister River	11.67	Banister River mainstem from the mouth of Bearskin Creek upstream to its headwaters.	4ABAN070.20	Total Fecal Coliform	2/18
VAC-L67R-01	Banister River	13.18	Elkhorn Creek to Banister Lake	4ABAN023.28	E. Coli	4/16
VAC-L65R-02	Bearskin Creek	9.31	Bearskin Creek and its tributaries from its mouth on the Banister River upstream.	4ABKN000.52	E. coli	2/7
VAC-L66R-01	Cherrystone Creek	8.44	Cherrystone Creek mainstem from its mouth on the Banister River upstream to the Cherrystone Creek Dam.	4ACRR003.56	Total Fecal Coliform	1/8
VAC-L71R-05	Polecat Creek	9.66	Polecat Creek from its headwaters to the mouth at the Banister River	4APEC006.49	Total Fecal Coliform	3/13
VAC-L70R-01	Sandy Creek	11.78	Johns Run to mouth on Banister River	4ASNA000.20	Total Fecal Coliform	3/19
VAC-L69R-01	Stinking River	8.99	Stinking River mainstem from its mouth on the Banister River upstream to the mouth of the North Fork of Stinking River.	4ASNE005.30	Total Fecal Coliform	3/20
VAC-L68R-01	Whitehorn Creek	24.73	Whitehorn Creek mainstem from its mouth upstream to its headwaters	AWRN000.43	E. coli (2006), Total Fecal Coliform (2002)	E. coli - 2/8 Fecal Coliform 1/8

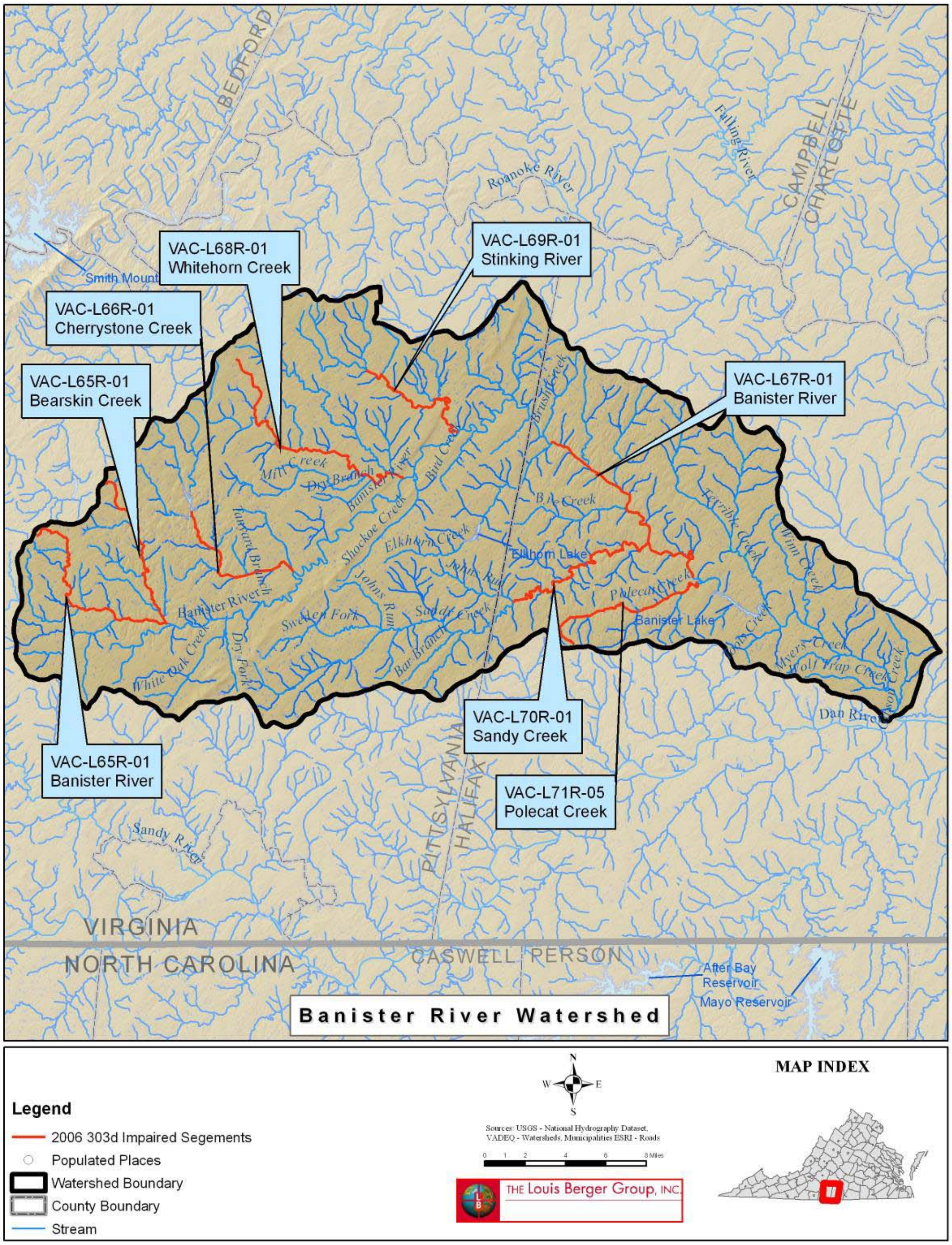

Figure 1-1: Location and Bacteria Impaired Segments of the Banister River, Cherrystone Creek, Stinking River, Sandy Creek, and Whitehorn Creek Watersheds

1.3 Applicable Water Quality Standard

Water quality standards consist of designated uses for a water body and water quality criteria necessary to support those designated uses. According to Virginia Water Quality Standards (9 VAC 25-260-5), the term "water quality standards means provisions of state or federal law which consist of a designated use or uses for the waters of the Commonwealth and water quality criteria for such waters based upon such uses. Water quality standards are to protect the public health or welfare, enhance the quality of water 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.)."

1.3.1 Designated Uses

According to Virginia Water Quality Standards (9 VAC 25-260-10):

> *"all state waters 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 be reasonably expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish)."*

1.3.2 Applicable Water Quality Criteria

Effective January 15, 2003, DEQ specified a new bacteria standard in 9 VAC 25-260-170.A, and also revised the disinfection policy in 9 VAC 25-260-170.B. These standards replaced the existing fecal coliform standard and disinfection policy of 9 VAC 25-260-170. For a non-shellfish supporting waterbody to be in compliance with Virginia bacteria standards for primary contact recreation, the current criteria are as follows:

> *"Fecal coliform bacteria shall not exceed a geometric mean of 200 fecal coliform bacteria per 100 mL of water for two or more samples taken 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 [E. coli] bacterial indicators have a minimum of 12 data points or after June 30, 2008, whichever comes first."*

"E. coli bacteria shall not exceed a geometric mean of 126 bacteria per 100 mL of water for two or more samples taken during any calendar month nor should it exceed 235 counts per 100 mL of water for a single sample maximum value. No single sample maximum for E. coli shall exceed a 75% upper one-sided confidence limit based on a site-specific log standard deviation. If site data are insufficient to establish a site-specific log standard deviation, then 0.4 shall be used as the log standard deviation in freshwater. Values shown are based on a log standard deviation of 0.4 in freshwater."

These criteria were adopted because there is a strong correlation between the concentration of *E. coli* and the incidence of gastrointestinal illness in comparison to fecal coliform. *E. coli* are bacteriological organisms that can be found in the intestinal tract of warm-blooded animals. Like fecal coliform bacteria, these organisms indicate the presence of fecal contamination.

For bacteria TMDL development after January 15, 2003, *E. coli* has become the primary applicable water quality target. However, the loading rates for watershed-based modeling are available only in terms of fecal coliform. Therefore, during the transition from fecal coliform to *E. coli* criteria, DCR, DEQ and EPA have agreed to apply a translator to in-stream fecal coliform data to determine whether reductions applied to the fecal coliform load would result in meeting in-stream *E. coli* criteria. The fecal coliform model and in-stream translator are used to calculate *E. coli* TMDLs (DEQ, 2003). The following regression based in-stream translator is used to calculate *E. coli* concentrations from fecal coliform concentrations:

$$E.\ coli\ conc.\ (cfu/100\ mL) = 2^{-0.0172} \times [fecal\ coliform\ conc.\ (cfu/100mL)]^{0.91905}$$

TMDLs are required to meet both the geometric mean and instantaneous criteria. The modeled daily fecal coliform concentrations are converted to daily *E. coli* concentrations using the in-stream translator. The TMDL development process also must account for seasonal and annual variations in precipitation, flow, land use, and pollutant contributions. Such an approach ensures that TMDLs, when implemented, do not result in violations under a wide variety of scenarios that affect fecal coliform loading.

2.0 TMDL Endpoint Identification

2.1 Selection of TMDL Endpoint and Water Quality Targets

The eight bacteria impaired segments within the Banister River Watershed, Bearskin Creek, Cherrystone Creek, Polecat Creek, Stinking River, Sandy Creek, and Whitehorn Creek watersheds are located within the boundaries of Halifax and Pittsylvania Counties in southern Virginia. These segments were initially placed on either the 1996, 1998, 2002, 2004, and/or 2006 Virginia 303(d) lists due to exceedences of the fecal coliform or E. coli standards for primary contact recreation. The impaired segments comprise a total of approximately 110 miles river miles.

One of the first steps in TMDL development is to determine numeric endpoints, or water quality targets, for each impaired segment. Water quality targets compare the current stream conditions to the expected restored stream conditions after TMDL load reductions are implemented. Numeric endpoints for the Bacteria TMDLs for the Banister River, Bearskin Creek, Cherrystone Creek, Polecat Creek, Stinking River, Sandy Creek, and Whitehorn Creek TMDLs are established in Virginia Water Quality Standards (9 VAC 25-260). These standards state that all waters in Virginia should be free from any substances that can cause the water to violate the state numeric standards, interfere with its designated uses, or adversely affect human health and aquatic life. Therefore, the current water quality target for these four impairments, as stated in 9 VAC 25-260-170, is an *E. coli* geometric mean no greater than 126 colony-forming units (cfu) per 100 ml for two or more water quality samples taken during any calendar month, and a single sample maximum of 235 cfu per 100 ml at all times.

2.2 Critical Condition

The critical condition is considered the "worst case scenario" of environmental conditions in the Banister River, Bearskin Creek, Cherrystone Creek, Polecat Creek, Stinking River, Sandy Creek, and Whitehorn Creek. Developing TMDLs to meet the water quality targets under the critical condition will insure that the targets would also be met under all other conditions.

EPA regulations, 40 CFR 130.7 (c)(1), require TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters. The intent of this requirement is to ensure that the water quality of the Banister River, Bearskin Creek, Cherrystone Creek, Polecat Creek, Stinking River, Sandy Creek, and Whitehorn Creek is protected during times when it is most vulnerable. Critical conditions are important because they describe the combination of factors to cause a violation of water quality standards and will help in identifying the actions that may have to be undertaken to meet water quality standards.

The Banister River, Bearskin Creek, Cherrystone Creek, Polecat Creek, Stinking River, Sandy Creek, and Whitehorn Creek flow through a predominantly rural setting. The dominant land uses in the basin are forested and agricultural. Potential sources of fecal coliform include run-off from livestock grazing, manure applications, point source dischargers, and residential waste.

Fecal coliform loadings result from sources that can contribute during wet weather and dry weather. The critical conditions were determined from the available in-stream water quality data and flow data obtained from USGS flow monitoring stations located within the impaired segment. Flow data were not available at all listing stations but were available near or at the following stations: 4ABAN023.28, 4ACRR0008.0, 4AWRN005.50, and 4SNE0005.30.

Figure 2-1 depicts fecal coliform concentrations recorded between 1990 and 2006 with the available corresponding stream flow distribution along several impaired segments. Also, **Figure 2-1** includes fecal coliform data from four water quality stations: on the downstream portion of Banister River (4ABAN023.28), Cherrystone Creek Cherrystone Creek at Route 703, near Chatham (4ACRR0008.00), Whitehorn Creek at Route 685 near Sonans (4AWRN005.50), and Stinking River at Route 927 near Mt Airy (4SNE0005.30).

Plotting fecal coliform data along with available stream flow data (**Figure 2-1**) revealed that the majority of exceedences tended to occur predominantly during high to moderate flow conditions. This observation applies to data recorded on the Banister River. Several samples collected at the other stations did show exceedances of the water quality standards during dry to low flow conditions.

E. coli and corresponding flow data were only available at DEQ bacteria listing stations 4ABAN023.28, 4ACRR0008.0, 4AWRN005.50, and 4SNE0005.30. The depiction of *E. coli* concentrations versus flows values is similar to the observations made regarding the fecal coliform data. The majority of the exceedances recorded were during moderate high flow to moderate low flow conditions (**Figure 2-2**).

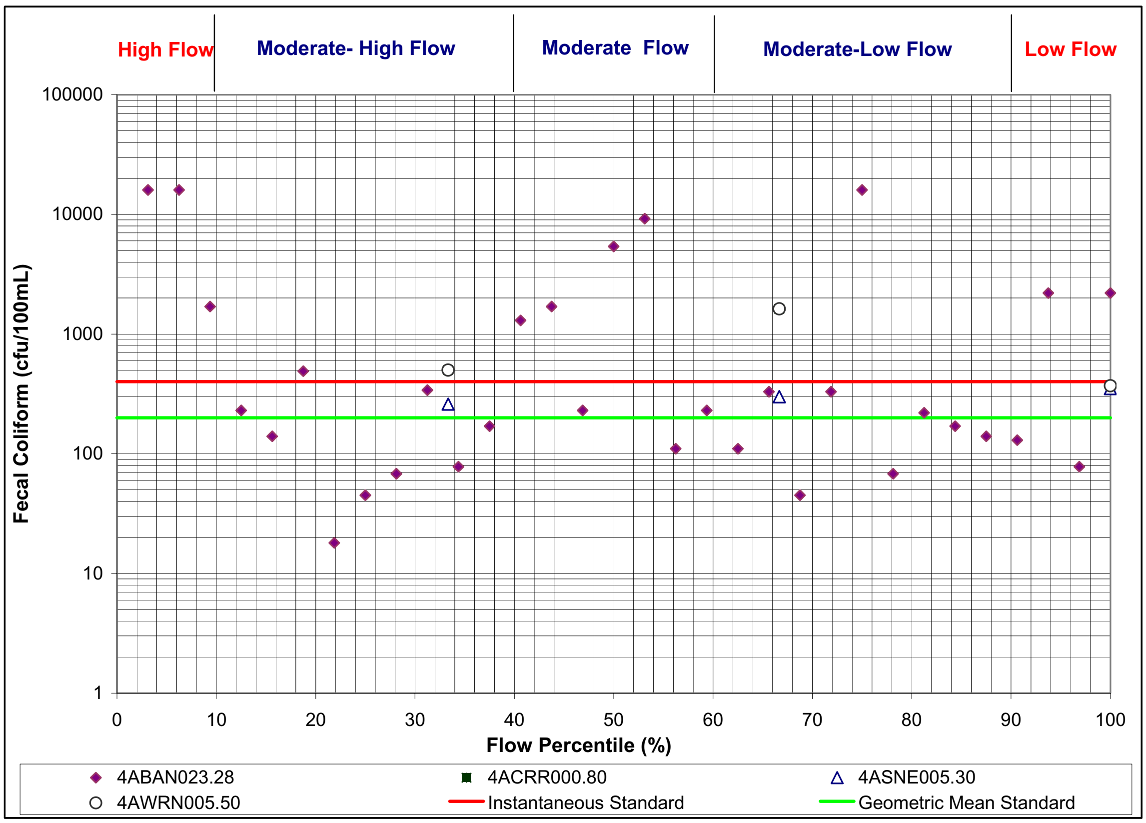

Figure 2-1: Flow Percentile and Fecal Coliform Concentrations

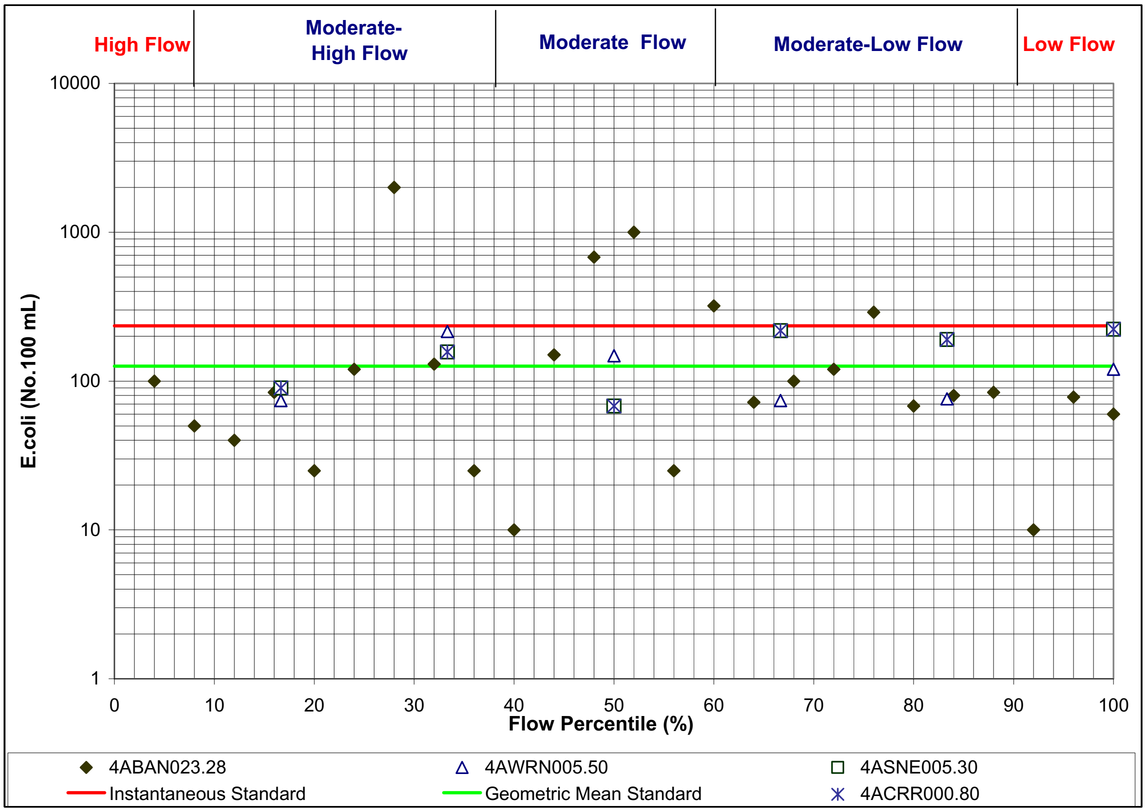

Figure 2-2: Flow Percentile and *E. coli* Concentrations

Consequently, both high and low flow periods were considered as the critical conditions because many of the observed exceedences occurred under these flow regimes. Exceedences under high-flow conditions would occur from indirect sources of bacteria, and would most likely exceed the instantaneous standard. Bacteria loads under low-flow conditions would likely occur from direct sources of bacteria, and would most likely violate the instantaneous and geometric mean standards.

These TMDLs are required to meet both the geometric mean and instantaneous bacteria standards. Therefore, it is necessary for the critical condition to consider both wet weather, high flow conditions and dry weather, and low flow conditions.

2.3 Consideration of Seasonal Variations

Seasonal variations involve changes in stream flow and water quality because of hydrologic and climatological patterns. Seasonal variations were explicitly included in the modeling approach for this TMDL. The continuous simulation model developed for this TMDL explicitly incorporates the seasonal variations of rainfall, runoff and fecal coliform wash-off by using an hourly time-step. In addition, fecal coliform accumulation rates for each land use were developed on a monthly basis. This allowed the consideration of temporal variability in fecal coliform loading within the watershed.

3.0 Watershed Description and Source Assessment

In this section, the types of data available and information collected for the development of the TMDLS for the Banister River, Bearskin Creek, Cherrystone Creek, Polecat Creek, Stinking River, Sandy Creek, and Whitehorn Creek watersheds are presented. This information was used to characterize each stream and its watershed and to inventory and characterize the potential point and nonpoint sources of fecal coliform in the watershed.

3.1 Data and Information Inventory

A wide range of data and information were used in the development of this TMDL. Categories of data that were used include the following:

(1) Physiographic data that describe physical conditions (i.e., topography, soils, and land use) within the watershed

(2) Hydrographic data that describe physical conditions within the stream, such as the stream reach network and connectivity, and the stream channel depth, width, slope, and elevation

(3) Data related to uses of the watershed and other activities in the basin that can be used in the identification of potential fecal coliform sources

(4) Environmental monitoring data that describe stream flow and water quality conditions in the stream

Table 3-1 shows the various data types and the data sources used in the Banister River, Bearskin Creek, Cherrystone Creek, Polecat Creek, Stinking River, Sandy Creek, and Whitehorn Creek watersheds.

Table 3-1: Inventory of Data and Information Used in the Banister River, Bearskin Creek, Cherrystone Creek, Polecat Creek, Stinking River, Sandy Creek, and Whitehorn Creek Watersheds

Data Category	Description	Source(s)
Watershed physiographic data	Watershed boundary	USGS, DEQ
	Land use/land cover	NLCD
	Soil data (SSURGO, STATSGO)	NRCS, BASINS
	Topographic data (USGS-30 meter DEM, USGS Quads)	USGS, DCR
Hydrographic data	Stream network and reaches (RF3)	BASINS, NHD, Field surveys
	Stream morphology	
Weather data	Hourly meteorological conditions	NCDC, Earth Info
Watershed activities/ uses data and information related to fecal coliform production	Information, data, reports, and maps that can be used to support fecal coliform source identification and loading	Pittsylvania and Halifax county governments, local groups and stakeholders
	Livestock inventory, grazing, stream access, and manure management	DCR, Pittsylvania and Halifax SWCDs, NRCS
	Wildlife inventory	DGIF
	Septic systems inventory and failure rates	Local Departments of Health, Utilities, U.S. Census Bureau
	Straight pipes	Census Data, USGS Quad maps
	Best management practices (BMPs)	DCR, NRCS, local SWCDs
Point sources and direct discharge data and information	Permitted facilities locations and discharge monitoring reports (DMRs)	EPA Permit Compliance System (PCS), VPDES, DEQ
Environmental monitoring data	Ambient in-stream monitoring data	DEQ
	Stream flow data	USGS, DEQ,

Notes
BASINS: Better Assessment Science Integrating Point and Nonpoint Sources
DCR: Virginia Department of Conservation and Recreation
DEQ: Virginia Department of Environmental Quality
DGIF: Virginia Department of Game and Inland Fisheries
EPA: Environmental Protection Agency
NCDC: National Climatic Data Center
NHD: National Hydrography Dataset
NLCD: National Land Coverage Data
NRCS: Natural Resources Conservation Service
SWCD: Soil and Water Conservation District
USGS: U.S. Geological Survey
VPDES: Virginia Pollutant Discharge Elimination System

3.2 Watershed Description and Identification

The Banister River watershed is located within the borders of Halifax and Pittsylvania counties. Within the watershed's boundaries there are two county seats Chatham and Halifax as well as the cities of Dry Fork, Mount Airy, Gretna, and Spring Garden. All impaired streams are located in the Banister River (USGS Cataloging Unit 0301010). The entire Banister watershed is approximately 353,319 acres. Approximately 70 percent of the entire drainage basin is located in Pittsylvania County and 30 percent in Halifax County. As shown in **Figure 3-1**, the major roadways that run through the watershed are Route 29 which runs from North to South in the western portion of the watershed and Route 501 which runs from North to South in the eastern portion of the watershed. Other major roads include state highway 57 which runs from east to west, highway 640 which runs northeast to southwest, highway 40 which runs from east to west in the northern portion of the watershed, and 41 and 360 which run along the southern border of the watershed.

The impaired segments of Bearskin Creek, Cherrystone Creek, Stinking River, Whitehorn Creek, and the upstream portion of the Banister River are located in Pittsylvania County. Sandy Creek, Polecat Creek, and the downstream portion of the Banister River are located within Halifax County.

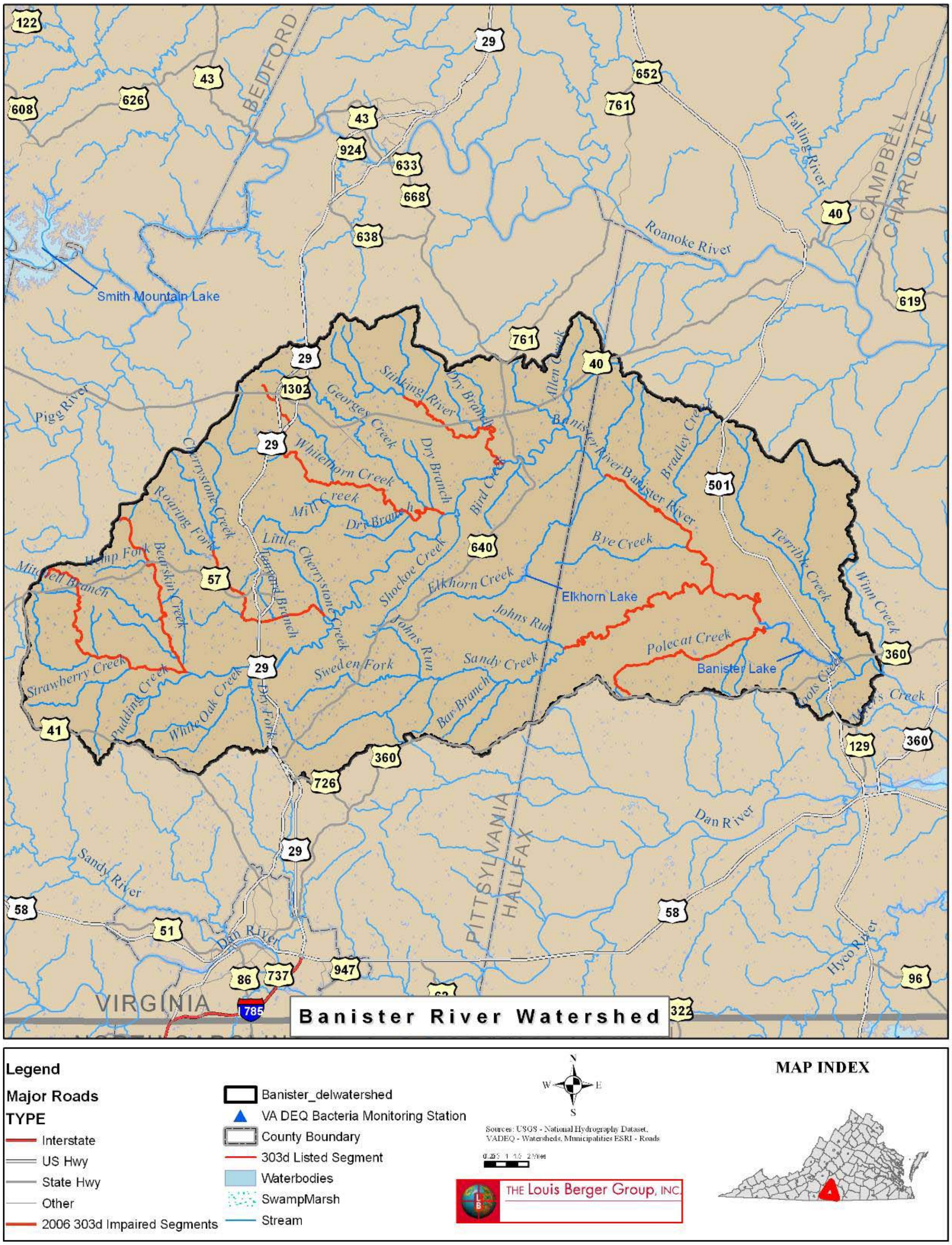

Figure 3-1: Location and Boundary of the Banister Watershed

3.2.1 Topography

A digital elevation model (DEM) based on USGS National Elevation Dataset (NED) was used to characterize topography in the watershed. NED data were obtained from the National Map Seamless Data Distribution System maintained by the USGS Eros Data Center. Elevation within the watershed ranges from 321 to 1,181 feet (95 to 360 meters) above mean sea level.

3.2.2 Soils

The Banister River watershed soil characterization was based on data obtained from BASINS, an EPA approved program multi-purpose environmental analysis system that integrates GIS, national watershed data, and environmental assessment and modeling tools. There are four general soil associations located in the watershed (see **Table 3-2)**. The Madison-Cecil soils, which compose of 78% of the watershed are very deep, well drained, and moderately permeable soils.

Table 3-2: Major Soil Associations within the Banister River Watershed

Soil Name	Acres	Percentage of the Watershed
Madison-Cecil (s8279)	278,233	78%
Pinkston-Mayodan-Creedmoor (s8302)	54,790	15%
Poindexter-Pacolet-Iredell (s8289)	21,213	6%
Wehadkee-Congaree-Chewacla (s8292)	1,083	<1%
Total	**355,319**	**100%**

The hydrologic soil group linked with each soil association is also presented in **Table 3-3**. The hydrologic soil groups represent different levels of infiltration capacity of the soils. Hydrologic soil group "A" designates soils that are well to excessively well drained, whereas hydrologic soil group "D" designates soils that are poorly drained. This means that soils in hydrologic group "A" allow a larger portion of the rainfall to infiltrate into the ground water system, while soils in hydrologic group "D" allow a smaller portion of the rainfall to infiltrate into the ground water. Consequently, more rainfall becomes part of the surface water runoff. Descriptions of the hydrologic soil groups are presented in **Table 3-4**.

Table 3-3: Soil Hydrogroups within the Banister River Watershed		
Hydrogroup	**Acres**	**Percentage of Watershed**
B	296,106	83%
C	41,979	12%
D	14,554	4%
Not identified	2,679	1%
Total	**355,319**	**100%**

Table 3-4: Descriptions of Hydrologic Soil Groups	
Hydrologic Soil Group	**Description**
A	High infiltration rates. Soils are deep, well drained to excessively drained sand and gravels.
B	Moderate infiltration rates. Deep and moderately deep, moderately well and well-drained soils with moderately coarse textures.
C	Moderate to slow infiltration rates. Soils with layers impeding downward movement of water or soils with moderately fine or fine textures.
D	Very slow infiltration rates. Soils are clayey, have high water table, or shallow to an impervious cover
C/D	Combination of Hydrologic Soil Groups C and D

3.2.3 Land Use

The land use characterization for the Banister River watershed was based on land cover data from NLCD using 2001 reference data. The distribution of land uses in the watershed, by land area and percentage, is presented in **Table 3-5**. Dominant land uses in the watershed are forest (60%) and agriculture (27%) account for a combined 87% of the total land area in the watershed. Brief descriptions of land use classifications are presented in **Table 3-6**. **Figure 3-2** depicts the land use distribution within the Banter River watershed.

Table 3-5: Land Use Categories within the Banister River Watershed

Land Use Category	NLCD Land Use Type	Acres		Percent of Watershed's Land Use Area	
Water/ Wetlands	Open Water	1,272	6,677	0%	2%
	Woody Wetlands	5,362		2%	
	Emergent Herbaceous Wetlands	43		0%	
Urban	Developed, Low Intensity	2,961	3,675	1%	1%
	Developed, Medium Intensity	487		0%	
	Developed, High Intensity	226		0%	
Agriculture	Pasture/Hay	90,558	95,457	26%	27%
	Cultivated Crops	4,899		1%	
Forest	Deciduous Forest	143,095	214,195	40%	60%
	Evergreen Forest	45,710		13%	
	Mixed Forest	12,959		4%	
	Shrub/Scrub	12,431		3%	
Other	Developed, Open Space	17,843	35,316	5%	10%
	Barren Land (Rock/Sand/Clay)	780		0%	
	Grassland/Herbaceous	16,693		5%	
Total		**355,319**		**100%**	

Table 3-6 Descriptions of Land Use Types	
Land Use Type	**Description**
Open Water	Areas of open water, generally with less than 25 percent or greater cover of water.
Woody Wetlands	Areas where forest or shrubland vegetation accounts for 25-100 percent of the cover and the soil or substrate is periodically saturated with or covered with water.
Emergent Herbaceous Wetlands	Areas where perennial herbaceous vegetation accounts for 75-100 percent of the cover and the soil or substrate is periodically saturated with or covered with water.
Low Intensity Residential	Includes areas with a mixture of constructed materials and vegetation. Constructed materials account for 30-80 percent of the cover. Vegetation may account for 20 to 70 percent of the cover. These areas most commonly include single-family housing units. Population densities will be lower than in high intensity residential areas.
High Intensity Residential	Includes heavily built up urban centers where people reside in high numbers. Examples include apartment complexes and row houses. Vegetation accounts for less than 20 percent of the cover. Constructed materials account for 80-100 percent of the cover.
Commercial/ Industrial/ Transportation	Includes infrastructure (e.g. roads, railroads, etc.) and all highways and all developed areas not classified as High Intensity Residential.
Pasture/Hay	Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops.
Row Crop	Areas used for the production of crops, such as corn, soybeans, vegetables, tobacco, and cotton.
Deciduous Forest	Areas dominated by trees where 75 percent or more of the tree species shed foliage simultaneously in response to seasonal change.
Evergreen Forest	Areas characterized by trees where 75 percent or more of the tree species maintain their leaves all year. Canopy is never without green foliage.
Mixed Forest	Areas dominated by trees where neither deciduous nor evergreen species represent more than 75 percent of the cover present.
Quarries/Strip Mines/Gravel Pits	Areas of extractive mining activities with significant surface expression.
Transitional	Areas of sparse vegetative cover (less than 25 percent that are dynamically changing from one land cover to another, often because of land use activities. Examples include forest clearcuts, a transition phase between forest and agricultural land, the temporary clearing of vegetation, and changes due to natural causes (e.g. fire, flood, etc.)
Urban/Recreational Grasses	Vegetation (primarily grasses) planted in developed settings for recreation, erosion control, or aesthetic purposes. Examples include parks, lawns, golf courses, airport grasses, and industrial site grasses.

Source: Multi-Resolution Land Characteristics Consortium NLCD (2001)

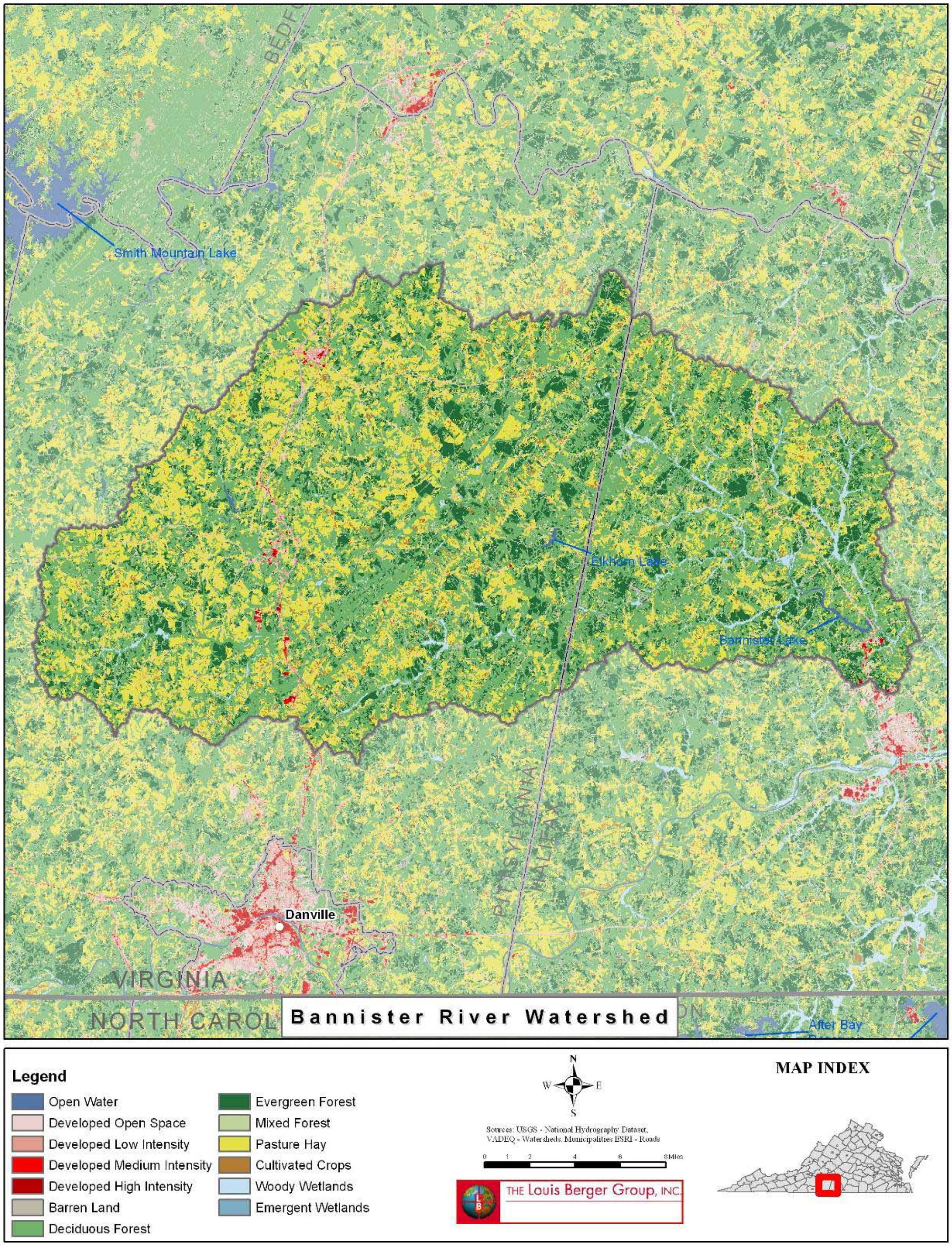

Figure 3-2: Land Use in the Banister River Watershed

3.3 Stream Flow Data

Stream flow data were available at two USGS stream flow-gauging stations located within the watershed. Station 2076500 is located on Georges Creek, a tributary to the Banister River. Station 2076500 is located below the Banister Lake Dam (**Figure 3-3)**. Only data from station 2076500 was considered adequate for modeling purposes since this station has unrestricted flow. Data collected at this station is shown in **Table 3-7.**

Table 3-7: USGS Stream Flow Data located on Georges Creek

Site ID	Stream	Start Date	End Date	Data Recorded	Number of Records
2076500	Georges Creek	9/13/1950	3/3/1997	Peak Streamflow	48
		10/1/1949	10/8/1997	Daily Streamflow	17,540

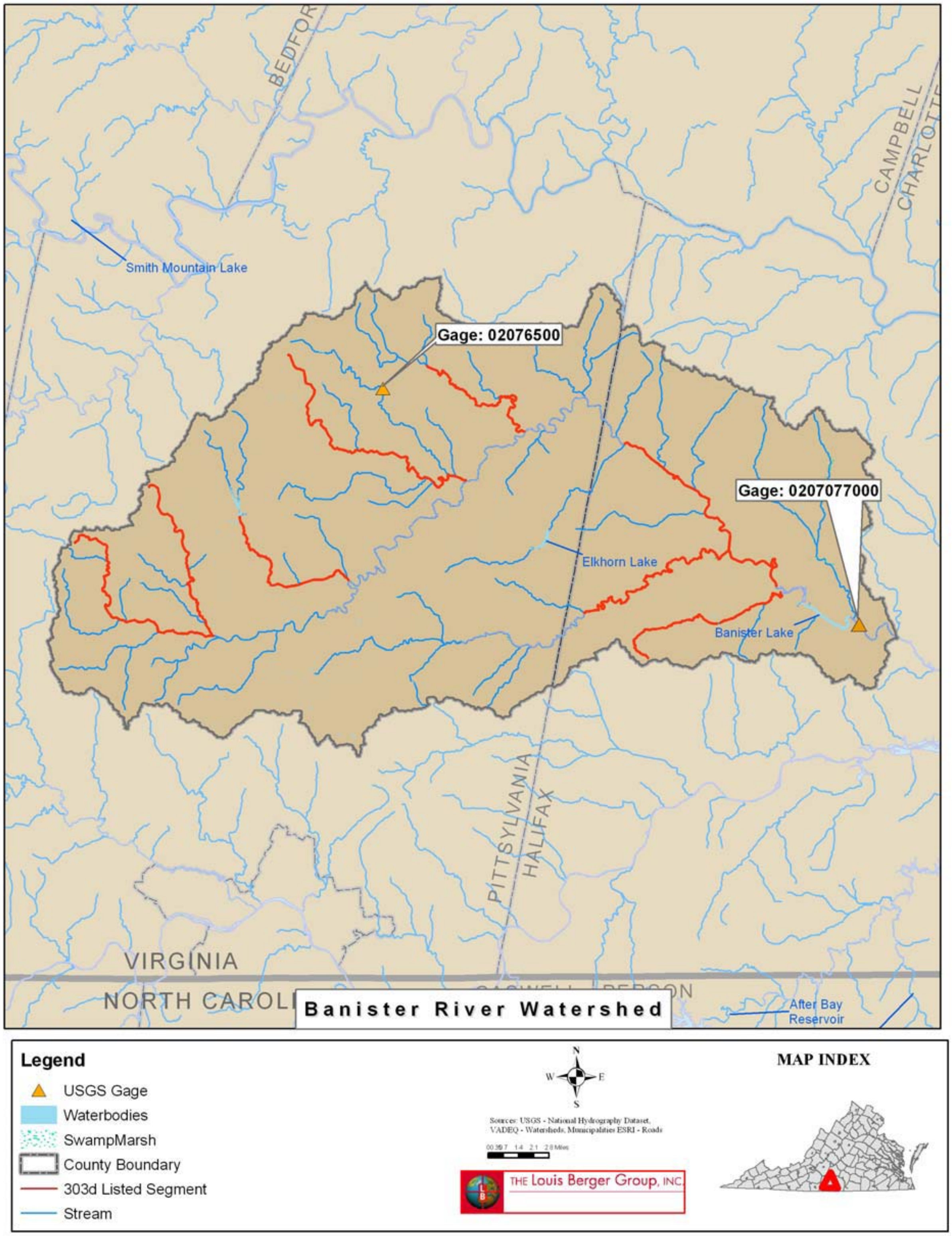

Figure 3-3: USGS Gages within the Banister River Watershed

3.4 DEQ Ambient Water Quality Data

Water quality data were obtained from DEQ, which conducted sampling at 38 water quality monitoring stations located within the watershed. Locations of these stations are summarized in **Table 3-8**. **Figure 3-4** depicts the locations of these monitoring stations.

Table 3-8: VA DEQ Water Quality Station

Station ID	Station Description	Stream Name
4AALL001.13	Allen Cr at Hermosa Road	Allen Creek
4ABAN012.46	Banister Lake (Halifax Reservoir)	Banister River
4ABAN022.24	Downstream of Sandy Creek confluence	Banister River
4ABAN023.28	Rt. 642 Bridge	Banister River
4ABAN026.65	W of 501 between 628 & 753	Banister River
4ABAN029.81	Banister River at Leda Rd (Rt 667)	Banister River
4ABAN039.76	Rt. 640 Bridge, Below Stinking River	Banister River
4ABAN044.76	Banister at Markham Rd (Rt 686)	Banister River
4ABAN053.77	Rt. 832 Bridge	Banister River
4ABAN070.20	Banister River at Rt. 703	Banister River
4ABAN074.58	Banister River at Strawberry Rd (Rt 750)	Banister River
4ABAR001.74	Upstream of Rt. 622	Bar Branch
4ABDB000.75	Bradley Cr. at Rt. 628	Bradley Creek
4ABKN000.52	Bearskin Cr. at Rt. 703 Tight Sqz. Rd	Bearskin Creek
4ABKN002.47	Bearskin Cr. at Mitchell Rd (Rt. 612)	Bearskin Creek
4ABYE000.85	Bye Creek at Rt. 753	Bye Creek
4ACRR000.80	Rt 703 Bridge, Below Chatham STP-PITT	Cherrystone Creek
4ACRR003.56	Business Route 29, Above Chatham STP	Cherrystone Creek
4ACRR008.32	Station #1 at Dam	Cherrystone Creek
4AEKH000.63	Elkhorn Cr at Logan Rd (Rt 702)	Elkhorn Creek
4AEKH003.18	McDowell Farm off of Rt. 976	Elkhorn Creek
4AGEO011.38	Georges Creek Res (Gretna Lake)	Georges Creek
4AJSR000.53	Johns Run at Johns Run Rd (Rt 664)	Johns Run
4ALCC000.59	L. Cherrystone Cr at Rt. 57 Halifax Rd	Little Cherrystone Creek
4APEC002.42	Polecat Cr. at Rt. 832	Polecat Creek
4APEC006.49	Rt. 677 bridge	Polecat Creek
4ARFK000.20	Roaring Fork Reservoir at Dam	Roaring Fork
4ASLC015.31	Sandy Cr. At Mt. Tabor Rd. (Rt. 729)	Sandy Creek
4ASNA000.20	RT. 832 Bridge	Sandy Creek
4ASNA019.51	Sandy Cr at Lester Rd	Sandy Creek
4ASNE005.30	Rt. 927 Bridge	Stinking River
4ASNE010.46	Stinking River at Midway Rd. (Rt. 671)	Stinking River

Table 3-8: VA DEQ Water Quality Station		
Station ID	**Station Description**	**Stream Name**
4ASRW002.32	Strawberry Cr at Strawberry Rd. (Rt. 750)	Strawberry Creek
4ATRR001.92	Terrible Cr. at Dudley Rd. (Rt. 615)	Terrible Creek
4AWRN000.43	Rt 683, Cedar Hill Road	Whitehorn Creek
4AWRN005.50	Rt. 685 Bridge	Whitehorn Creek
4AWRN011.05	Whitehorn Cr at Galveston Rd. (Rt. 903)	Whitehorn Creek
4AXUS000.65	UT to Sandy Cr and W of Rt. 770	Unnamed Trib to Sandy Creek

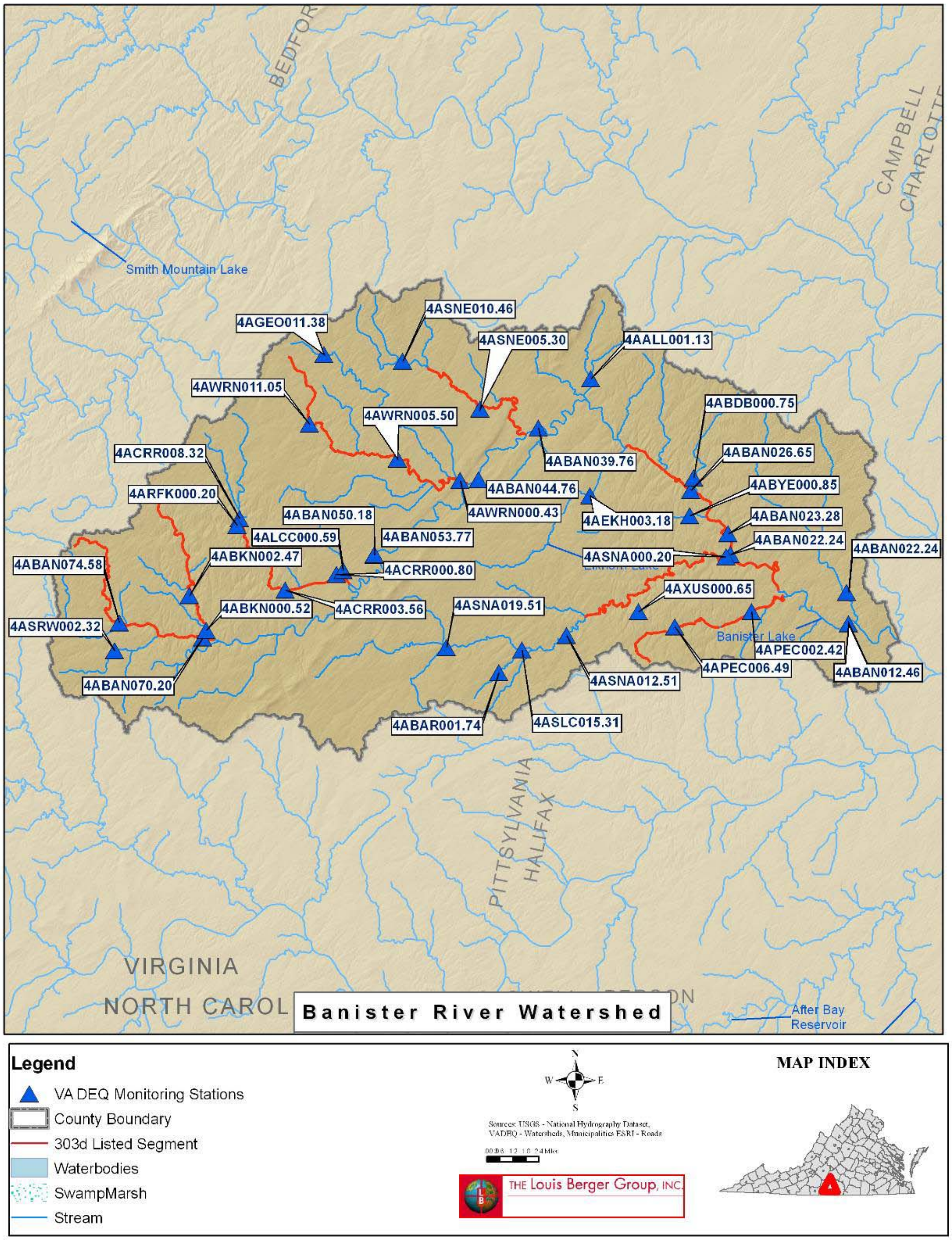

Figure 3-4: Banister River Watershed DEQ Water Quality Monitoring Stations

Stations were sampled between 1990 and 2005 for fecal coliform bacteria. **Table 3-9** lists the water quality sampling period of record, the number of samples, the minimum, maximum and average concentrations observed, and the number and percentage of samples violating the water quality standards collected between 1990 and 2005. The stations formatted in bold text are the DEQ listing stations for the bacteria impaired segments. Analysis of the water quality data indicated that exceedences of the fecal coliform standard ranged between 0 and 100 percent for the instantaneous maximum criterion of 400 cfu/100 ml.

Table 3-9: Fecal Coliform Data Collected within the Banister River Watershed

Station ID	Number of Samples	Date Sampled		Values (no/100mL)			Instantaneous Exceedences	
		First	Last	Min	Max	Average	Sum	Percent
4ABAN012.46	6	7/19/01	6/18/02	100	100	100	0	0%
4ABAN022.24	1	11/7/01	11/7/01	100	100	100	0	0%
4ABAN023.28	**35**	**3/13/95**	**9/26/05**	**18**	**16,000**	**2,174**	**11**	**31%**
4ABAN026.65	1	4/29/03	4/29/03	25	25	25	0	0%
4ABAN039.76	11	8/23/99	6/5/01	100	4,000	491	1	9%
4ABAN070.20	**41**	**2/13/95**	**8/31/05**	**100**	**2,500**	**307**	**7**	**17%**
4ABAR001.74	1	4/27/04	4/27/04	400	400	400	0	0%
4ACRR000.80	43	3/21/95	9/27/05	100	1,625	481	20	47%
4ACRR003.56	**28**	**3/21/95**	**6/5/01**	**100**	**2,300**	**493**	**11**	**39%**
4ACRR008.32	8	8/12/98	10/24/02	100	100	100	0	0%
4AEKH003.18	1	10/30/01	10/30/01	100	100	100	0	0%
4APEC006.49	**13**	**8/9/01**	**6/5/03**	**100**	**1,700**	**446**	**3**	**23%**
4ARFK000.20	7	4/25/02	10/24/02	100	100	100	0	0%
4ASNA000.20	**46**	**3/13/95**	**9/26/05**	**18**	**16,000**	**1,224**	**11**	**24%**
4ASNE005.30	**44**	**2/13/95**	**9/26/05**	**100**	**2,700**	**341**	**8**	**18%**
4ATRR001.92	33	2/9/95	1/30/01	0	16,000	958	4	12%
4AWRN005.50	32	2/13/95	9/27/05	100	8,000	751	7	22%
4AXUS000.65	1	4/12/05	4/12/05	25	25	25	0	0%

[1] Instantaneous maximum fecal coliform bacteria concentration of 400 cfu/100 ml.
[2] Geometric mean fecal coliform bacteria concentration of 200 cfu/100 ml, calculated only when two or more samples are collected within a calendar month.
Note: Rows in bold are listing stations for the bacteria impairment segments.

Thirty-eight stations within the watershed were sampled between 1990 and 2005 for *E.coli* bacteria. **Table 3-10** lists the water quality sampling period of record, the number of samples, the minimum, maximum and average concentrations observed, and the number and percentage of samples violating the water quality standards collected between 1990 and 2005. The stations formatted in bold text are the DEQ listing stations for bacteria. *E.coli* exceedences 235 cfu/ 100mL of the instantaneous maximum ranged between 0 percent and 100 percent and there were no exceedances recorded of the geometric mean.

Table 3-10: *E.coli* Sampling Data Collected within the Banister River Watershed

Station ID	No of Samples	Date Sampled		E. coli Values			Instantaneous Exceedences	
		First	Last	Min	Max	Average	No.	Percent
4AALL001.13	8	7/28/2005	9/11/2006	50	2000	778	6	75%
4ABAN023.28	**25**	**2/9/2000**	**12/12/2005**	**10**	**2000**	**229**	**5**	**20%**
4ABAN026.65	1	37740.5	37740.5	30	30	30	0	0%
4ABAN029.81	12	7/25/2005	6/19/2006	25	650	190	2	17%
4ABAN039.76	12	7/25/2005	6/19/2006	25	250	95	0	0%
4ABAN044.76	12	7/26/2005	6/20/2006	25	250	95	0	0%
4ABAN053.77	12	7/26/2005	6/20/2006	25	200	92	0	0%
4ABAN070.20	**5**	**7/26/2005**	**12/13/2005**	**84**	**198**	**127**	**0**	**0%**
4ABAN074.58	12	7/26/2005	6/20/2006	25	2000	305	2	17%
4ABAR001.74	1	4/27/2004	4/27/2004	300	300	300	1	100%
4ABDB000.75	8	7/28/2005	9/11/2006	25	950	163	1	13%
4ABKN000.52	**10**	**11/24/2003**	**5/10/2005**	**25**	**700**	**164**	**1**	**10%**
4ABKN002.47	12	7/26/2005	6/20/2006	25	2000	311	2	17%
4ABYE000.85	8	7/28/2005	9/11/2006	25	200	108	0	0%
4ACRR000.80	5	7/26/2005	12/13/2005	92	355	191	1	20%
4ACRR003.56	**12**	**7/30/2003**	**5/10/2005**	**25**	**580**	**170**	**2**	**17%**
4AEKH000.63	12	7/25/2005	6/19/2006	25	180	87	0	0%
4AGEO011.38	5	7/8/2003	10/22/2003	25	100	40	0	0%
4AJSR000.53	11	7/25/2005	6/19/2006	25	280	128	1	9%
4ALCC000.59	7	9/19/2005	9/11/2006	75	720	306	3	43%
4APEC002.42	7	10/3/2005	8/7/2006	25	150	71	0	0%
4ASLC015.31	7	10/3/2005	8/7/2006	25	220	74	0	0%
4ASNA000.20	**6**	**7/25/2005**	**12/12/2005**	**39**	**225**	**80**	**0**	**0%**
4ASNA012.51	12	7/25/2005	6/19/2006	25	250	123	0	0%
4ASNA019.51	12	7/26/2005	6/20/2006	25	220	100	0	0%
4ASNE005.30	**6**	**7/25/2005**	**12/12/2005**	**68**	**223**	**158**	**0**	**0%**
4ASNE010.46	12	7/25/2005	6/19/2006	25	620	171	2	17%
4ASRW002.32	12	7/26/2005	6/20/2006	25	250	130	0	0%
4AWRN000.43	**11**	**7/30/2003**	**5/10/2005**	**25**	**1400**	**225**	**2**	**18%**
4AWRN005.50	6	7/26/2005	12/13/2005	74	215	118	0	0%
4AWRN011.05	12	7/26/2005	6/20/2006	25	380	153	1	8%
4AXUS000.65	1	4/12/2005	4/12/2005	40	40	40	0	0%

[1] Instantaneous maximum *E.coli* bacteria concentration of 235/100 ml

[2] Geometric mean fecal *E.coli* bacteria concentration of 126/100 ml, of water for two or more samples taken during any calendar month

Note: Rows in **bold** are listing stations for the bacteria impairment segments.

3.4.1 DEQ Bacteria Source Data

As part of the TMDL development, Bacteria Source Tracking (BST) sampling was conducted at 6 locations throughout the watershed. The objective of the BST study was to identify the sources of fecal coliform in the listed segments of the Banister River Watershed. After identifying these sources, this information was used in the model set-up, and in the distribution of fecal coliform loadings among the various sources.

There are various methodologies used to perform BST, which fall into three major categories: molecular, biochemical and chemical. Molecular (genotype) methods are referred to as "DNA fingerprinting," and are based on the unique genetic makeup of different strains, or subspecies, of fecal coliform bacteria. Biochemical (phenotype) methods are based on detecting biochemical substances produced by bacteria. The type and quantity of these substances are measured to identify the bacteria source. Chemical methods are based on testing for chemical compounds that are associated with human wastewaters, and are restricted to determining if sources of pollution are human or non-human.

For the Banister River Watershed TMDLs, the Antibiotic Resistance Analysis (ARA) method of BST was used. ARA has been the most widely used and published BST method to date and has been employed in Virginia, Florida, Kansas, Oregon, South Carolina, Tennessee, and Texas. Advantages of ARA include low cost per sample, and fast turnaround times for analyzing samples. The method can also be performed on large numbers of isolates; typically, 48 isolates per unknown source such as an in-stream water quality sample.

BST was conducted monthly from June 2005 to July 2006 at stations 4ABAN023.28, 4ABAN070.20, 4ACRR000.80, 4ASNA000.20, 4AWRN005.50, and 4ASNE005.30. Results from both sampling periods indicate that bacteria from human, livestock, wildlife, and pet sources are present in the Banister River. The locations of each BST stations are presented in **Table 3-11**. **Figure 3-5** depicts the locations of the monitoring stations in the Banister River Watershed.

Table 3-11: VA DEQ Water Quality Station		
4ABAN023.28	Rt. 642 Bridge	Banister River
4ABAN070.20	Banister River at Rt. 703	Banister River
4ACRR000.80	Rt 703 Bridge, Below Chatham STP-PITT	Cherrystone Creek
4ASNA000.20	RT. 832 Bridge	Sandy Creek
4AWRN005.50	Rt. 685 Bridge	Whitehorn Creek
4ASNE005.30	Rt. 927 Bridge	Stinking River

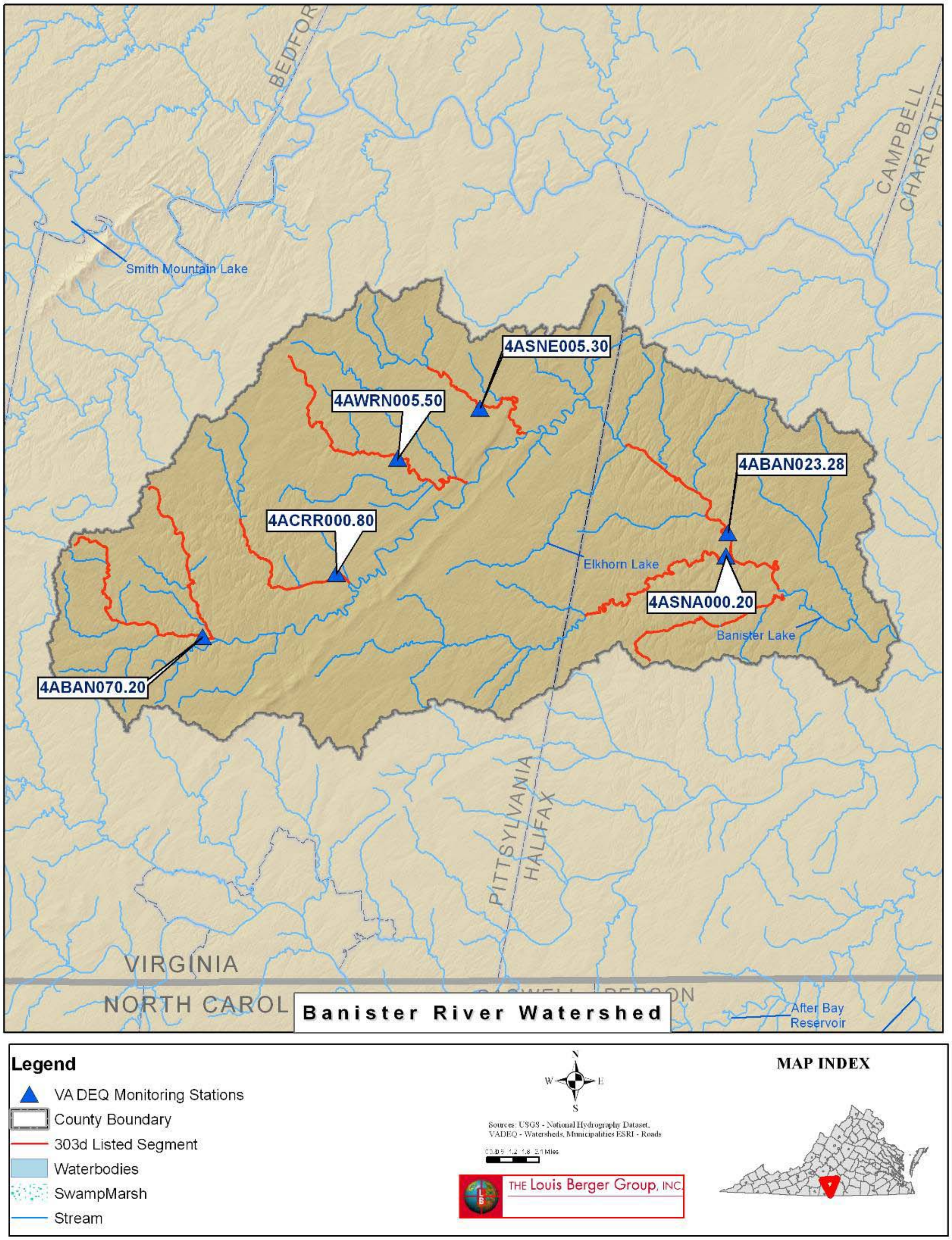

Figure 3-5: BST Monitoring Stations in the Bannister River Watershed

Four categories of fecal bacteria sources were considered: wildlife, human, livestock and pet. Results from 12 sampling events at each station, are presented in **Table 3-12** and results are depicted in **Figures 3-6** through **3-11**. *E.coli* concentrations exceeded the instantaneous maximum *E.coli* bacteria criterion of 235 cfu/100mL 25 times in the 144 samples collected at all 6 stations. In terms of percentages, the instantaneous *E.coli* standard was violated anywhere from 0 to 17% percent of the time.

Table 3-12: BST Data Collected between 2005-2006 within the Banister River Watershed

Station ID	Date of Sample	*E. coli* cfu/100ml	No of Isolates	Wildlife	Human	Livestock	Pet
4ABAN070.20 1 out of 12 samples (8%) exceed 235 cfu/100ml	7/26/2005	198	24	4%	0%	79%	17%
	8/31/2005	96	24	25%	21%	46%	8%
	9/27/2005	186	24	0%	8%	0%	92%
	10/18/2005	88	24	4%	0%	0%	96%
	11/16/2005	169	24	25%	4%	4%	67%
	12/13/2005	84	24	4%	4%	0%	92%
	1/10/2006	102	24	4%	0%	4%	92%
	2/7/2006	62	24	25%	0%	4%	71%
	3/14/2006	100	24	29%	0%	17%	54%
	4/11/2006	80	24	41%	0%	21%	38%
	5/23/2006	124	24	25%	0%	0%	75%
	6/20/2006	240	24	4%	4%	17%	75%
4ABAN023.28 1 out of 12 samples (8%) exceed 235 cfu/100ml	7/25/2005	72	24	25%	55%	8%	12%
	8/30/2005	68	22	59%	9%	5%	27%
	9/26/2005	60	24	88%	8%	0%	4%
	10/17/2005	84	24	38%	38%	0%	24%
	11/15/2005	78	24	17%	38%	12%	33%
	12/12/2005	84	24	29%	17%	17%	37%
	1/9/2006	82	24	8%	17%	4%	71%
	2/6/2006	337	24	12%	55%	8%	25%
	3/13/2006	40	15	20%	53%	27%	0%
	4/10/2006	66	24	88%	4%	8%	0%
	5/22/2006	84	4	0%	0%	25%	75%
	6/19/2006	220	24	17%	8%	58%	17%
4ACRR000.80 1 out of 12 samples (8%) exceed 235 cfu/100ml	7/26/2005	355	24	0%	100%	0%	0%
	8/31/2005	207	24	25%	42%	0%	33%
	9/27/2005	207	24	38%	42%	8%	12%
	10/18/2005	192	24	46%	42%	0%	12%
	11/16/2005	96	24	55%	4%	8%	33%
	12/13/2005	92	24	8%	4%	29%	59%
	1/10/2006	66	24	8%	4%	12%	76%
	2/7/2006	64	22	55%	27%	9%	9%
	3/14/2006	66	24	46%	46%	8%	0%
	4/11/2006	106	24	25%	33%	21%	21%
	5/23/2006	112	24	12%	12%	29%	47%
	6/20/2006	152	24	29%	25%	8%	38%

Table 3-12: BST Data Collected between 2005-2006 within the Banister River Watershed							
Station ID	**Date of Sample**	***E. coli* cfu/100ml**	**No of Isolates**	**Wildlife**	**Human**	**Livestock**	**Pet**
4AWRN005.50 0 out of 12 samples (0%) exceed 235 cfu/100ml	7/26/2005	215	24	29%	12%	0%	59%
	8/31/2005	148	24	50%	33%	0%	17%
	9/27/2005	120	24	51%	33%	8%	8%
	10/18/2005	76	24	17%	29%	25%	29%
	11/16/2005	74	24	67%	0%	12%	21%
	12/13/2005	74	24	17%	33%	25%	25%
	1/10/2006	84	24	33%	21%	25%	21%
	2/7/2006	72	24	8%	63%	21%	8%
	3/14/2006	54	24	42%	33%	25%	0%
	4/11/2006	46	24	50%	29%	17%	4%
	5/23/2006	124	20	5%	10%	40%	45%
	6/20/2006	110	24	25%	34%	12%	29%
4ASNE005.30 2 out of 12 samples (17%) exceed 235 cfu/100ml	7/25/2005	168	24	0%	100%	0%	0%
	8/30/2005	218	24	55%	25%	8%	12%
	9/26/2005	223	24	25%	21%	4%	50%
	10/17/2005	190	24	33%	46%	0%	21%
	11/15/2005	68	24	17%	67%	8%	8%
	12/12/2005	90	24	12%	12%	21%	55%
	1/9/2006	64	24	4%	17%	4%	75%
	2/6/2006	78	24	42%	33%	8%	17%
	3/13/2006	42	15	0%	73%	7%	20%
	4/10/2006	118	24	33%	26%	33%	8%
	5/22/2006	440	8	12%	25%	25%	38%
	6/19/2006	580	24	4%	21%	67%	8%
4ASNA000.20 0 out of 12 samples (0%) exceed 235 cfu/100ml	7/25/2005	50	24	12%	88%	0%	0%
	8/30/2005	30	11	91%	0%	9%	0%
	9/26/2005	225	24	41%	21%	38%	0%
	10/17/2005	48	24	42%	16%	0%	**42%**
	11/15/2005	48	24	4%	33%	8%	55%
	12/12/2005	72	24	38%	8%	0%	54%
	1/9/2006	70	24	8%	17%	0%	75%
	2/6/2006	205	24	8%	88%	4%	0%
	3/13/2006	54	24	12%	59%	25%	4%
	4/10/2006	58	23	78%	0%	22%	0%
	5/22/2006	36	8	0%	0%	50%	50%
	6/19/2006	38	24	4%	21%	33%	42%

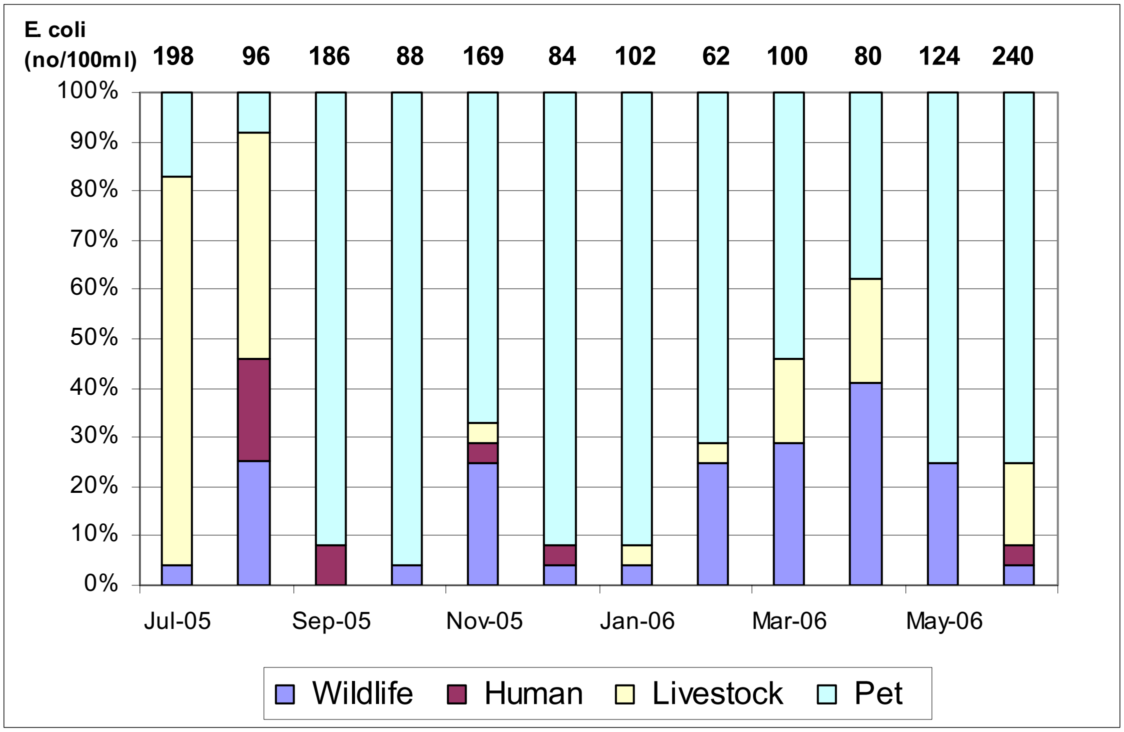

Figure 3-6: BST Source Distributions at 4ABAN070.20

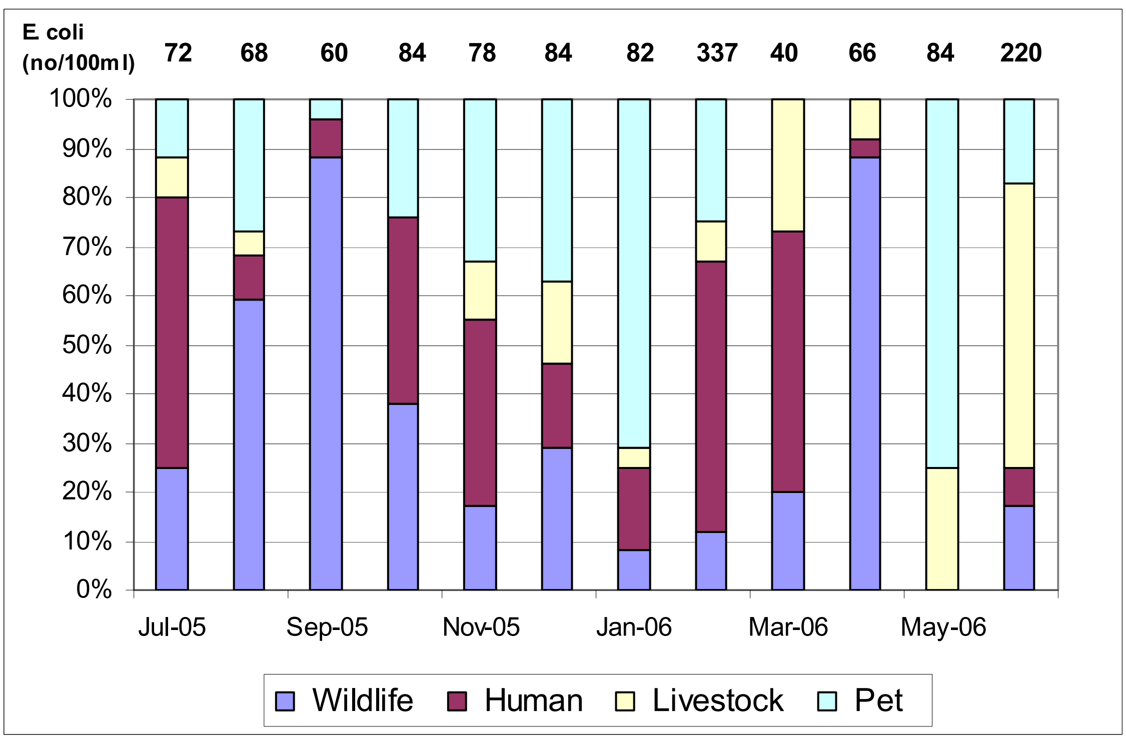

Figure 3-7: BST Source Distributions at 4ABAN023.28

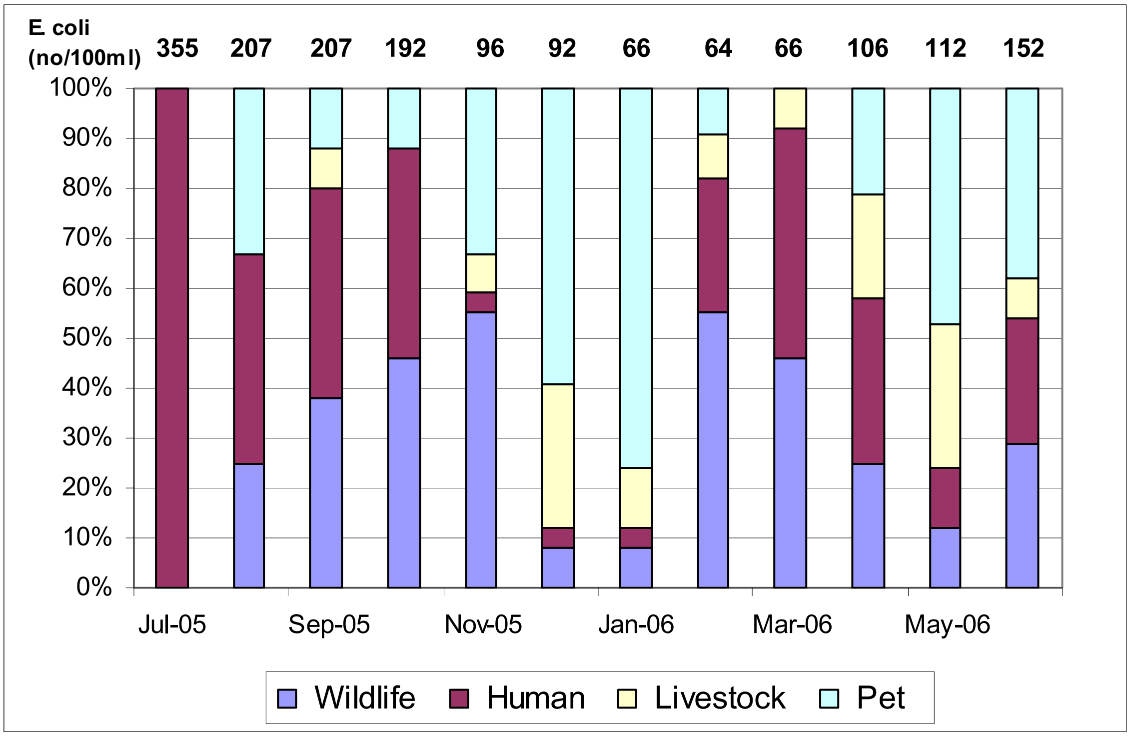

Figure 3-8: BST Source Distributions at 4ACRR000.80

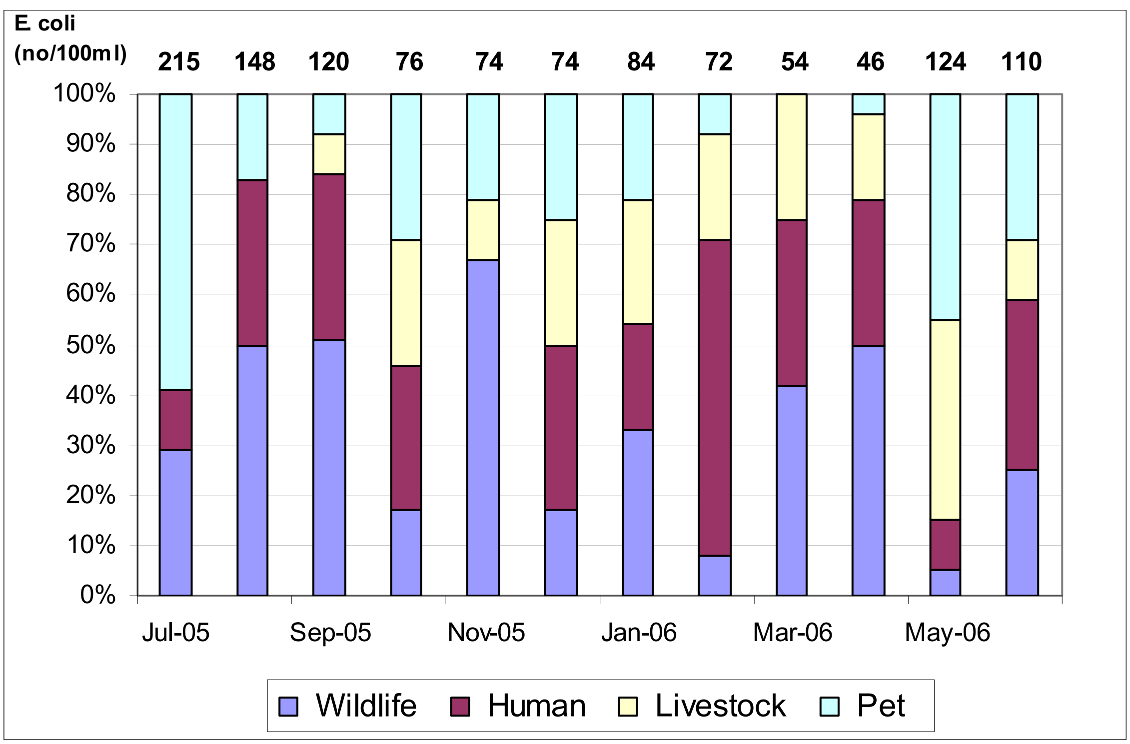

Figure 3-9: BST Source Distributions at 4AWRN005.50

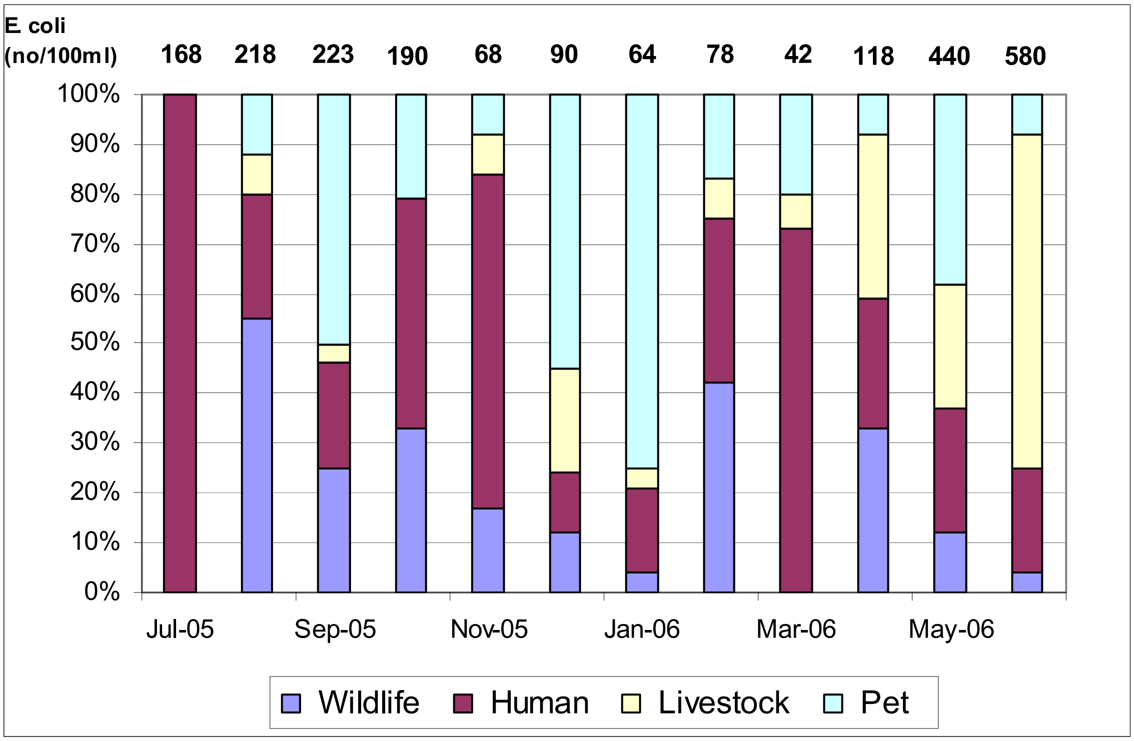

Figure 3-10: BST Source Distributions at 4ASNE005.30

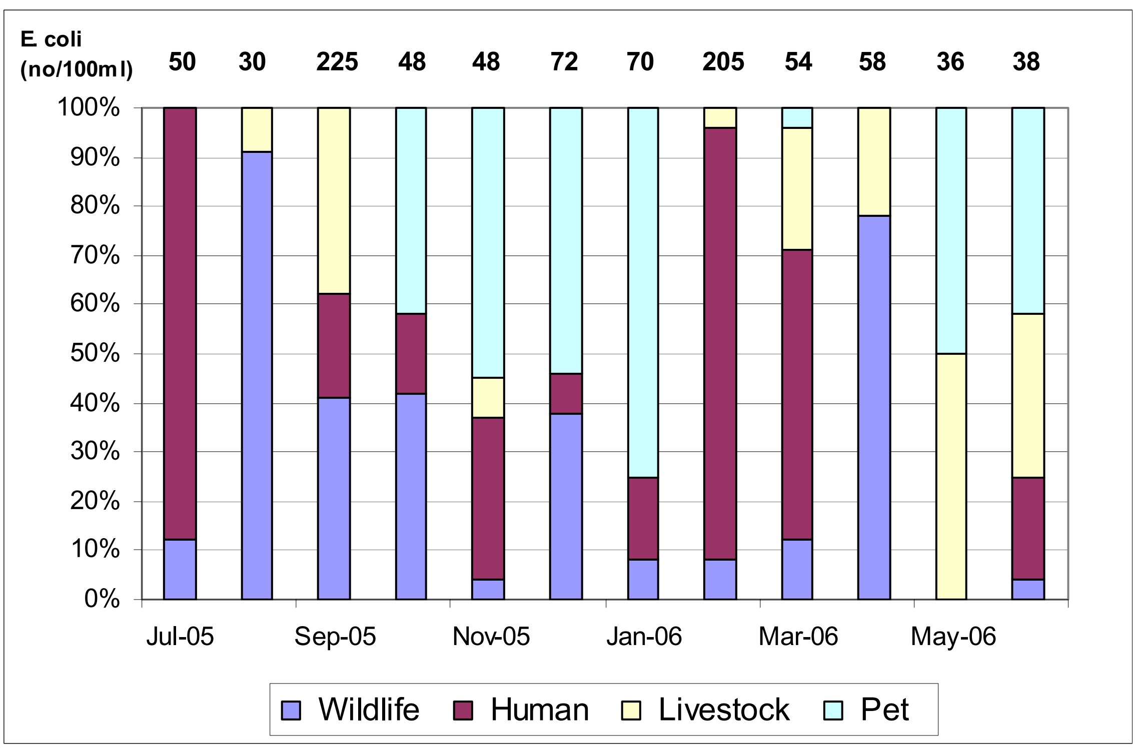

Figure 3-11: BST Source Distributions at 4ASNA000.20

3.5 Fecal Coliform Source Assessment

This section focuses on characterizing the sources that potentially contribute to the fecal coliform loading in the Banister River watershed. These sources include permitted facilities, sanitary sewer systems and septic systems, livestock, wildlife, pets, and land application of manure and biosolids. Chapter 4 includes a detailed presentation of how these sources are incorporated and represented in the model.

3.5.1 Permitted Facilities

Data obtained from the DEQ's South Central Regional Office Regional Office indicate that there are 8 individually permitted facilities currently active or under application within in the Banister River Watershed. The permit number, design flow, and status for each permit are presented in **Table 3-13** and shown in **Figure 3-12**.

The available flow data for the permitted facilities was retrieved and analyzed. Bacteria concentrations were not recorded for any of the permitted facilities within the watershed. Average flows for the permitted facilities were used in the HSPF model set-up and calibration. The waste treatment plants use chlorine for disinfection, and many measure total contact chlorine as an indication of fecal coliform levels. The available data indicate that adequate disinfection was achieved at the plants, and that these facilities were not a large source of fecal coliform loading. DMR data is summarized in Appendix A.

Table 3-13: Individual Permitted Facilities within the Banister River Watershed

Permit No	Facility Name	Receiving Stream	Status	Size	Category	Design Flow (GPD)	Permitted to Discharge Bacteria? (Y/N)
VA0006513	Gretna Town - Water Treatment Plant	Georges Creek	Active	Minor	Industrial	27,000	N
VA0020524	Chatham Town - Sewage Treatment Plant	Cherrystone Creek	Active	Minor	Municipal	685,000	Y
VA0022721	Halifax County Schools Meadville Elem	Sandy Creek/U.T.	Active	Minor	Municipal	5,100	N
VA0022730	Halifax County Schools Sydnor Jennings Elem	Bradley Creek/U.T.	Active	Minor	Municipal	5,100	N
VA0027707	Pittsylvania Co - Mount Airy Elementary School	Blacks Creek, UT	Active	Minor	Municipal	5,000	N
VA0027715	Pittsylvania Co - Union Hall Elem School	Wet Sleeve Creek, UT	Active	Minor	Municipal	6,000	N
VA0063843	Gretna Town - Sewage Treatment Plant	Georges Creek	Active	Minor	Municipal	350,000	Y
VA0001309	Cook Composites and	Banister	Active	Minor	Industrial	50,000	N

Table 3-13: Individual Permitted Facilities within the Banister River Watershed							
Permit No	**Facility Name**	**Receiving Stream**	**Status**	**Size**	**Category**	**Design Flow (GPD)**	**Permitted to Discharge Bacteria? (Y/N)**
	Polymers Co	River, UT					
VA0001643	Jones Patio Doors Inc and Holleman Acres	Banister River	History	Minor	Industrial	73,000	N
VA0023442	DOC Chatham Diversion Center	Green Rock Branch, UT	Active	Minor	Municipal	21,000	N
VA0074063	Hatcher Center - Sewage Treatment Plant	Sandy Creek, UT	History	Minor	Municipal	10,000	Y

There are also general permits issued within the watershed. Latitudes and longitudes were not consistently available for the general permits and therefore these facilities could not be mapped. The active and application general permits are shown in **Table 3-14**. The flow from all permitted dischargers will be considered in model setup and calibration.

Table 3-13: Active and Application General Permits within the Banister River Watershed			
Permit No	**Facility**	**Receiving Stream**	**Discharge (GPD)**
VAG404183	Residence	Banister River UT	450
VAG404088	Residence	Gibson Creek UT	450
VAG404087	Residence	Banister River UT	450
VAG407226	Residence	UT to Banister River	600
VAG402031	Residence	Banister River	1,000
VAG407210	Residence	Banister River UT	1,000
VAG402084	Residence	UT Bannister River	300
VAG407202	Residence	UT to Runaway Creek	300
VPG270077	Poultry Facility	N/A	N/A
VAR51737	Colonial Pipeline	N/A	N/A
VPA00513	Industrial	N/A	N/A
VPA00514	Industrial	N/A	N/A
VPA00522	Industrial	N/A	N/A
VPA00563	Industrial	N/A	N/A
VPA00566	Industrial	N/A	N/A
VPA02048	Industrial	N/A	N/A
VPA00514	Industrial	N/A	N/A
VPA00566	Industrial	N/A	N/A
VPA005x2	Industrial	N/A	N/A

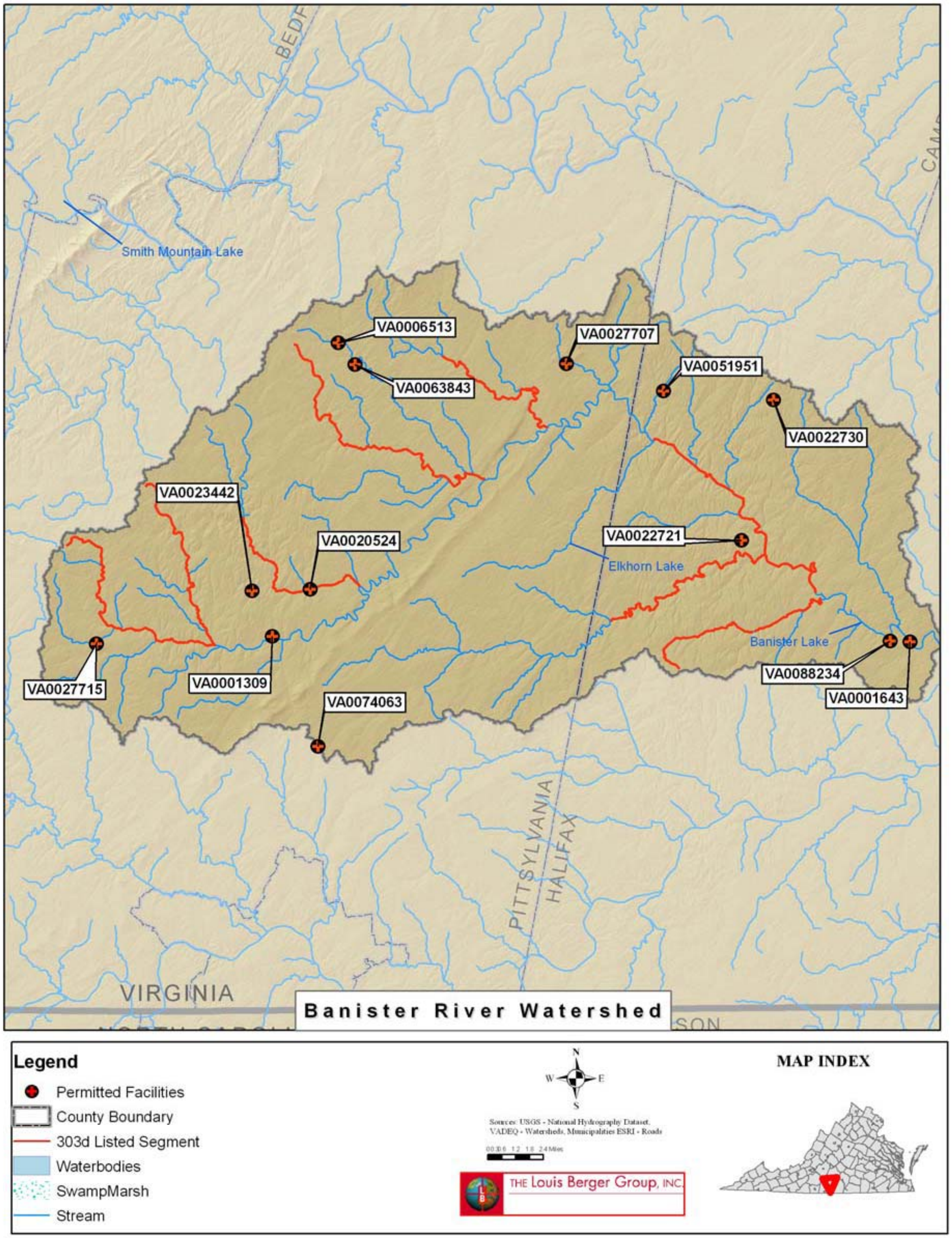

Figure 3-12: Location of Permitted Facilities in the Banister River Watershed

3.5.2 Extent of Sanitary Sewer Network

Houses can be connected to a public sanitary sewer, a septic tank, or the sewage can be disposed by other means. Estimates of the total number of households using each type of waste disposal are presented in the next section.

3.5.2.1 Septic Systems

There are no data available for the total number of septic systems in the watershed. Estimates of the total number of housing units located in the watershed and the identification of whether these housing units are connected to a public sewer or on septic systems were based U.S. Census Bureau data. The U.S. Census Bureau 2000 data for Halifax and Pittsylvania, were reviewed to establish the population growth rates in the counties and to validate the housing units' calculation. A summary of the census data and population estimates used for the Banister River watershed are presented in **Table 3-15**.

Table 3-14: 2000 Census Data Summary for Banister River Watershed

County	Total population	Total Households
Halifax	7,394	3,281
Pittsylvania	17,686	8,276
Total	**24,909**	**10,031**

Source: U.S. Census Data, USGS Quad Maps

The 1990 U.S Census Report presents the percent of houses on each sewage disposal type as shown in **Table 3-16**. The 1990 U.S Census Report category "Other Means" includes the houses that dispose of sewage in other ways than by public sanitary sewer or a private septic system. The houses included in this category are assumed to be disposing of sewer directly via straight pipes if located within 200 feet of a stream.

Table 3-15: Percent of Houses within Each County on Public Sewers, Septic Systems, and Other Means

County	Public Sewer	Septic Tank	Other Means
Halifax	6%	77%	10%
Pittsylvania	8%	86%	5%

Source: U.S. Census Data

3.5.2.2 Failed Septic Systems

In order to determine the amount of fecal coliform contributed by human sources, the failure rates of septic systems must be estimated. Septic system failures are generally attributed to the age of a system. For this TMDL model, the failure rate was assumed to be 3 percent of the total septic systems in the watershed. In order to determine the load of bacteria from these sources, it was assumed that the septic system design flow is 75 gallons per person per day (based on previous studies and TMDLs). In addition, it was estimated that typical fecal coliform concentrations from a failed septic system is 10,000 cfu/100mL and from a straight pipe is 1,040,000 cfu/100mL (Tinker Creek TMDL Report, 2004). **Table 3-17** shows the estimates of the population on septic systems and straight pipes, the amount of failing systems, and the flow and fecal coliform load produced daily.

Table 3-16: Estimates of the Number of Septic Systems and Straight Pipes

Category	# of People on system	# People per Household	# Failing Systems	People Served	Flow (gal/day)	Daily Load (#cfu/day)
Septic Systems	16,853	2.12	25	53	3,975	3.98E+07
Straight Pipes	822	2.12	19	40	3,021	3.14E+09

3.5.3 Livestock

An inventory of the livestock residing in the Banister River watersheds was conducted using data and information provided by United States Department of Agriculture (USDA) National Agricultural Statistics Service, Virginia's Department of Conservation and Recreation, NRCS, Virginia Agricultural Statistics Service (2002), the 2001 Virginia Equine Report, Soil and Water Conservation Districts (SWCD), as well as field surveys. Original estimates were reviewed and modified by stakeholder, in particular the SWCD districts of Halifax and Pittsylvania Counties. **Table 3-18** summarizes the livestock inventory in the watershed.

Table 3-17: Livestock Inventory			
Livestock Type	**Halifax**	**Pittsylvania**	**Total**
Beef cows	4,811	17,206	22,018
Milk cows	0	4,100	4,100
Hogs and pigs inventory	2,758	1,544	4,301
Sheep and lambs inventory	23	118	141
Chickens	20,000	153,000	173,000
Horses and ponies, inventory	402	2,500	2,902

The livestock inventory was used to determine the fecal coliform loading by livestock in the watershed. **Table 3-19** shows the average fecal coliform production per animal per day contributed by each type of livestock.

Table 3-18: Daily Fecal Coliform Production of Livestock		
Livestock Type	**Daily Fecal Coliform Production (millions of cfu/day)**	**Reference**
Cattle and calves	5,400	Metcalf and Eddy, 1991
Beef Cows	100,000	ASAE, 1998
Dairy Cows	100,000	ASAE, 1998
Hogs & Pigs	8,900	Metcalf and Eddy, 1991
	11,000	ASAE, 1998
Sheep & Lambs	18,000	Metcalf and Eddy, 1991
	12,000	ASAE, 1998
Horses & Ponies	420	ASAE, 1998

Source: USEPA Protocol for Developing Pathogen TMDLs, 2001

The impact of fecal coliform loading from livestock is dependent upon whether loadings are directly deposited into the stream, or indirectly delivered to the stream via surface runoff. For this TMDL, fecal coliform deposited while livestock were in confinement or grazing was considered indirect deposit, and fecal coliform deposited when livestock directly defecate into the stream was considered direct deposit. The distribution of daily fecal coliform loading between direct and indirect deposits was based on livestock daily schedules.

For the Banister River watersheds, the initial estimates of the beef cattle daily schedule were based on the Dodd Creek TMDL. The amount of time beef cattle spend in the pasture and stream was also presented during the TAC meetings where local stakeholders provided comments. The monthly schedule was adjusted to reflect the conditions in the watershed.

The daily schedule for beef cattle that was accepted by the stakeholders is presented in **Table 3-20**. The daily schedule for dairy cows that was accepted by the stakeholders is presented in **Table 3-21**. The time beef cattle and dairy cows spend in the pasture or loafing was used to determine the fecal coliform load deposited indirectly. The directly deposited fecal coliform load from livestock was based on the amount of time they spend in the stream.

Table 3-19: Daily Schedule for Beef Cattle

Month	Time Spent in		
	Pasture (Hour)	Stream (Hour)	Loafing Lot (Hour)
January	23.50	0.50	0
February	23.50	0.50	0
March	23.25	0.75	0
April	23.00	1.00	0
May	23.00	1.00	0
June	22.75	1.25	0
July	22.75	1.25	0
August	22.75	1.25	0
September	23.00	1.00	0
October	23.25	0.75	0
November	23.25	0.75	0
December	23.50	0.50	0

Source: Dodd Creek TMDL Report, DCR 2002.

Table 3-20: Daily Schedule for Dairy Cows			
Month	Time Spent in		
	Pasture (Hour)	Stream (Hour)	Loafing Lot (Hour)
January	7.45	0.25	16.30
February	7.45	0.25	16.30
March	8.10	0.50	15.40
April	9.35	0.75	13.90
May	10.05	0.75	13.20
June	10.30	1.00	12.70
July	10.80	1.00	12.20
August	10.80	1.00	12.20
September	11.05	0.75	12.20
October	11.00	0.50	12.50
November	10.30	0.50	13.20
December	9.15	0.25	14.60

Source: Dodd Creek TMDL Report, DCR 2002.

3.5.4 Land Application of Manure

Land application of the manure that cattle produce while in confinement is a typical agricultural practice. Both dairy operations and beef cattle are present in the watershed. The manure produced by confined livestock was directly applied on the pasturelands, and was treated as an indirect source in the development of the Banister River TMDLs.

3.5.5 Land Application of Biosolids

Non-point human sources of fecal coliform can be associated with the spreading of biosolids. Data provided by Virginia Department of Health (VDH) indicated that there has been no biosolids application in Halifax County in the last three to four years. Recorded biosolids application conducted in 2005 and 2006 is presented in **Table 3-22**.

Table 3-21: Biosolids Application by County (dry ton/year) *		
Year	Halifax	Pittsylvania
2005	-	2,344
2006	-	2,636

* Source: VDH

3.5.6 Wildlife

Similar to livestock contributions, wildlife contributions of fecal coliform can be both indirect and direct. Indirect sources are those that are carried to the stream from the surrounding land via rain and runoff events, whereas direct sources are those that are directly deposited into the stream.

The wildlife inventory for this TMDL was developed based on a number of information and data sources, including: (1) habitat availability, (2) Department of Game and Inland Fisheries (DGIF) harvest data and population estimates, and (3) stakeholder comments and observations.

A wildlife inventory was conducted based on habitat availability within the watershed. The number of animals in the watershed was estimated by combining typical wildlife densities with available stream wildlife habitat. Typical wildlife densities are presented in **Table 3-23.**

Table 3-22: Wildlife Densities

Wildlife type	Population Density	Habitat Requirements
Deer	0.047 animals/acre	Entire watershed
Raccoon	0.07 animals/acre	Within 600 feet of streams and ponds
Muskrat	2.75 animals/acre	Within 66 feet of streams and ponds
Beaver	4.8 animals/mile of stream	Within 66 feet of streams and ponds
Goose	0.02 animals/acre*	Entire Watershed
Mallard	0.002 animals/acre	Entire Watershed
Wood Duck	0.0018 animals/acre	Within 66 feet of streams and ponds
Wild Turkey	0.01 animals/acre	Entire watershed excluding urban land uses
Source: Map Tech, Inc., 2001, *Source: Goose Creek TMDL, 2004; Catoctin Creek TMDL, 2004		

The wildlife inventory presented in **Table 3-24** was confirmed by DGIF and DCR, and presented to stakeholders and local residents for approval. Based on the typical wildlife densities shown in **Table 3-25**, the population of geese, mallards, and wood ducks were determined to be less than what stakeholders had observed within the watershed. Therefore, these estimates were increased based on information provided by the SWCDs.

Table 3-23: Banister Watersheds Wildlife Inventory

Wildlife Animal	Halifax	Pittsylvania	Total
Deer	5,114	11,586	16,700
Raccoon	4,773	10,058	14,831
Muskrat	20,627	43,466	64,093
Beaver	2,250	4,742	6,992
Goose	1,072	2,428	3,500
Mallard	161	339	500
Wood duck	161	339	500
Wild Turkey	832	1,601	2,433

The wildlife inventory was used to determine the fecal coliform loading by wildlife within the watershed. **Table 3-25** shows the average fecal coliform production per animal, per day, contributed by each type of wildlife. Separation of the wildlife daily fecal coliform load into direct and indirect deposits was based on estimates of the amount of time each type of wildlife spends on land versus time spent in the stream. **Table 3-25** also shows the percent of time each type of wildlife spends in the stream on a daily basis.

Table 3-24: Fecal Coliform Production from Wildlife

Wildlife	Daily Fecal Production (in millions of cfu/day)	Portion of the Day in Stream (%)
Deer	347	1
Raccoon	113	10
Muskrat	25	50
Goose	799	50
Beaver	0.2	90
Duck	2,430	75
Wild Turkey	93	5

Source: ASAE, 1998; Map Tech, Inc., 2000; EPA, 2001.

3.5.7 Pets

The contribution of fecal coliform loading from pets was also examined in the assessment of fecal coliform loading to the Banister River Watershed. The two types of domestic pets that were considered as sources of bacteria in this TMDL were cats and dogs. The number of pets residing in the watershed was estimated by determining the number of households in the watershed, and multiplying this number by national average estimates of the number of pets per household as 0.543 dogs per household and 0.593 cats per household (AVMA, 2005). The original estimates based on the AVMA values were presented to stakeholders. Based on stakeholder comments, the number of dogs within the watershed was revised based estimates by the Halifax and Pittsylvania Counties Animal Control Departments **(Table 3-26).**

Table 3-25: Pet Estimates within the Banister River Watershed

County	Halifax	Pittsylvania	Total
Cats	1,720	4,229	5,948
Dogs	4,000	6,000	10,000

Fecal coliform loading from pets occurs primarily in residential areas. The load was estimated based on daily fecal coliform production rate of 5.04 $x10^2$ cfu/day per cat and 4.09 $x10^9$ cfu/day per dog.

4.0 Modeling Approach

This section describes the modeling approach used in the TMDL development. The primary focus is on the sources represented in the model, assumptions used, model set-up, calibration, and validation, and the existing load.

4.1 Modeling Goals

The goals of the modeling approach were to develop a predictive tool for the water body that can:

- represent the watershed characteristics
- represent the point and nonpoint sources of fecal coliform and their respective contribution
- use input time series data (rainfall and flow) and kinetic data (die-off rates of fecal coliform)
- estimate the in-stream pollutant concentrations and loadings under the various hydrologic conditions
- allow for direct comparisons between the in-stream conditions and the water quality standard

4.2 Watershed Boundaries

The eight impaired segments are located in the Banister River Basin (USGS Cataloging Unit 0301010). The Banister River flows through Halifax and Pittsylvania Counties. Bearskin Creek, Cherrystone Creek, Polecat Creek, Stinking River, Sandy Creek, and Whitehorn Creek are tributaries to the Banister River and also flow through Halifax and Pittsylvania Counties. The watershed that encompasses these impaired segments is approximately 353,319 acres. **Figure 4-1** shows the boundaries of the watershed that encompasses the Banister River, Bearskin Creek, Cherrystone Creek, Polecat Creek, Stinking River, Sandy Creek, and Whitehorn Creek Watersheds.

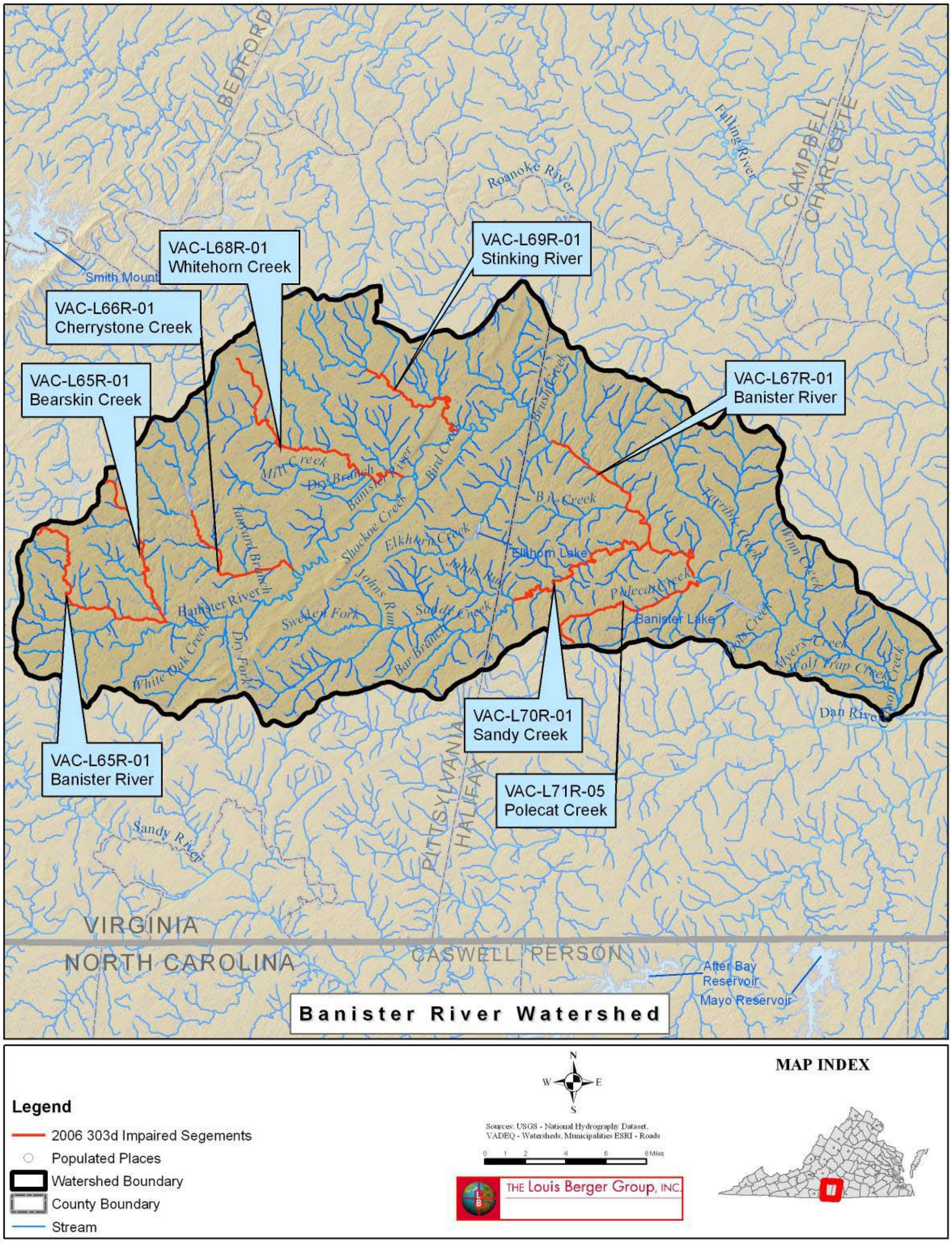

Figure 4-1: Watershed Boundary

4.3 Modeling Strategy

4.3.1 Model Selection

The Hydrologic Simulation Program-Fortran (HSPF) model was selected and used to predict the in-stream water quality conditions under varying scenarios of rainfall and fecal coliform loading. The results from the model are subsequently used to develop the TMDL allocations based on the existing fecal coliform load.

HSPF is a hydrologic, watershed-based water quality model. Consequently, HSPF can explicitly account for the specific watershed conditions, the seasonal variations in rainfall and climate conditions, and activities and uses related to fecal coliform loading.

The modeling process in HSPF starts with the following steps:

- delineate the watershed into smaller subwatersheds
- enter the physical data that describe each subwatershed and stream segment
- enter values for the rates and constants that describe the sources and the activities related to the fecal coliform loading in the watershed

These steps are discussed in the next sections.

4.4 Watershed Delineation

The Banister river watershed was delineated into 63 smaller subwatersheds to represent the watershed characteristics and to improve the accuracy of the HSPF model. This delineation was based on topographic characteristics, and was created using a Digital Elevation Model (DEM), stream reaches obtained from the RF3 dataset and the National Hydrography Dataset (NHD), and stream flow and in-stream water quality data. Size distributions of the 63 subwatersheds are presented in **Table 4-1.** **Figure 4-2** is a map showing the delineated subwatersheds for Banister River, Bearskin Creek, Cherrystone Creek, Polecat Creek, Stinking River, Sandy Creek, and Whitehorn Creek Watersheds.

Table 4-1: Subwatershed Acres

Subwatershed	Drainage Area (acres)	Subwatershed	Drainage Area (acres)
1	5,500	33	7,053
2	6,255	34	3,232
3	9,236	35	6,678
4	9,676	36	99
5	5,653	37	3,675
6	5,750	38	4,122
7	3,008	39	12,529
8	1,409	40	4,266
9	7,121	41	4,337
10	2,524	42	5,598
11	4,929	43	7,606
12	2,600	44	13,807
13	7,437	45	1,916
14	26	46	2,548
15	6,623	47	8,666
16	4,315	48	9,188
17	5,321	49	10,011
18	7,918	50	6,211
19	4,677	51	6,455
20	4,505	52	7,805
21	4,990	53	6,828
22	2,359	54	6,074
23	363	55	8,823
24	159	56	6,095
25	3,817	57	11,334
26	28	58	4,423
27	3,888	59	4,301
28	7,247	60	10,182
29	2,034	61	12,010
30	3,318	62	5,474
31	6,660	63	6,886
32	7,737		
Total Subwatershed Acres	**355,319**		

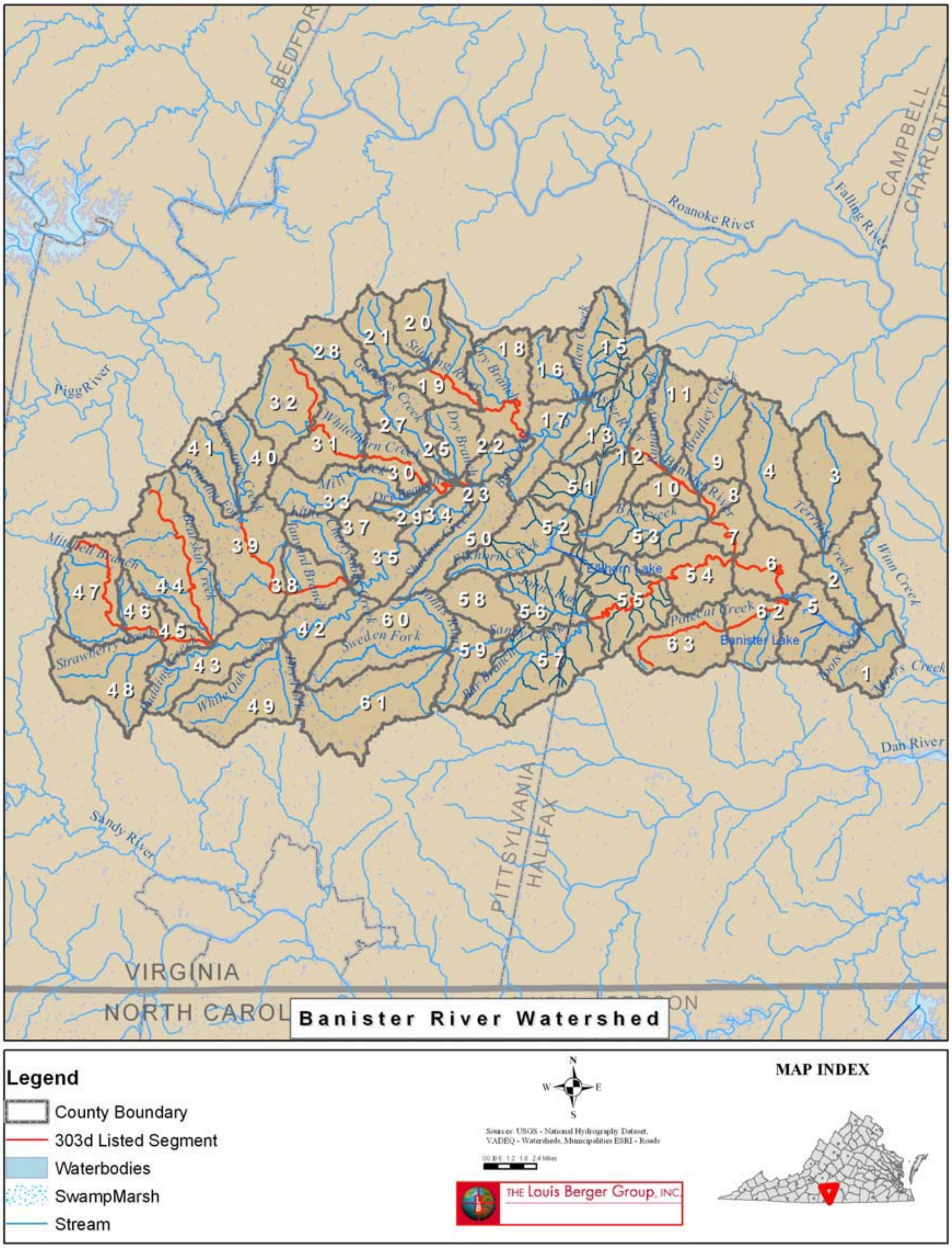

Figure 4-2: Modeled Subwatersheds

4.5 Land Use Reclassification

As previously mentioned, land use distribution in the study area was determined using USGS NLCD and NVRC data. The land use data and distribution of land uses were presented in Chapter 3. There are 14 land use classes present in the watershed; the dominant land uses are forested and agricultural land uses. The original 14 land use types were consolidated into 9 land use categories to meet modeling goals, facilitate model parameterization, and reduce modeling complexity. This reclassification reduced the 14 land use types to a representative number of categories that best describe conditions and the dominant fecal coliform source categories in the watersheds. Land use reclassification was based on similarities in hydrologic characteristics and potential fecal coliform production characteristics. The reclassified land uses are presented in **Tables 4-2** through **4-8** for the impaired watersheds.

Table 4-2: Banister River (Segment VAC-L65R-01) Land Use Reclassification

Land Use Category	Acres	Percent
High Residential	2	0%
Medium Residential	3	0%
Low Residential	124	1%
Commercial/Industrial/Transportation	1,126	5%
Cropland	179	1%
Pasture	7,210	32%
Forest	13,362	60%
Wetland	287	1%
Water	25	0%
Total	22,319	100%

Table 4-3: Banister River (Segment VAC-L67R-01) Land Use Reclassification

Land Use Category	Acres	Percent
High Residential	98	0%
Medium Residential	176	0%
Low Residential	719	1%
Commercial/Industrial/Transportation	5,475	4%
Cropland	2,116	2%
Pasture	33,839	28%
Forest	77,721	64%
Wetland	1,792	1%
Water	376	0%
Total	122,312	100%

Table 4-4: Bearskin Creek Reach (Segment VAC-L65R-02) Land Use Reclassification		
Land Use Category	**Acres**	**Percent**
High Residential	0	0%
Medium Residential	1	0%
Low Residential	92	1%
Commercial/Industrial/Transportation	837	6%
Cropland	113	1%
Pasture	5,668	41%
Forest	7,067	51%
Wetland	13	0%
Water	17	0%
Total	13,807	100%

Table 4-5: Cherrystone Creek (VAC-L66R-01 Segment) Land Use Reclassification		
Land Use Category	**Acres**	**Percent**
High Residential	46	0%
Medium Residential	104	0%
Low Residential	496	2%
Commercial/Industrial/Transportation	1,955	7%
Cropland	230	1%
Pasture	10,815	37%
Forest	15,063	52%
Wetland	128	0%
Water	191	1%
Total	29,029	100%

Table 4-6: Sandy Creek (Segment VAC-L70R-01) Land Use Reclassification		
Land Use Category	**Acres**	**Percent**
High Residential	3	0%
Medium Residential	42	0%
Low Residential	443	1%
Commercial/Industrial/Transportation	3,073	4%
Cropland	1,042	1%
Pasture	21,240	28%
Forest	48,119	64%
Wetland	1,429	2%
Water	210	0%
Total	75,601	100%

Table 4-7: Stinking River (Segment VAC-L69R-01) Land Use Reclassification		
Land Use Category	**Acres**	**Percent**
High Residential	0	0%
Medium Residential	2	0%
Low Residential	69	0%
Commercial/Industrial/Transportation	866	6%
Cropland	190	1%
Pasture	4,943	35%
Forest	8,068	57%
Wetland	26	0%
Water	9	0%
Total	14,172	100%

Table 4-8: Whitehorn Creek (Segment VAC-L68R-01) Land Use Reclassification		
Land Use Category	**Acres**	**Percent**
High Residential	32	0%
Medium Residential	85	0%
Low Residential	770	2%
Commercial/Industrial/Transportation	2,708	6%
Cropland	720	2%
Pasture	16,044	38%
Forest	21,418	51%
Wetland	97	0%
Water	68	0%
Total	41,942	100%

4.6 Hydrographic Data

Hydrographic data describing the stream network were obtained from the National Hydrography Dataset (NHD) and the Reach File Version 3 (RF3) dataset contained in BASINS. These data were used for HSPF model development and TMDL development. Information regarding the reach number, reach name, and length of each stream segment of Banister River, Bearskin Creek, Cherrystone Creek, Stinking River, Sandy Creek, and Whitehorn Creek are included in the RF3 database.

The stream geometry was field surveyed for representative reaches of Banister River, Bearskin Creek, Cherrystone Creek, Stinking River, Sandy Creek, and Whitehorn Creek. The Banister River and its tributaries were represented as trapezoidal channels. The channel slopes were estimated using the reach length and the corresponding change in elevation from DEM data. The flow was calculated using the Manning's equation using a 0.05 roughness coefficient. Model representation of the stream reach segments is presented in Appendix C.

4.7 Fecal Coliform Sources Representation

This section demonstrates how the fecal coliform sources identified in Chapter 3 were included or represented in the model. These sources include permitted sources, human sources (failed septic systems and straight pipes), livestock, wildlife, pets, and land application of manure and biosolids.

4.7.1 Permitted Facilities

There are 8 individually permitted facilities and 18 general permits located in the Banister River watershed. The permit number, design flow, and status for each facility were presented in **Table 3-13** and **3-14**.

For TMDL development, average discharge flow values were considered representative of flow conditions at each permitted facility, and were used in HSPF model set-up and calibration. For TMDL allocation development, permitted facilities were represented as constant sources discharging at their design flow and permitted fecal coliform concentrations.

4.7.2 Failed Septic Systems

Failed septic system loading to the watershed can be direct (point) or land-based (indirect or nonpoint), depending on the proximity of the septic system to the stream. In cases where the septic system is within the 200 foot stream buffer, the failed septic system was represented in the model as a constant source (similar to a permitted facility). As explained in Chapter 3, the total number of septic systems in the watershed was estimated at 10,031 systems. Based on GIS data, only approximately 300 of the households on septic systems were located within the 200 foot stream buffer. Therefore, the failed septic system load was considered a land-based load in the watershed.

For TMDL development, it was assumed that a 3% failure rate for septic systems would be representative of conditions in the watershed. This corresponds to a total of 25 failed septic systems in the study area. To account for uncontrolled discharges in the watershed and failed septic systems within the stream buffer, a total of 19 straight pipes were included in the model. This estimate was based on field observations, discussions with DCR and DEQ, stakeholder comments, evaluation of the BST results, and 1990 Census data.

In each subwatershed, the load from failing septic systems was calculated as the product of the total number of septic systems, septic systems failure rate, flow rate of septic discharge, typical fecal concentration in septic outflow, and the average household size in the watershed. The septic systems' design flow of 75 gallons per person per day and a fecal coliform concentration of 10,000 cfu/100mL were used in the fecal coliform load calculations. Fecal coliform loading from failed septic systems that are not within the 200 ft buffer of the stream is considered to be a predominantly indirect source. Failed septic systems within the stream buffer and straight pipes were represented as constant sources of fecal coliform. **Table 4-9** shows the distribution of the septic systems and straight pipes in the watershed.

Table 4-9: Failed Septic Systems and Straight Pipes Assumed in Model Development

Subwatershed	Septic Failures	Straight Pipes	Subwatershed	Septic Failures	Straight Pipes
1	0	1	33	0	0
2	0	0	34	0	0
3	0	0	35	0	0
4	1	1	36	0	0
5	3	4	37	0	0
6	0	0	38	0	0
7	0	0	39	0	0
8	0	0	40	1	0
9	0	0	41	0	0
10	0	0	42	0	0
11	0	0	43	0	0
12	0	0	44	1	0
13	0	0	45	0	0
14	0	0	46	0	0
15	1	1	47	1	0
16	0	0	48	0	0
17	0	0	49	1	1
18	0	0	50	0	0
19	0	0	51	0	0
20	0	0	52	8	5
21	0	0	53	0	0
22	0	0	54	0	0
23	0	0	55	0	0
24	0	0	56	0	0
25	0	0	57	1	1
26	0	0	58	0	0
27	0	0	59	0	0
28	1	1	60	0	0
29	0	0	61	0	0
30	0	0	62	0	0
31	0	0	63	0	0
32	1	0			
Total				**25**	**19**

4.7.3 Livestock

Livestock contribution to the total fecal coliform load in the watershed was represented in a number of ways, which are presented in **Figure 4-3**. The model accounts for fecal coliform directly deposited in the stream, fecal coliform deposited while livestock are in confinement and later spread onto the crop and pasture lands in the watershed (land application of manure), and finally, land-based fecal coliform deposited by livestock while grazing.

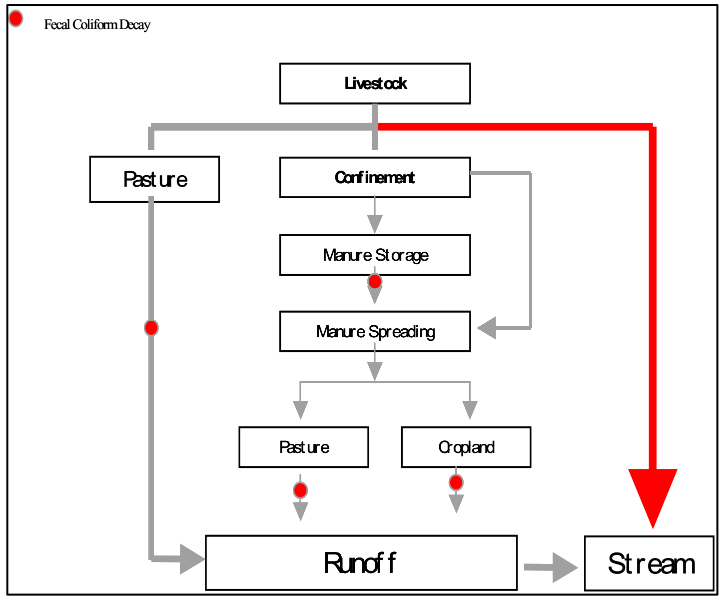

Figure 4-3: Livestock Contribution

Based on the inventory of livestock in the watershed, it was determined that beef cattle, and chicken are the predominant types of livestock, though dairy cows, horses, pigs, and sheep are also present in the watershed.

The distribution of the daily fecal coliform load between direct in-stream and indirect (land-based) loading was based on livestock daily schedules. The direct deposition load from livestock was estimated from the number of livestock in the watershed, the daily fecal coliform production per animal, and the amount of time livestock spent in the stream. The amount of time livestock spend in the stream was presented in Chapter 3. The distribution of livestock by subwatershed is shown in Appendix B.

The land-based load of fecal coliform from livestock while grazing was determined based on the number of livestock in the watershed, the daily fecal coliform production per animal, and the percent of time each animal spends in pasture. The monthly loading rates are presented in Appendix D.

4.7.4 Land Application of Manure

Beef cattle, as well as several dairy operations, are present in the watersheds. Because there are no feedlots or large manure storage facilities present in the watershed, the daily produced manure is applied to pastureland in the watershed, and was treated as an indirect source in the development of the TMDLs. Beef cattle spend the majority of their time on pastureland and are not confined. Thus, fecal coliform loading from beef cattle was accounted for via the methods described above. Dairy cattle do spend time in confinement, and their fecal coliform load was included in the calculation of land application of manure. Fecal coliform loading from land application of manure was estimated based on the total number of dairy cows in the watershed, the fecal coliform production per animal per day, and the percent of time dairy cows were in confinement.

4.7.5 Land Application of Biosolids

Biosolids application in the watersheds was considered under this TMDL development. Biosolids were modeled as land based loads applied to crop and pasture lands in each watershed. The loads modeled were based on county specific annual application estimates reported by the Virginia Department of Health (VDH).

4.7.6 Wildlife

Fecal loading from wildlife was estimated in the same way as loading from livestock. As with livestock, fecal coliform contributions from wildlife can be both indirect and direct. The distribution between direct and indirect loading was based on estimates of the amount of time each type of wildlife spends on the surrounding land versus in the stream.

Daily fecal coliform production per animal and the amount of time each type of wildlife spends in the stream was presented previously in the wildlife inventory (Chapter 3). The direct fecal coliform load from wildlife was calculated by multiplying the number of each type of wildlife in the watershed by the fecal coliform production per animal per day, and by the percentage of time each animal spends in the stream. Indirect (land-based) fecal coliform loading from wildlife was estimated as the product of the number of each type of wildlife in the watershed, the fecal coliform production per animal per day, and the percent of time each animal spends on land within the watersheds. The resulting fecal coliform load was then distributed to forest and pasture land uses, which represent the most likely areas in the watershed where wildlife would be present and defecate. This was accomplished by converting the indirect fecal coliform load to a unit loading (cfu/acre), then multiplying the unit loading by the total area of forest and pasture in each subwatershed. The distribution of wildlife by subwatershed is shown in Appendix B.

4.7.7 Pets

For the TMDLs, pet fecal coliform loading was considered a land-based load that was primarily deposited in urban land within the watershed. In response to stakeholder's comments, the original dog inventories of 1 dog for every two houses were changed to reflect the number of hunting dogs in the watershed. The daily fecal coliform loading was calculated as the product of the number of pets in the watershed and the daily fecal coliform production per type of pet.

4.8 Fecal Coliform Die-off Rates

Representative fecal coliform decay rates were included in the HSPF model developed for the watersheds. Three fecal coliform die-off rates required by the model to accurately represent watershed conditions included:

1. **In-storage fecal coliform die-off**. Fecal coliform concentrations are reduced while manure is in storage facilities.

2. **On-surface fecal coliform die-off**. Fecal coliform deposited on the land surfaces undergoes decay prior to being washed into streams.

3. **In-stream fecal coliform die-off**. Fecal coliform directly deposited into the stream, as well as fecal coliform entering the stream from indirect sources, will also undergo decay.

For the TMDLs, in-storage die-off was not included in the model because there is no manure storage facility located in the watershed. Decay rates of 1.37 and 1.152 per day were used to estimate die-off rates for on-surface and in-stream fecal coliform, respectively (EPA, 1985).

4.9 Model Set-up, Calibration, and Validation

Hydrologic calibration of the HSPF model involves the adjustment of model parameters to control various flow components (e.g. surface runoff, interflow and base flow, and the shape of the hydrographs) and make simulated values match observed flow conditions during the desired calibration period.

The model credibility and stakeholder faith in the outcome hinges on developing a model that has been calibrated and validated. Model calibration is a reality check. The calibration process compares the model results with observed data to ensure the model output is accurate for a given set of conditions. Model validation establishes the model's credibility. The validation process compares the model output to the observed data set, which is different from the one used in the calibration process, and estimates the model's prediction accuracy. Water quality processes were calibrated following calibration of the hydrologic processes of the model.

4.9.1 Model Set-Up

4.9.1.1 Stream Flow Data

The HSPF model was set up and calibrated based on flow data taken by USGS gage at Georges Creek (gage ID 02076500) **(Figure 3-3).** This station was selected because of its unrestricted flow within the watershed. A 2-year period (1992-1993) was selected as the calibration period for the hydrologic model. The validation period selected was 1994.

4.9.1.2 Rainfall and Climate Data

Hourly precipitation data gathered from two weather stations was used in the hydrological modeling. These stations were at the Lynchburg Airport and Chatham Airport. Surface airways data (including wind speed/direction, ceiling height, dry bulb temperature, dew point temperature, and solar radiation) were also obtained from these stations.

4.9.2 Model Hydrologic Calibration Results

HSPEXP software was used to calibrate the hydrology of the watershed. After each model's iteration, summary statistics were calculated to compare model results with observed values, in order to provide guidance on parameter adjustment according to built-in rules. The rules were derived from the experience of expert modelers and listed in the HSPEXP user manual (Lumb and Kittle, 1993).

Using the recommended default criteria as target values for an acceptable hydrologic calibration, the hydrologic model was calibrated from January 1992 to December 1993 at the flow station. Calibration results are presented in **Table 4-10**, showing the simulated and observed values for nine flow characteristics. An error statistics summary for seven flow conditions is presented in **Table 4-11**. The model results and the observed daily average flow at the calibration station are plotted in **Figure 4-4**.

Table 4-10:Model Calibration Results

Category	Simulated	Observed
Total runoff, in inches	34.59	32.991
Total of highest 10% flows, in inches	10.88	11.662
Total of lowest 50% flows, in inches	8.25	8.196
Total storm volume, in inches	1.46	2.279
Baseflow recession rate	0.97	0.96
Summer flow volume, in inches	5.61	5.063
Winter flow volume, in inches	10.68	9.878
Summer storm volume, in inches	0.37	0.505

Table 4-11: Model Calibration Error Statistics

Category	Current	Criterion
Error in total volume	4.8	± 10.000
Error in low flow recession	-0.01	± 0.01
Error in 50% lowest flows	0.7	± 10.000
Error in 10% highest Flow	-6.7	± 15.000
Seasonal volume error	2.7	± 10.000
Summer Storm Volume Error	9.2	± 15.000

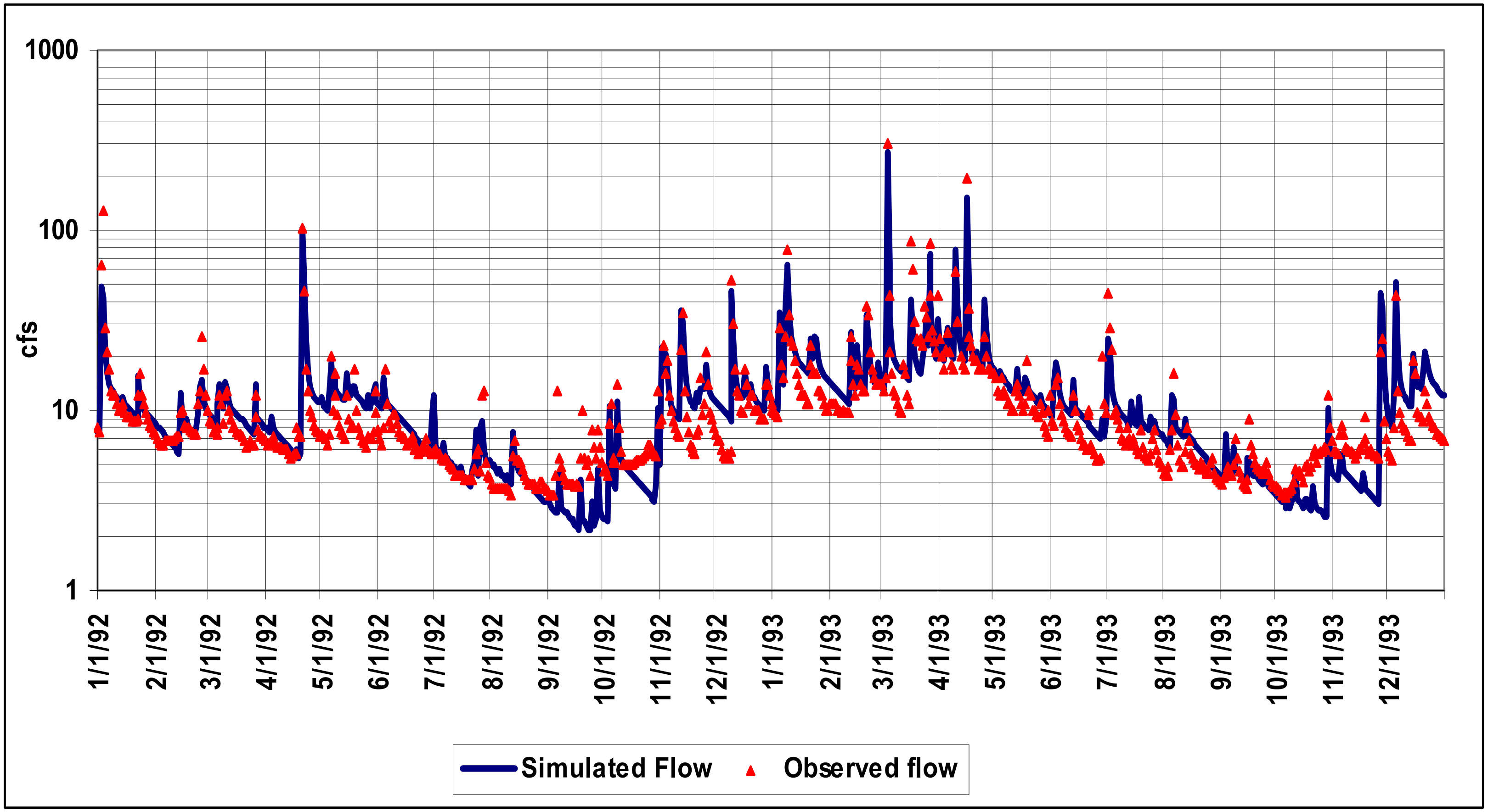

Figure 4-4: Model Hydrologic Calibration Results

4.9.3 Model Hydrologic Validation Results

The period of January 1994 to December 1994 was used to validate the HSPF model. Model validation results at the Georges Creek Station are presented in **Table 4-12**, showing the simulated and observed values for nine flow characteristics. An error statistics summary for seven flow conditions is also presented for this station in **Table 4-13**. The error statistics indicate that the validation results were within the recommended ranges in HSPF. The model's hydrology validation results are plotted in **Figure 4-5**.

Table 4-12: Model Calibration Results Model Validation Results

Category	Simulated	Observed
Total runoff, in inches	15.87	15.2
Total of highest 10% flows, in inches	4.42	5.119
Total of lowest 50% flows, in inches	4.43	4.228
Total storm volume, in inches	1.7	2.26
Baseflow recession rate	0.97	0.96
Summer flow volume, in inches	2.86	2.939
Winter flow volume, in inches	3.56	3.888
Summer storm volume, in inches	0.39	0.5

Table 4-13: Model Calibration Results Model Validation Error Statistics

Category	Current	Criterion
Error in total volume	4.4	± 10.000
Error in low flow recession	-0.01	± 0.01
Error in 50% lowest flows	4.8	± 10.000
Error in 10% highest Flow	-13.7	± 15.000
Seasonal volume error	5.7	± 10.000
Summer Storm Volume Error	2.8	± 15.000

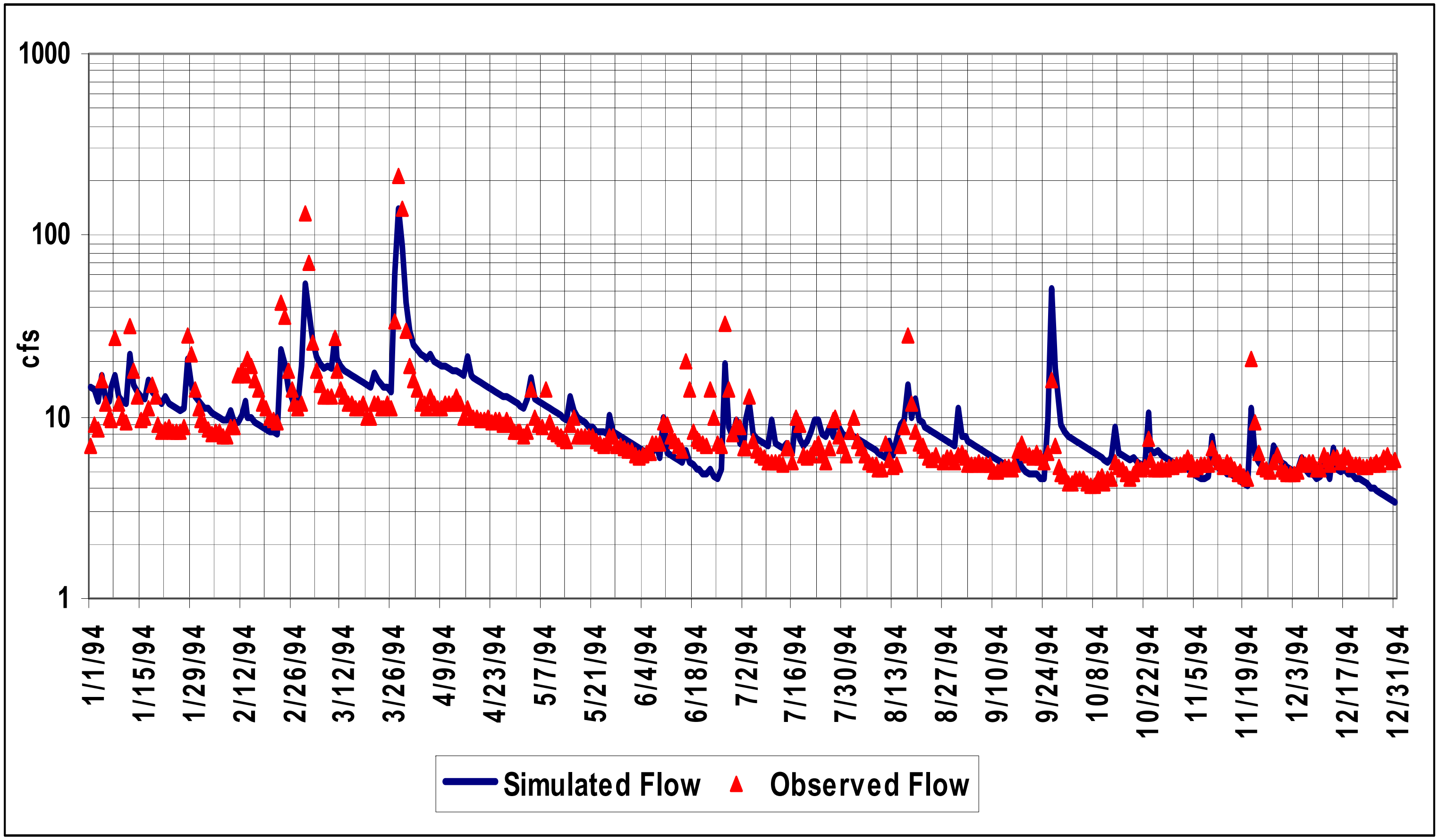

Figure 4-5: Model Hydrologic Validation Results

There is good agreement between the observed and simulated stream flow, indicating that the model parameterization is representative of the hydrologic characteristics of the watershed. Model results closely match the observed flows during low flow conditions, base flow recession, and storm peaks. The final parameter values of the calibrated hydrology model are listed in **Table 4-14**.

Table 4-14: Banister River, Bearskin Creek, Cherrystone Creek, Polecat Creek, Stinking River, Sandy Creek, and Whitehorn Creek HSPF Calibration Parameters (Typical, Possible and Final Values)

Parameter	Definition	Units	Typical		Possible		Banister River, Bearskin Creek, Cherrystone Creek, Polecat Creek, Stinking River, Sandy Creek, and Whitehorn Creek
			Min	Max	Min	Max	
FOREST	Fraction forest cover	None	0.00	0.5	0	1.0	0.0-1.0
LZSN	Lower zone nominal soils moisture	inch	3	8	0.01	100	3.5-5.0
INFILT	Index to infiltration capacity	Inch/hour	0.01	0.25	0.0001	100	0.22-0.24
LSUR	Length of overland flow	Ft	200	500	1	None	250-300
SLSUR	Slope of overland flowpath	None	0.01	0.15	0.00001	10	0.04
KVARY	Groundwater recession variable	1/inch	0	3	0	None	0
AGWRC	Basic groundwater recession	None	0.92	0.99	0.001	0.999	0.97
PETMAX	Air temp below which ET is reduced	Deg F	35	45	None	None	40
PETMIN	Air temp below which ET is set to zero	Deg F	30	35	None	None	32
INFEXP	Exponent in infiltration equation	None	2	2	0	10	2
INFILD	Ratio of max/mean infiltration capacities	None	2	2	1	2	2
DEEPER	Fraction of groundwater inflow to deep recharge	None	0	0.2	0	1.0	0.15
BASETP	Fraction of remaining ET from base flow	None	0	0.05	0	1.0	0.00

Table 4-14: Banister River, Bearskin Creek, Cherrystone Creek, Polecat Creek, Stinking River, Sandy Creek, and Whitehorn Creek HSPF Calibration Parameters (Typical, Possible and Final Values)

AGWETP	Fraction of remaining ET from active groundwater	None	0	0.05	0	1.0	0
CEPSC	Interception storage capacity	Inch	0.03	0.2	0.00	10.0	0.05
UZSN	Upper zone nominal soils moisture	inch	0.10	1	0.01	10.0	0.1-0.25
NSUR	Manning's n	None	0.15	0.35	0.001	1.0	0.20-.30
INTFW	Interflow/surface runoff partition parameter	None	1	3	0	None	0.9
IRC	Interflow recession parameter	None	0.5	0.7	0.001	0.999	0.30
LZETP	Lower zone ET parameter	None	0.2	0.7	0.0	0.999	0.30 - 0.70
ACQOP*	Rate of accumulation of constituent	#/ac day					4.45E6 - 2.09E10
SQOLIM*	Maximum accumulation of constituent	#					8.01E6 - 3.76E10
WSQOP*	Wash-off rate	Inch/hour					0.45-1.00
IOQC*	Constituent concentration in interflow	#/CF					1416
AOQC*	Constituent concentration in active groundwater	#/CF					283
KS*	Weighing factor for hydraulic routing		0.5				0.5
FSTDEC*	First order decay rate of the constituent	1/day	1.152 (FC)				1.152
THFST*	Temperature correction coefficient for FSTDEC	none	1.07				1.07

*Typical values these parameters are unavailable because they are site-specific and determined through model calibration.

4.9.4 Water Quality Calibration

Calibrating the water quality component of the HSPF model involves setting up the build-up, wash-off, and kinetic rates for fecal coliform that best describe fecal coliform sources and environmental conditions in the watershed. It is an iterative process in which the model results are compared to the available in-stream fecal coliform data, and the model parameters are adjusted until there is an acceptable agreement between the observed and simulated in-stream concentrations and the build-up and wash-off rates are within the acceptable ranges.

The availability of water quality data is a major factor in determining calibration and validation periods for the model. In Chapter 3, in-stream monitoring stations on the impaired segments were listed and sampling events conducted on the Banister River, Bearskin Creek, Cherrystone Creek, Polecat Creek, Stinking River, Sandy Creek, and Whitehorn Creek were summarized and presented. **Table 4-15** lists the stations used in the water quality calibration for each impaired segment.

Table 4-15: Water Quality Station used in the HSPF Fecal Coliform Simulations

Watershed	Water Quality Station	HSPF Model Segment
Banister River	4ABAN023.28	7
Cherrystone Creek	4ACRR003.56	39
Polecat Creek	4APEC006.49	63
Stinking River	4ASNE005.30	19
Sandy Creek	4ASNA000.20	54

The period used for water quality calibration of the model, and the period used for model validation depended on the time the water quality observations were collected. It is important to keep in mind that the observed fecal coliform concentrations are instantaneous values that are highly dependent on the time and location the sample was collected. The model-simulated fecal coliform concentrations represent the average daily values.

A total of 8 TMDLs were developed for this report and for clarity reasons only a sample of water quality simulations is shown in **Figure 4-6** and **Figure 4-7**, which depict the simulated water quality at Cherrystone Creek and Sandy Creek, respectively. All the water quality plots are presented in Appendix E for each station.

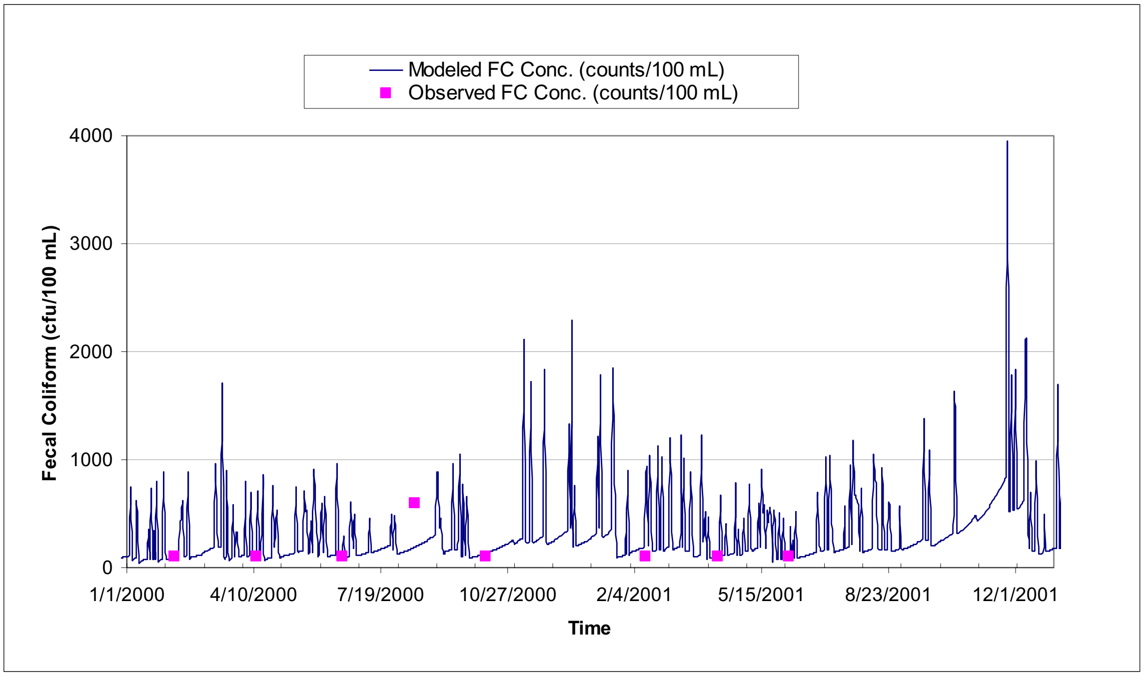

Figure 4-6: Fecal Coliform Calibration Cherrystone Creek (Reach 39)

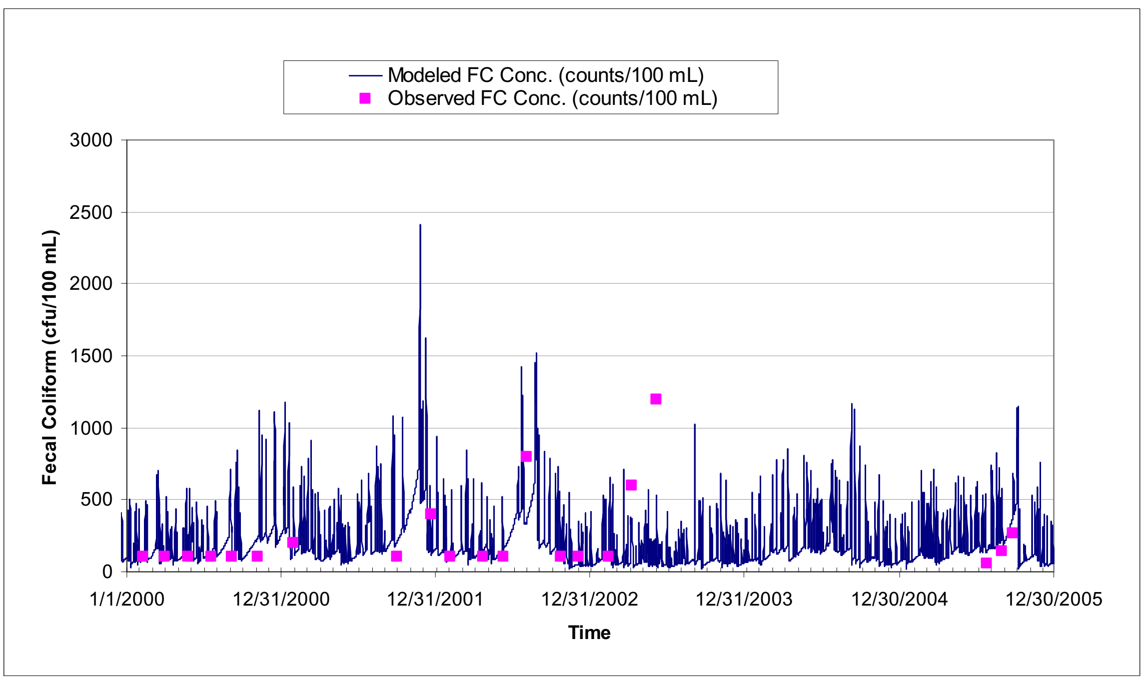

Figure 4-7: Fecal Coliform Validation Sandy Creek (Reach 54)

The goodness of fit for the water quality calibration was evaluated visually. Analysis of the model results indicated that the model was capable of predicting the range of fecal coliform concentrations under both wet and dry weather conditions, and thus was well-calibrated. **Table 4-16** shows the observed and simulated geometric mean fecal coliform concentration spanning the period from 2000 to 2004. **Table 4-17** shows the observed and simulated exceedance rates of the 400 cfu/100 ml instantaneous fecal coliform standard.

Table 4-16: Observed and Simulated Geometric Mean Fecal Coliform Concentration

Station	Reach	Geometric Mean	
		Simulated	Observed
7	Banister River	203	178
19	Stinking River	170	155
39	Cherrysone Cr	125	183
54	Sandy Creek	109	149
63	Polecat Creek	201	134

Table 4-17: Observed and Simulated Exceedance Rates of the 400 cfu/100ml Instantaneous Fecal Coliform Standard

Station	Reach	Exceedances of the Instantaneous Standard	
		Simulated	Observed
7	Banister River	0.10	0.20
19	Stinking River	0.13	0.12
39	Cherrysone Cr	0.13	0.22
54	Sandy Creek	0.14	0.14
63	Polecat Creek	0.23	0.08

4.10 Existing Bacteria Loading

The existing fecal coliform loading for each watershed was calculated based on current watershed conditions. Model input parameters reflected conditions during the period of 2000 to 2005. The standards used for fecal coliform concentrations were a geometric mean standard of 200 cfu/100 ml and an instantaneous standard of 400 cfu/100 ml. For *E. coli* concentrations, the standards used were a geometric mean of 126 cfu/100ml and an instantaneous standard of 235 cfu/100ml (DEQ, 2006). The *E. coli* concentrations in the impaired segments were calculated from fecal coliform concentrations using a regression based instream translator, which is presented below:

$$E.\ coli\ concentration\ (cfu/100\ ml) = 2^{-0.0172}\ x\ (FC\ concentration\ (cfu/100ml))^{0.91905}$$

Below are presented the fecal coliform and *E. coli* existing load distribution by source for each of the impaired segment. The figures depicting the existing conditions for fecal coliform and *E. coli* geometric mean and instantaneous simulations are presented in Appendix F.

4.10.1 Banister River (Segment VAC-L65R-01)

Distribution of the existing fecal coliform load by source in Banister River (Segment VAC-L65R-01) is presented in **Table 4-18**. The corresponding *E. coli* loading is presented in **Table 4-19**. *E. coli* concentrations in the impaired Banister River (Segment VAC-L65R-01) segment were calculated from fecal coliform concentrations using the instream translator. **Table 4-18** and **Table 4-19** show that direct deposition from cattle and wildlife as well as loading from pastures and residential areas (which includes the fecal load from pets) are the predominant sources of bacteria in Banister River (Segment VAC-L65R-01) watershed. However, both wet weather and dry weather conditions were identified as the critical condition. Under wet weather conditions, the indirect deposition loads from pets and wildlife in low residential areas will dominate. Under dry weather conditions, the direct deposition loads from wildlife and cattle will dominate.

Table 4-18: Banister River (Segment VAC-L65R-01) Fecal Coliform Existing Load Distribution

Source	Annual Average Fecal Coliform Loads	
	cfu/year	**%**
Forest	4.94E+11	0.53%
Cropland	1.49E+12	1.60%
Pasture	2.32E+13	24.86%
Low Density Residential/Pets	2.70E+13	28.91%
Medium Density Residential/Pets	9.51E+11	1.02%
High Density Residential/Pets	7.25E+11	0.78%
Commercial/Industrial	6.19E+12	6.63%
Cattle - Direct Deposition	1.45E+13	15.51%
Wildlife-Direct Deposition	1.87E+13	20.03%
Failed Septics & Straight Pipes	4.95E+08	0.00%
Point Source	6.83E+09	0.01%
Total	**9.33E+13**	**100.0%**

Table 4-19: Banister River (Segment VAC-L65R-01) *E. coli* Existing Load Distribution		
Source	**Annual Average *E. Coli* Loads**	
	cfu/year	**%**
Forest	3.14E+11	0.53%
Cropland	9.48E+11	1.60%
Pasture	1.47E+13	24.86%
Low Density Residential/Pets	1.71E+13	28.91%
Medium Density Residential/Pets	6.03E+11	1.02%
High Density Residential/Pets	4.60E+11	0.78%
Commercial/Industrial	3.93E+12	6.63%
Cattle - Direct Deposition	9.19E+12	15.51%
Wildlife-Direct Deposition	1.19E+13	20.03%
Failed Septics & Straight Pipes	3.14E+08	0.00%
Point Source	4.30E+09	0.01%
Total	**5.91E+13**	**100.0%**

4.10.2 Banister River (Segment VAC-L67R-01)

Distribution of the existing fecal coliform load by source in Banister River (Segment VAC-L67R-01) is presented in **Table 4-20**. The corresponding *E. coli* loading is presented in **Table 4-21**. *E. coli* concentrations in the impaired Banister River (Segment VAC-L67R-01) segment were calculated from fecal coliform concentrations using the instream translator. **Table 4-20** and **Table 4-21** show that direct deposition from cattle and wildlife as well as loading from pastures and residential areas (which includes the fecal load from pets) are the predominant sources of bacteria in the Banister River (Segment VAC-L67R-01) watershed. However, both wet weather and dry weather conditions were identified as the critical condition. Under wet weather conditions, the indirect deposition loads from pets and wildlife in low residential areas will dominate as well as the nonpoint source loads from pasture and cropland areas.

Table 4-20: Banister River (Segment VAC-L67R-01) Fecal Coliform Existing Load Distribution		
Source	Annual Average Fecal Coliform Loads	
	cfu/year	%
Forest	6.76E+12	0.49%
Cropland	3.66E+13	2.65%
Pasture	3.10E+14	22.44%
Low Density Residential/Pets	5.78E+14	41.90%
Medium Density Residential/Pets	1.34E+14	9.74%
High Density Residential/Pets	7.47E+13	5.41%
Commercial/Industrial	8.52E+13	6.18%
Cattle - Direct Deposition	5.57E+13	4.03%
Wildlife-Direct Deposition	9.84E+13	7.13%
Failed Septics & Straight Pipes	2.79E+10	0.00%
Point Source	8.48E+10	0.01%
Total	**1.38E+15**	**100%**

Table 4-21: Banister River (Segment VAC-L67R-01) E. coli Existing Load Distribution		
Source	Annual Average E. Coli Loads	
	cfu/year	%
Forest	4.27E+12	0.49%
Cropland	2.31E+13	2.65%
Pasture	1.95E+14	22.44%
Low Density Residential/Pets	3.65E+14	41.90%
Medium Density Residential/Pets	8.48E+13	9.74%
High Density Residential/Pets	4.71E+13	5.41%
Commercial/Industrial	5.38E+13	6.18%
Cattle - Direct Deposition	3.51E+13	4.03%
Wildlife-Direct Deposition	6.21E+13	7.13%
Failed Septics & Straight Pipes	1.76E+10	0.00%
Point Source	5.34E+10	0.01%
Total	**8.70E+14**	**100%**

4.10.3 Bearskin Creek (Segment VAC-L65R-02)

Distribution of the existing fecal coliform load by source in Bearskin Creek (Segment VAC-L65R-02) is presented in **Table 4-22**. The corresponding *E. coli* loading is presented in **Table 4-23**. *E. coli* concentrations in the impaired (VAC-L65R-02) segment were calculated from fecal coliform concentrations using the instream translator. **Table 4-22** and **Table 4-23** show that loading from low density residential areas (which includes the fecal load from pets), pasture, and direct deposition from cattle and wildlife are the predominant sources of bacteria in Bearskin Creek (Segment VAC-L65R-02) watershed. However, both wet weather and dry weather conditions were identified as the critical condition. Under wet weather conditions, the indirect deposition loads from pets and wildlife in low residential areas will dominate as well as the nonpoint source loads from pasture and cropland areas. Under dry weather conditions, the direct-deposition loads from wildlife cattle will dominate.

Table 4-22: Bearskin Creek (Segment VAC-L65R-02) Fecal Coliform Existing Load Distribution

Source	Annual Average Fecal Coliform Loads	
	cfu/year	**%**
Forest	2.61E+11	0.38%
Cropland	9.38E+11	1.38%
Pasture	1.82E+13	26.73%
Low Density Residential/Pets	2.00E+13	29.28%
Medium Density Residential/Pets	3.78E+11	0.55%
High Density Residential/Pets	0.00E+00	0.00%
Commercial/Industrial	4.60E+12	6.74%
Cattle - Direct Deposition	1.23E+13	18.08%
Wildlife-Direct Deposition	1.15E+13	16.86%
Failed Septics & Straight Pipes	2.30E+08	0.00%
Point Source	0.00	0.00%
Total	**6.82E+13**	**100%**

Table 4-23: Bearskin Creek (Segment VAC-L65R-02) E. coli Existing Load Distribution

Source	Annual Average E. Coli Loads	
	cfu/year	**%**
Forest	1.64E+11	0.38%
Cropland	5.88E+11	1.38%
Pasture	1.14E+13	26.73%
Low Density Residential/Pets	1.25E+13	29.28%
Medium Density Residential/Pets	2.37E+11	0.55%
High Density Residential/Pets	0.00E+00	0.00%
Commercial/Industrial	2.88E+12	6.74%
Cattle - Direct Deposition	7.72E+12	18.08%
Wildlife-Direct Deposition	7.20E+12	16.86%
Failed Septics & Straight Pipes	1.44E+08	0.00%
Point Source	0.00E+00	0.00%
Total	**4.27E+13**	**100%**

4.10.4 Cherrystone Creek (Segment VAC-L66R-01)

Distribution of the existing fecal coliform load by source in Cherrystone Creek (Segment VAC-L66R-01) is presented in **Table 4-24**. The corresponding *E. coli* loading is presented in **Table 4-25**. *E. coli* concentrations in the impaired Cherrystone Creek (Segment VAC-L66R-01) segment were calculated from fecal coliform concentrations using the instream translator. **Table 4-24** and **Table 4-25** show that loading from residential areas (which includes the fecal load from pets) and pasture are the predominant sources of bacteria in Cherrystone Creek (Segment VAC-L66R-01) watershed. However, both wet weather and dry weather conditions were identified as the critical condition. Under wet weather conditions, the indirect deposition load from pets and wildlife in low residential areas will dominate. Under dry weather conditions, the direct deposition loads from cattle will dominate.

Table 4-24: Cherrystone Creek (Segment VAC-L66R-01) Fecal Coliform Existing Load Distribution

Source	Annual Average Fecal Coliform Loads	
	cfu/year	%
Forest	5.57E+11	0.21%
Cropland	1.92E+12	0.71%
Pasture	3.48E+13	12.97%
Low Density Residential/Pets	1.08E+14	40.25%
Medium Density Residential/Pets	3.59E+13	13.39%
High Density Residential/Pets	2.22E+13	8.27%
Commercial/Industrial	1.07E+13	4.00%
Cattle - Direct Deposition	2.94E+13	10.95%
Wildlife-Direct Deposition	2.35E+13	8.75%
Failed Septics & Straight Pipes	5.28E+08	0.00%
Point Source	2.46E+10	0.01%
Total	**2.67E+14**	**100%**

Table 4-25: Cherrystone Creek (Segment VAC-L66R-01) E. *coli* Existing Load Distribution		
	Annual Average E. Coli Loads	
Source	**cfu/year**	**%**
Forest	3.32E+11	0.21%
Cropland	1.14E+12	0.71%
Pasture	2.07E+13	12.97%
Low Density Residential/Pets	6.44E+13	40.25%
Medium Density Residential/Pets	2.14E+13	13.39%
High Density Residential/Pets	1.32E+13	8.27%
Commercial/Industrial	6.40E+12	4.00%
Cattle - Direct Deposition	1.75E+13	10.95%
Wildlife-Direct Deposition	1.40E+13	8.75%
Failed Septics & Straight Pipes	3.15E+08	0.00%
Point Source	1.55E+10	0.01%
Total	**1.59E+14**	**100%**

4.10.5 Polecat Creek (Segment VAC-L71R-05)

Distribution of the existing fecal coliform load by source in Polecat Creek (Segment VAC-L71R-05) is presented in **Table 4-26**. The corresponding *E. coli* loading is presented in **Table 4-27**. *E. coli* concentrations in the impaired Polecat Creek (Segment VAC-L71R-05) segment were calculated from fecal coliform concentrations using the instream translator. **Table 4-26** and **Table 4-27** show that loading from residential areas (which includes the fecal load from pets), pasture, and direct deposition from wildlife are the predominant sources of bacteria in Polecat Creek (Segment VAC-L71R-05) watershed. However, both wet weather and dry weather conditions were identified as the critical condition. Under wet weather conditions, the direct deposition load from pets and wildlife in low residential areas will dominate. Under dry weather conditions, the direct loads from cattle and wildlife will dominate.

Table 4-26: Polecat Creek (Segment VAC-L71R-05) Fecal Coliform Existing Load Distribution		
Source	Annual Average Fecal Coliform Loads	
	cfu/year	%
Forest	2.93E+11	0.73%
Cropland	9.55E+11	2.38%
Pasture	1.09E+13	27.11%
Low Density Residential/Pets	8.11E+12	20.20%
Medium Density Residential/Pets	2.90E+11	0.72%
High Density Residential/Pets	5.05E+11	1.26%
Commercial/Industrial	2.81E+12	6.99%
Cattle - Direct Deposition	5.36E+12	13.37%
Wildlife-Direct Deposition	1.09E+13	27.25%
Failed Septics & Straight Pipes	1.97E+08	0.00%
Point Source	0.00E+00	0.00%
Total	**4.01E+13**	**100%**

Table 4-27: Polecat Creek (Segment VAC-L71R-05) E. *coli* Existing Load Distribution		
Source	Annual Average E. Coli Loads	
	cfu/year	%
Forest	1.90E+11	0.73%
Cropland	6.18E+11	2.38%
Pasture	7.04E+12	27.11%
Low Density Residential/Pets	5.25E+12	20.20%
Medium Density Residential/Pets	1.88E+11	0.72%
High Density Residential/Pets	3.27E+11	1.26%
Commercial/Industrial	1.82E+12	6.99%
Cattle - Direct Deposition	3.47E+12	13.37%
Wildlife-Direct Deposition	7.08E+12	27.25%
Failed Septics & Straight Pipes	1.28E+08	0.00%
Point Source	0.00E+00	0.00%
Total	**2.60E+13**	**100%**

4.10.6 Sandy Creek (Segment VAC-L70R-01)

Distribution of the existing fecal coliform load by source in Sandy Creek (Segment VAC-L70R-01) is presented in **Table 4-28**. The corresponding *E. coli* loading is presented in **Table 4-29**. *E. coli* concentrations in the impaired segment were calculated from fecal coliform concentrations using the instream translator. **Table 4-28** and **Table 4-29** show that loading from residential (which includes the fecal load from pets) and pasture areas and direct deposition from wildlife and cattle are the predominant sources of bacteria in Sandy Creek (Segment VAC-L70R-01) watershed. Under wet weather conditions, the direct deposition load from pets and wildlife in low residential areas will dominate. Under dry weather conditions, the direct loads from cattle and wildlife will dominate.

Table 4-28: Sandy Creek (Segment VAC-L70R-01) Fecal Coliform Existing Load Distribution

Source	Annual Average Fecal Coliform Loads	
	cfu/year	**%**
Forest	1.49E+12	0.55%
Cropland	7.72E+12	2.87%
Pasture	5.75E+13	21.40%
Low Density Residential/Pets	8.84E+13	32.91%
Medium Density Residential/Pets	1.44E+13	5.35%
High Density Residential/Pets	9.64E+11	0.36%
Commercial/Industrial	1.41E+13	5.24%
Cattle - Direct Deposition	2.86E+13	10.64%
Wildlife-Direct Deposition	5.55E+13	20.66%
Failed Septics & Straight Pipes	3.99E+09	0.00%
Point Source	2.05E+10	0.01%
Total	**2.69E+14**	**100%**

Table 4-29:Sandy Creek (Segment VAC-L70R-01)E. *coli* Existing Load Distribution

Source	Annual Average E. Coli Loads	
	cfu/year	**%**
Forest	9.42E+11	0.55%
Cropland	4.89E+12	2.87%
Pasture	3.64E+13	21.40%
Low Density Residential/Pets	5.60E+13	32.91%
Medium Density Residential/Pets	9.11E+12	5.35%
High Density Residential/Pets	6.11E+11	0.36%
Commercial/Industrial	8.92E+12	5.24%
Cattle - Direct Deposition	1.81E+13	10.64%
Wildlife-Direct Deposition	3.52E+13	20.66%
Failed Septics & Straight Pipes	2.52E+09	0.00%
Point Source	1.29E+10	0.01%
Total	**1.70E+14**	**100%**

4.10.7 Stinking River (Segment VAC-L69R-01)

Distribution of the existing fecal coliform load by source in Stinking River (Segment VAC-L69R-01) is presented in **Table 4-30**. The corresponding *E. coli* loading is presented in **Table 4-31**. *E. coli* concentrations in the impaired Stinking River (Segment VAC-L69R-01) segment were calculated from fecal coliform concentrations using the instream translator. **Table 4-30** and **Table 4-31** show that loading from residential and pasture areas(which includes the fecal load from pets) and direct deposition from wildlife and cattle are the predominant sources of bacteria in Stinking River (Segment VAC-L69R-01) watershed. Under wet weather conditions, the direct deposition load from pets and wildlife in low residential areas will dominate. Under dry weather conditions, the direct loads from cattle and wildlife will dominate.

Table 4-30: Stinking River (Segment VAC-L69R-01)Fecal Coliform Existing Load Distribution

	Annual Average Fecal Coliform Loads	
Source	**cfu/year**	**%**
Forest	4.74E+11	0.47%
Cropland	3.95E+12	3.97%
Pasture	2.36E+13	23.66%
Low Density Residential/Pets	3.02E+13	30.30%
Medium Density Residential/Pets	1.30E+12	1.30%
High Density Residential/Pets	0.00E+00	0.00%
Commercial/Industrial	7.06E+12	7.08%
Cattle - Direct Deposition	1.45E+13	14.57%
Wildlife-Direct Deposition	1.86E+13	18.65%
Failed Septics & Straight Pipes	2.30E+08	0.00%
Point Source	0.00E+00	0.00%
Total	**9.97E+13**	**100%**

Table 4-31: Stinking River (Segment VAC-L69R-01)E. *coli* Existing Load Distribution

	Annual Average E. Coli Loads	
Source	**cfu/year**	**%**
Forest	2.99E+11	0.47%
Cropland	2.49E+12	3.97%
Pasture	1.49E+13	23.66%
Low Density Residential/Pets	1.91E+13	30.30%
Medium Density Residential/Pets	8.18E+11	1.30%
High Density Residential/Pets	0.00E+00	0.00%
Commercial/Industrial	4.45E+12	7.08%
Cattle - Direct Deposition	9.17E+12	14.57%
Wildlife-Direct Deposition	1.17E+13	18.65%
Failed Septics & Straight Pipes	1.45E+08	0.00%
Point Source	0.00E+00	0.00%
Total	**6.29E+13**	**100%**

4.10.8 Whitehorn Creek (Segment VAC-L68R-01)

Distribution of the existing fecal coliform load by source in Whitehorn Creek (Segment VAC-L68R-01) is presented in **Table 4-32.** The corresponding *E. coli* loading is presented in **Table 4-33** *E. coli* concentrations in the impaired Whitehorn Creek (Segment VAC-L68R-01) segment were calculated from fecal coliform concentrations using the instream translator. **Table 4-32** and **Table 4-33** show that loading from residential (which includes the fecal load from pets) and pasture areas are the predominant sources of bacteria in the Whitehorn Creek (Segment VAC-L68R-01) watershed. However, both wet weather and dry weather conditions were identified as the critical condition. Under wet weather conditions, the indirect deposition loads from pets and wildlife in low residential areas will dominate. Under dry weather conditions, the direct deposition loads from wildlife cattle will dominate.

Table 4-32: Whitehorn Creek (Segment VAC-L68R-01) Fecal Coliform Existing Load Distribution

Source	Annual Average Fecal Coliform Loads	
	cfu/year	**%**
Forest	7.92E+11	0.23%
Cropland	6.00E+12	1.71%
Pasture	5.10E+13	14.51%
Low Density Residential/Pets	1.68E+14	47.76%
Medium Density Residential/Pets	2.92E+13	8.31%
High Density Residential/Pets	1.54E+13	4.37%
Commercial/Industrial	1.49E+13	4.23%
Cattle - Direct Deposition	3.12E+13	8.88%
Wildlife-Direct Deposition	3.45E+13	9.81%
Failed Septics & Straight Pipes	4.23E+09	0.00%
Point Source	1.38E+10	0.004%
Total	**3.51E+14**	**100%**

Table 4-33: Whitehorn Creek (Segment VAC-L68R-01) E. *coli* Existing Load Distribution

Source	Annual Average E. Coli Loads	
	cfu/year	**%**
Forest	4.75E+11	0.23%
Cropland	3.60E+12	1.71%
Pasture	3.06E+13	14.51%
Low Density Residential/Pets	1.01E+14	47.76%
Medium Density Residential/Pets	1.75E+13	8.31%
High Density Residential/Pets	9.22E+12	4.37%
Commercial/Industrial	8.93E+12	4.23%
Cattle - Direct Deposition	1.87E+13	8.88%
Wildlife-Direct Deposition	2.07E+13	9.81%
Failed Septics & Straight Pipes	2.54E+09	0.00%
Point Source	8.70E+09	0.004%
Total	**2.11E+14**	**100%**

5.0 Allocation

For the Banister River, Bearskin Creek, Cherrystone Creek, Polecat Creek, Stinking River, Sandy Creek, and Whitehorn Creek TMDLs, allocation analysis was the third stage in development. Its purpose was to develop the framework for reducing bacteria loading under the existing watershed conditions so water quality standards can be met. The TMDL represents the maximum amount of pollutant that the stream can receive without exceeding the water quality standard. The load allocations for the selected scenarios were calculated using the following equation:

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

Where,

WLA = waste load allocation (point source contributions);

LA = load allocation (nonpoint source allocation); and

MOS = margin of safety.

Typically, several potential allocation strategies would achieve the TMDL endpoint and water quality standards. Available control options depend on the number, location, and character of pollutant sources.

5.1 Incorporation of Margin of Safety

The margin of safety (MOS) is a required component of the TMDL to account for any lack of knowledge concerning the relationship between effluent limitations and water quality. According to EPA guidance (*Guidance for Water Quality-Based Decisions: The TMDL Process, 1991*), the MOS can be incorporated into the TMDL using two methods:

- Implicitly incorporating the MOS using conservative model assumptions to develop allocations; or
- Explicitly specifying a portion of the TMDL as the MOS and using the remainder for allocations.

The MOS will be implicitly incorporated into this TMDL. Implicitly incorporating the MOS will require that allocation scenarios be designed to meet the monthly fecal *coli*form geometric mean standard of 200 cfu/100 mL and the instantaneous fecal *coli*form standard of 400 cfu/100 mL with 0% exceedance. In terms of *E. coli*, incorporating an implicit MOS will require that the allocation scenario be designed to meet the monthly geometric mean standard of 126 cfu/100 mL and the instantaneous standard of 235 cfu/100 mL with 0 violations.

5.2 Sensitivity Analysis

The sensitivity analysis of the fecal coliform loadings and the waterbody response provides a better understanding of the watershed conditions that lead to the water quality standard violations, and provides insight and direction in developing the TMDL allocations and implementation. Based on the sensitivity analysis, several allocation scenarios were developed. For each scenario developed, the percent of days water quality conditions violate the monthly geometric mean standard and instantaneous standard for *E. coli* were calculated. The results of the sensitivity analysis are presented in Appendix G.

5.3 Allocation Scenario Development

Allocation scenarios were modeled using the calibrated HSPF model to adjust the existing conditions until the water quality standard was attained. The TMDLs developed for Banister River, Bearskin Creek, Cherrystone Creek, Polecat Creek, Stinking River, Sandy Creek, and Whitehorn Creek were based on the Virginia water quality criteria for *E. coli*. As detailed in Section 1.2, the *E. coli* standard states that the calendar month geometric-mean concentration shall not exceed 126 cfu/100 mL, and that a maximum single sample concentration of *E. coli* shall not exceed 235 cfu/100 mL. According to the guidelines put forth by the DEQ (DEQ, 2003) for modeling *E. coli* with HSPF, the model was set up to estimate loads of fecal coliform. The fecal coliform model output then processed to convert concentrations to *E. coli* using the following equation:

$$\log_2 (C_{ec}) = -0.0172+0.91905*\log2(c_{fc})$$

Where C_{ec} is the concentration of *E. coli* in cfu/100 mL, and C_{fc} is the concentration of fecal coliform in cfu/100 mL.

The pollutant concentrations were simulated over the entire duration of a representative modeling period, and pollutant loads were adjusted until the standard was met. The pollutant loads were calculated at the outlet of each impaired segment and include the loads from all upstream reaches and WLAs. The development of the allocation scenarios was an iterative process requiring numerous runs where each run was followed by an assessment of source reduction against the water quality target. The long-term average *E. Coli* loads and coefficient of variations were determined to implement the final allocation scenarios and to express the TMDL on a daily basis. Assuming a log-normal distribution of data and a probability of occurrence of 95%, the maximum daily loads were determined using the following equation (*USEPA OWOW 2007 Options for Expressing Daily Loads in TMDLs*):

$$MDL = LTA \times Exp[z\sigma - 0.5\sigma^2]$$

Where;

MDL = maximum daily limit (cfu/day)

LTA = long-term average (cfu/day)

z = z statistic of the probability of occurrence

$\sigma^2 = \ln(CV^2+1)$

CV = coefficient of variation

The following sections present the waste load allocation (WLA) and load allocations (LA) for the eight impaired segments.

5.4 Waste Load Allocation

This section outlines the waste load allocations (WLA) for each impaired segment. It presents the existing and allocated loads for each permitted (VPDES) facility contributing to the impaired segment.

The existing load for general domestic permits is based on the allowable flow rate of 1,000 gal/day and a maximum *E. coli* concentration of 126 cfu/100 ml. The allocated load for domestic sewage facilities is based on the actual design flow of the system as presented in **Table 3-17**. This load is computed by applying a factor of five to the actual design flow of the system to account for future growth. While the growth-expanded

WLA is presented individually for each facility, it will be allocated to both new and existing facilities at the discretion of the permitting agency staff through permit issuances.

In general, the waste load allocation for point sources under individual VPDES permits was set assuming that they were operating at five times their design flow at their permitted maximum average concentration. The factor of five was introduced as a conservative measure to account for potential growth. This growth-expanded allocation for the individual permitted facilities was calculated and presented based on the current design limits of existing permits in the watershed, but it will be allocated to both new and existing permits as needed on a first-come, first-served basis. All current permit limits remain in effect and can only be altered through the VADEQ permitting process. Allocation of bacteria loadings shall be determined at the discretion of DEQ staff.

5.5 Load Allocation Development

The reduction of loadings from nonpoint sources, including livestock and wildlife direct deposition, is incorporated into the load allocation. A number of load allocation scenarios were developed in order to determine the final TMDL load allocation. Fecal coliform loading and instream fecal coliform concentrations were estimated for each potential scenario using the HSPF model for the hydrologic period of January 2000 to December 2005. **Table 5-1** shows the key load allocation scenarios that were implemented to arrive at the final TMDL allocations. It should be noted that these key scenarios were implemented for all segments. However, additional scenarios were also implemented when deemed necessary to attain the final TMDL. The following is a brief summary of the key scenarios:

- Scenario 0 is the existing load, no reduction of any of the sources.
- Scenario 1 represents elimination of human sources (septic systems and straight pipes).
- Scenario 2 represents the elimination of human sources (septic systems and straight pipes) as well as half the direct instream loading from livestock.
- Scenario 3 represents elimination of the human sources (septic systems and straight pipes) as well as the direct instream loading from livestock.
- Scenario 4 represents the direct instream loading from wildlife (all other sources are eliminated).
- Scenario 5 represents the elimination of the direct loading from nonpoint sources and a 50% reduction of the wildlife contribution.

- Scenario 6 represents the elimination of the direct loading from nonpoint sources and a 75% reduction of wildlife contribution

Table 5-1: TMDL Load Allocation Scenarios (%Reduction)

Scenario	Failed Septic & Pipes	Direct Livestock	NPS (Agriculture)	NPS (Urban)	Direct Wildlife
0	0	0	0	0	0
1	100	0	0	0	0
2	100	50	0	0	0
3	100	100	0	0	0
4	100	100	100	100	0
5	100	100	0	0	50
6	100	100	0	0	75

The estimated load reductions and percent exceedences under each scenario for the different impaired segments derived from these allocation scenarios are presented separately in Appendix H. The fecal coliform monthly loads under existing and allocated conditions are shown in Appendix I. In addition, the percent of days the 126 cfu/100mL *E. coli* geometric mean water quality standard and the 235 cfu/100mL *E. coli* instantaneous water quality standard were violated under each scenario are presented.

5.6 Banister River (Segment VAC-L65R-01)

5.6.1 Banister River (Segment VAC-L65R-01) Waste Load Allocation

There are no permitted facilities currently discharging bacteria to Banister River (Segment VAC-L65R-01).

5.6.2 Banister River (Segment VAC-L65R-01) Allocation Plan and TMDL Summary

The requirements to meet the calendar month *E. coli* geometric mean water quality standard of 126 cfu/100mL and the instantaneous water quality standard of 235 cfu/100mL for Banister River (Segment VAC-L65R-01) are **(Table 5-2)**:

- 100 % reduction of the human sources (failed septic systems and straight pipes).
- 100 % reduction of the direct instream loading from livestock.
- 81 % reduction of bacteria loading from agricultural and urban nonpoint sources.
- 35% reduction of bacteria loading from direct deposition from wildlife
- No reductions from the forested land (wildlife indirect loads)

The coefficient of variation of the simulated daily loads for Banister River (Segment VAC-L65R-01) is 1.76.

Table 5-2: Banister River (Segment VAC-L65R-01) Distribution of *E. coli* Load under Existing Conditions and TMDL Allocation

Land Use/Source	Annual Average *E. coli* Loads (cfu/yr) Existing	Modeled Loads for Allocation	Reduction (%)	Maximum Daily Loads (MDL) for Allocation (cfu/day)
Forest	3.14E+11	3.14E+11	0.0%	2.99E+09
Cropland	9.48E+11	1.80E+11	81.0%	1.72E+09
Pasture	1.47E+13	2.80E+12	81.0%	2.67E+10
Low Density Residential/Pets	1.71E+13	3.25E+12	81.0%	3.11E+10
Medium Density Residential/Pets	6.03E+11	1.15E+11	81.0%	1.09E+09
High Density Residential/Pets	4.60E+11	8.75E+10	81.0%	8.35E+08
Commercial/Industrial	3.93E+12	7.46E+11	81.0%	7.12E+09
Cattle - Direct Deposition	9.19E+12	0.00E+00	100.0%	0.00E+00
Wildlife-Direct Deposition	1.19E+13	7.71E+12	35.0%	7.36E+10
Failed Septics & Straight Pipes	3.14E+08	0.00E+00	100.0%	0.00E+00
Point Source*	8.86E+10	1.52E+11	0.0%	4.17E+08
Total Loads/Overall Reductions	**5.92E+13**	**1.54E+13**	**74.1%**	**1.46E+11**

(*) there are no individual VPDES municipal point source dischargers; the WLA includes 1 percent of the total NPS allocations to account for future growth as well as allocated bacteria loads from the domestic sewage discharges

The resulting geometric mean and instantaneous *E. coli* concentrations under the TMDL allocation plan are presented in **Figure 5-1** and **Figure 5-2.** **Figure 5-1** shows the calendar month geometric mean *E. coli* concentrations for existing as well as allocation conditions. **Figure 5-2** shows the instantaneous *E. coli* concentrations under the allocations, as well as under existing conditions. For Banister River (Segment VAC-L65R-01), the allocation results in bacteria concentrations that are consistently below both the geometric mean and instantaneous standards for *E. coli*. A summary of the TMDL allocation plan loads for Banister River (Segment VAC-L67R-01) is presented in **Table 5-3**.

Table 5-3:Banister River (Segment VAC-L65R-01) TMDL Allocation Plan Loads (cfu/day) for *E. coli*			
WLA (Point Sources)	**LA (Nonpoint sources)**	**MOS (Margin of safety)**	**TMDL**
4.17E+08	1.45E+11	IMPLICT	1.46E+11

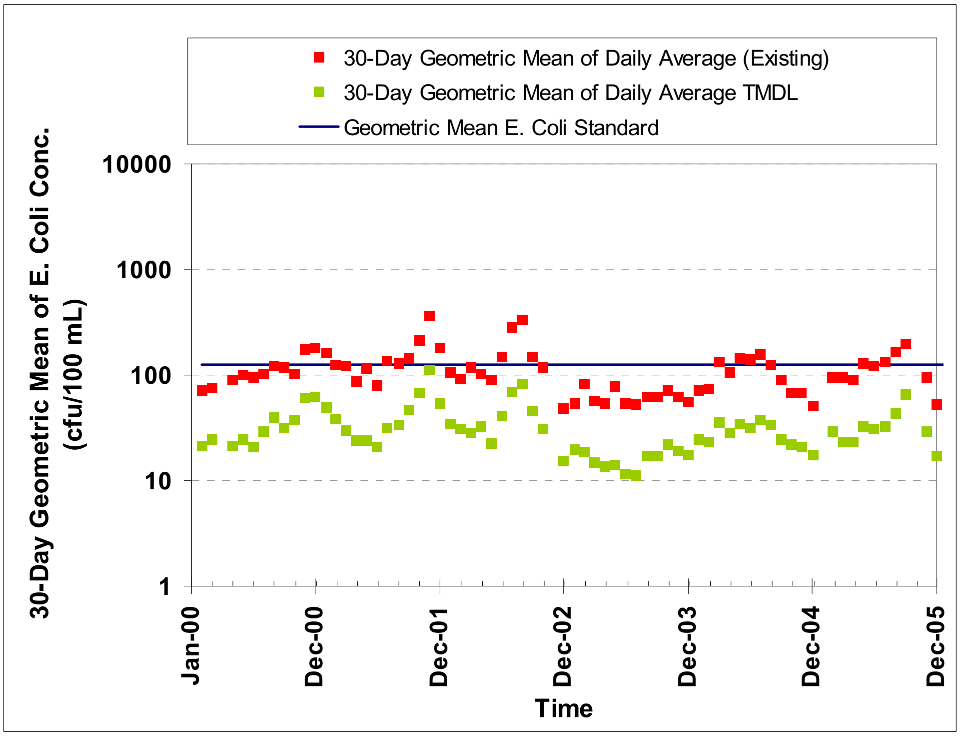

Figure 5-1: Banister River (Segment VAC-L65R-01) Geometric Mean *E. coli* Concentrations under Existing Conditions and the Allocation Scenario

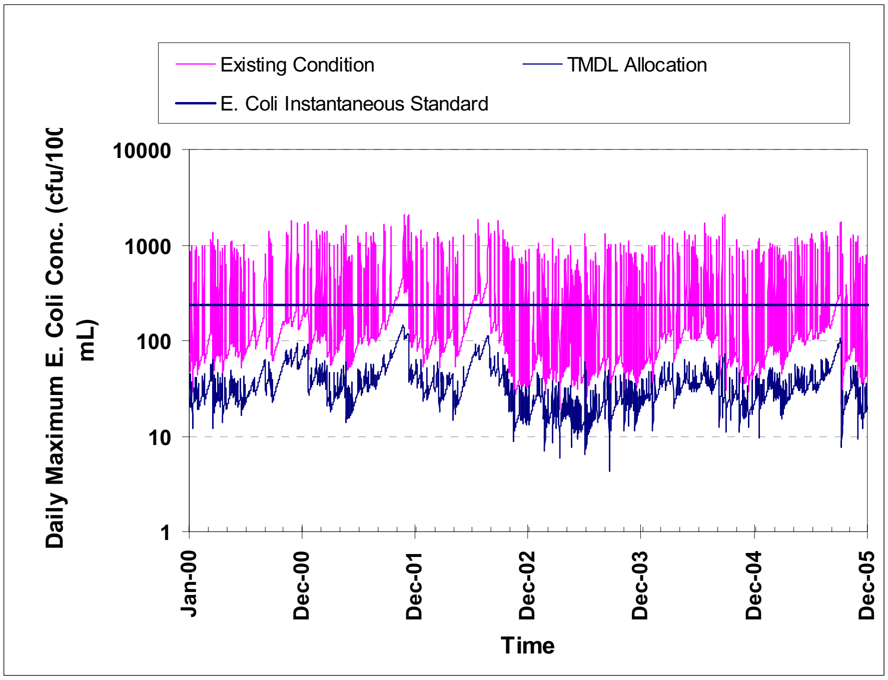

Figure 5-2: Banister River (Segment VAC-L65R-01) Instantaneous *E. coli* Concentrations under Existing Conditions and the Allocation Scenario

5.7 Banister River (Segment VAC-L67R-01)

5.7.1 Banister River Segment (VAC-L67R-01) Waste Load Allocation

There are five general domestic sewage permitted facilities, but no VPDES facility permitted to discharge bacteria to Banister River (Segment VAC-L67R-01). For this TMDL, following DEQ guidance the waste load allocation for such facilities is to assume the discharge at five-times the design flow limits and bacteria concentrations at the existing *E. coli* standard of 126 cfu/100mL. **Table 5-4** shows the existing and allocated loads of dischargers in Banister River (Segment VAC-L67R-01)

Table 5-4: Banister River (Segment VAC-L67R-01) Waste load Allocation for *E. coli*

Point Source	Facility Type	Existing Load (cfu/yr)	Allocated Load (cfu/yr)	Percent Reduction
VAG407226	Domestic Sewage Discharge	1.04E+09	5.20E+09	-
VAG402031	Domestic Sewage Discharge	1.74E+09	8.70E+09	-
VAG407210	Domestic Sewage Discharge	1.74E+09	8.70E+09	-
VAG402084	Domestic Sewage Discharge	5.22E+08	2.61E+09	-
VAG407202	Domestic Sewage Discharge	5.22E+08	2.61E+09	-
Total		**5.56E+09**	**2.78E+10**	-

5.7.2 Banister River (Segment VAC-L67R-01) Allocation Plan and TMDL Summary

The requirements to meet the calendar month *E. coli* geometric mean water quality standard of 126 cfu/100mL and the instantaneous water quality standard of 235 cfu/100mL for Banister River (Segment VAC-L67R-01) are **(Table 5-5)**:

- 100 % reduction of the human sources (failed septic systems and straight pipes).
- 100 % reduction of the direct instream loading from livestock.
- 92 % reduction of bacteria loading from agricultural and urban nonpoint sources.
- 35% reduction of bacteria loading from direct deposition from wildlife
- No reductions from the forested land (wildlife indirect loads)

The coefficient of variation of the simulated daily loads for the Banister River (Segment VAC-L67R-01) is 1.50.

Table 5-5: Banister River (Segment VAC-L67R-01) Distribution of *E. coli* Load under Existing Conditions and TMDL Allocation

Land Use/Source	Annual Average *E. coli* Loads (cfu/yr)		Reduction (%)	Maximum Daily Loads (MDL) for Allocation
	Existing	Modeled Loads for Allocation		(cfu/day)
Forest	4.27E+12	4.27E+12	0.00%	3.87E+10
Cropland	2.31E+13	1.85E+12	92.00%	1.67E+10
Pasture	1.95E+14	1.56E+13	92.00%	1.42E+11
Low Density Residential/Pets	3.65E+14	2.92E+13	92.00%	2.64E+11
Medium Density Residential/Pets	8.48E+13	6.79E+12	92.00%	6.15E+10
High Density Residential/Pets	4.71E+13	3.77E+12	92.00%	3.42E+10
Commercial/Industrial	5.38E+13	4.30E+12	92.00%	3.90E+10
Cattle - Direct Deposition	3.51E+13	0.00E+00	100.00%	0.00E+00
Wildlife-Direct Deposition	6.21E+13	4.04E+13	35.00%	3.66E+11
Failed Septics & Straight Pipes	1.76E+10	0.00E+00	100.00%	0.00E+00
Point Source	5.56E+09	2.78E+10	0.00%	2.78E+10
Total Loads/Overall Reductions	**8.70E+14**	**1.06E+14**	**87.80%**	**9.89E+11**

The resulting geometric mean and instantaneous *E. coli* concentrations under the TMDL allocation plan are presented in **Figure 5-1** and **Figure 5-2. Figure 5-1** shows the calendar month geometric mean *E. coli* concentrations for existing as well as allocation conditions. **Figure 5-2** shows the instantaneous *E. coli* concentrations under the allocations, as well as under existing conditions. For Banister River (Segment VAC-L67R-01), the allocation results in bacteria concentrations that are consistently below both the geometric mean and instantaneous standards for *E. coli*. A summary of the TMDL allocation plan loads for Banister River (Segment VAC-L67R-01) is presented in **Table 5-6**.

Table 5-6:Banister River (Segment VAC-L67R-01) TMDL Allocation Plan Loads (cfu/day) for *E. coli*			
WLA (Point Sources)	**LA (Nonpoint sources)**	**MOS(Margin of safety)**	**TMDL**
7.62E+07	9.61E+11	IMPLICT	9.62E+11

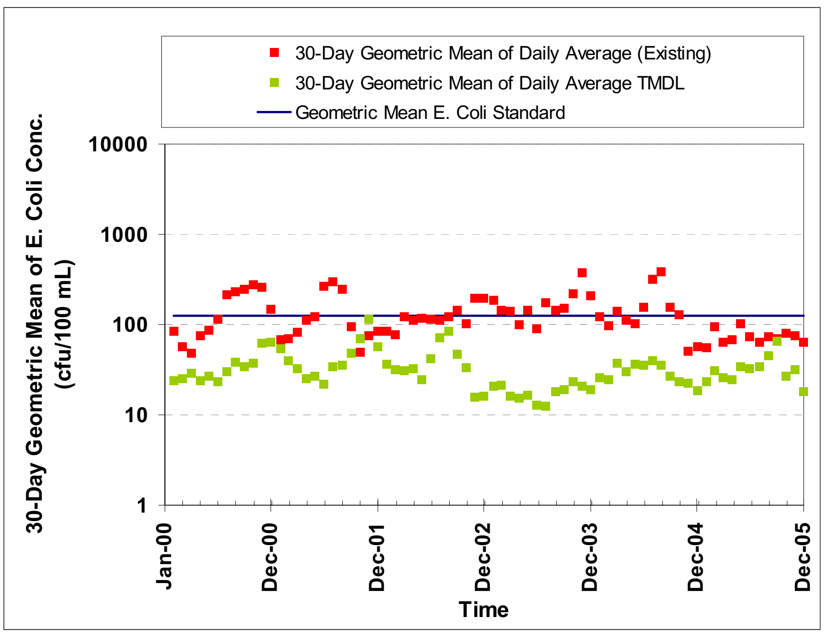

Figure 5-3: Banister River (Segment VAC-L67R-01) Geometric Mean *E. coli* Concentrations under Existing Conditions and the Allocation Scenario

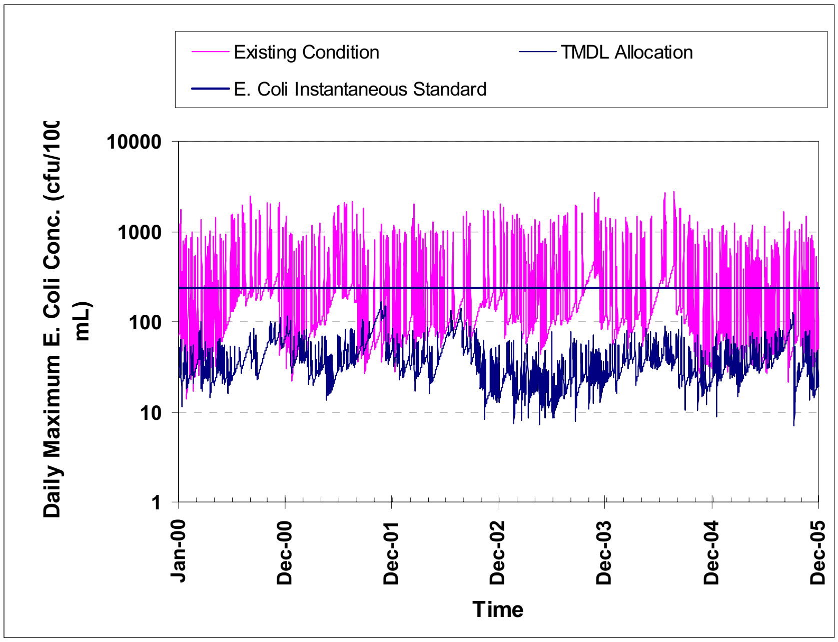

Figure 5-4: Banister River (Segment VAC-L67R-01) Instantaneous *E. coli* Concentrations under Existing Conditions and the Allocation Scenario

5.8 Bearskin Creek (Segment VAC-L65R-02)

5.8.1 Bearskin Creek Segment (VAC-L65R-02) Waste Load Allocation

There are no permitted faculties currently discharging bacteria to Bearskin Creek (Segment VAC-L65R-02).

5.8.2 Bearskin Creek (Segment VAC-L65R-02) Allocation Plan and TMDL Summary

The requirements to meet the calendar month *E. coli* geometric mean water quality standard of 126 cfu/100mL and the instantaneous water quality standard of 235 cfu/100mL for Bearskin Creek (Segment VAC-L65R-02) are:

- 100 % reduction of the human sources (failed septic systems and straight pipes).
- 100 % reduction of the direct instream loading from livestock.
- 83 % reduction of bacteria loading from agricultural and urban nonpoint sources.
- 40% reduction of bacteria loading from direct deposition from wildlife
- No reductions from the forested land (wildlife indirect loads)

The coefficient of variation of the simulated daily loads for Bearskin Creek (Segment VAC-L65R-02) is 2.63.

Waste load allocations in watersheds where there are no individual VPDES permitted facilities containing bacteria effluent limitations are usually represented in the TMDL as 1% of the Total Maximum Daily Load. This 1% is then subtracted from the Load allocations. This is reflected in **Table 5-7** which shows the *E. coli* TMDL allocation plan for Bearskin Creek (Segment VAC-L65R-02).

Table 5-7: Bearskin Creek (Segment VAC-L65R-02) Distribution of *E. coli* Load under Existing Conditions and TMDL Allocation

Land Use/Source	Annual Average *E. coli* Loads (cfu/yr)		Reduction (%)	Maximum Daily Loads (MDL) for Allocation
	Existing	Modeled Loads for Allocation		(cfu/day)
Forest	1.64E+11	1.64E+11	0.0%	1.67E+09
Cropland	5.88E+11	9.99E+10	83.0%	1.02E+09
Pasture	1.14E+13	1.94E+12	83.0%	1.98E+10
Low Density Residential/Pets	1.25E+13	2.13E+12	83.0%	2.17E+10
Medium Density Residential/Pets	2.37E+11	4.02E+10	83.0%	4.11E+08
High Density Residential/Pets	0.00E+00	0.00E+00	83.0%	0.00E+00
Commercial/Industrial	2.88E+12	4.90E+11	83.0%	5.00E+09
Cattle - Direct Deposition	7.72E+12	0.00E+00	100.0%	0.00E+00
Wildlife-Direct Deposition	7.20E+12	4.32E+12	40.0%	4.41E+10
Failed Septics & Straight Pipes	1.44E+08	0.00E+00	100.0%	0.00E+00
Point Source*	0.00E+00	9.18E+10	0.0%	2.52E+08
Total Loads/Overall Reductions	**4.27E+13**	**9.27E+12**	**78.3%**	**9.40E+10**

(*) there are no individual VPDES municipal point source dischargers; the WLA includes 1 percent of the total NPS allocations to account for future growth as well as allocated bacteria loads from the domestic sewage discharges

The resulting geometric mean and instantaneous *E. coli* concentrations under the TMDL allocation plan are presented in **Figure 5-5** and **Figure 5-6.** **Figure 5-5** shows the calendar month geometric mean *E. coli* concentrations for existing as well as allocation conditions. **Figure 5-6** shows the instantaneous *E. coli* concentrations under the allocations, as well as under existing conditions. For Banister River (Segment VAC-L67R-01), the allocation results in bacteria concentrations that are consistently below both the geometric mean and instantaneous standards for *E. coli*. A summary of the TMDL allocation plan loads for Bearskin Creek (Segment VAC-L65R-02) is presented in **Table 5-8**.

Table 5-8: Bearskin Creek (Segment VAC-L65R-02) TMDL Allocation Plan Loads (cfu/day) for *E. coli*

WLA (Point Sources)	LA (Nonpoint sources)	MOS (Margin of safety)	TMDL
2.52E+08	9.38E+10	IMPLICT	9.40E+10

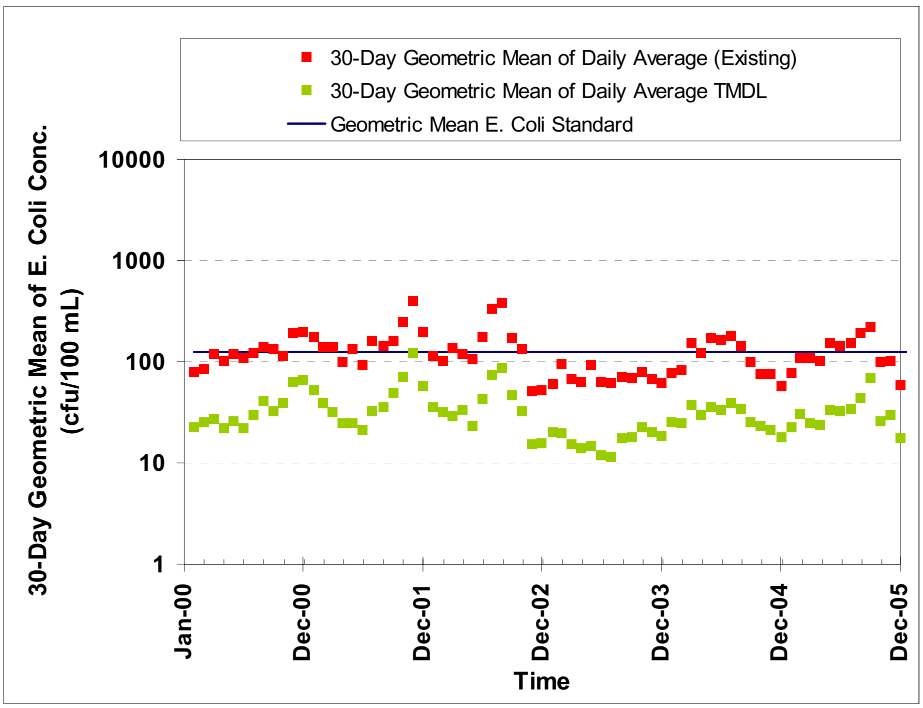

Figure 5-5: Bearskin Creek (Segment VAC-L65R-02) Geometric Mean *E. coli* Concentrations under Existing Conditions and the Allocation Scenario

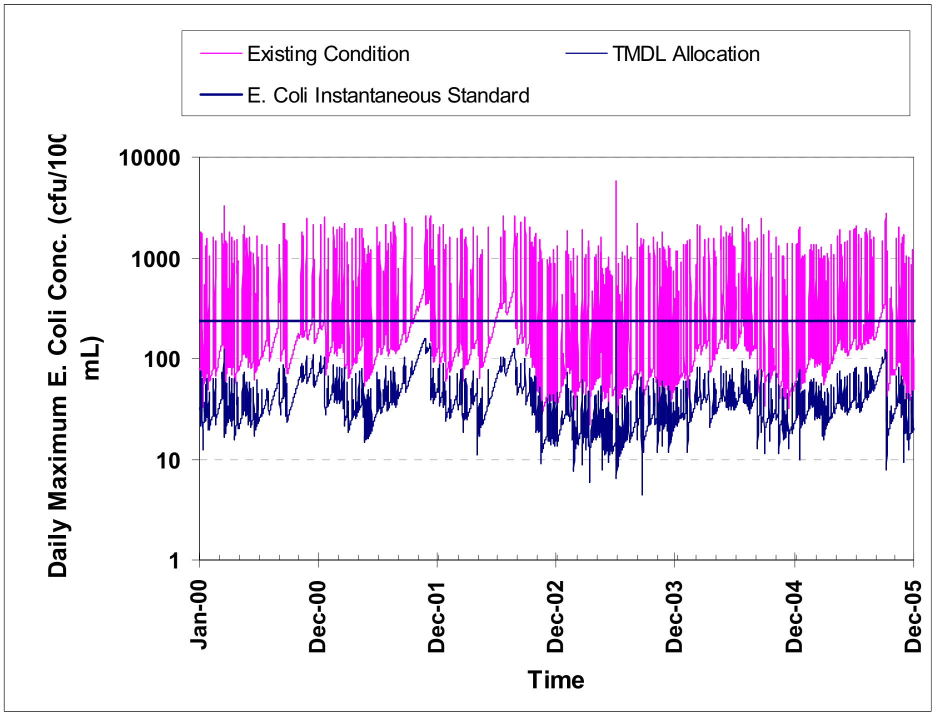

Figure 5-6: Bearskin Creek (Segment VAC-L65R-02) Instantaneous *E. coli* Concentrations under Existing Conditions and the Allocation Scenario

5.9 Cherrystone Creek (Segment VAC-L66R-01)

5.9.1 Cherrystone Creek Segment Waste Load Allocation

There are two permitted facilities discharging bacteria to Cherrystone Creek (Segment VAC-L66R-01). For this TMDL, following DEQ guidance the waste load allocation for such facilities is to assume the discharge at five-times the design flow limits and bacteria concentrations at the existing *E. coli* standard of 126 cfu/100mL. **Table 5-9** shows the existing and allocated loads from the dischargers in Cherrystone Creek (Segment VAC-L66R-01).

Table 5-9: Cherrystone Creek (Segment VAC-L66R-01) Waste load Allocation for *E. coli*

Point Source	Facility Type	Existing Load (cfu/yr)	Allocated Load (cfu/yr)	Percent Reduction
VA0023442	DOC Chatham Diversion Center	3.67E+10	1.83E+11	
VA0020524	Chatham Town - STP	1.13E+12	5.67E+12	-
Total		**1.17E+12**	**5.86E+12**	**-**

5.9.2 Cherrystone Creek Allocation Plan and TMDL Summary

The requirements to meet the calendar month *E. coli* geometric mean water quality standard of 126 cfu/100mL and the instantaneous water quality standard of 235 cfu/100mL for Cherrystone Creek (Segment VAC-L66R-01) are **(Table 5-10)**:

- 100 % reduction of the human sources (failed septic systems and straight pipes).
- 100 % reduction of the direct instream loading from livestock.
- 94 % reduction of bacteria loading from agricultural and urban nonpoint sources.
- 25% reduction of bacteria loading from direct deposition from wildlife
- No reductions from the forested land (wildlife indirect loads)

The coefficient of variation of the simulated daily loads for Cherrystone Creek (Segment VAC-L66R-01) is 1.68.

Table 5-10: Cherrystone Creek (Segment VAC-L66R-01) Distribution of *E. coli* Load under Existing Conditions and TMDL Allocation

Land Use/Source	Annual Average *E. coli* Loads (cfu/yr)		Reduction (%)	Maximum Daily Loads (MDL) for Allocation
	Existing	Modeled Loads for Allocation		(cfu/day)
Forest	3.32E+11	3.32E+11	0.0%	3.12E+09
Cropland	1.14E+12	6.85E+10	94.0%	6.45E+08
Pasture	2.07E+13	1.24E+12	94.0%	1.17E+10
Low Density Residential/Pets	6.44E+13	3.86E+12	94.0%	3.64E+10
Medium Density Residential/Pets	2.14E+13	1.28E+12	94.0%	1.21E+10
High Density Residential/Pets	1.32E+13	7.93E+11	94.0%	7.47E+09
Commercial/Industrial	6.40E+12	3.84E+11	94.0%	3.62E+09
Cattle - Direct Deposition	1.75E+13	0.00E+00	100.0%	0.00E+00
Wildlife-Direct Deposition	1.40E+13	1.05E+13	25.0%	9.88E+10
Failed Septics & Straight Pipes	3.15E+08	0.00E+00	100.0%	0.00E+00
Point Source	4.71E+10	5.86E+12	0.0%	1.60E+10
Total Loads/Overall Reductions	**1.59E+14**	**2.43E+13**	**84.7%**	**1.90E+11**

The resulting geometric mean and instantaneous *E. coli* concentrations under the TMDL allocation plan are presented in **Figure 5-7** and **Figure 5-8.** **Figure 5-7** shows the calendar month geometric mean *E. coli* concentrations for existing as well as allocation conditions. **Figure 5-8** shows the instantaneous *E. coli* concentrations under the allocations, as well as under existing conditions. For Cherrystone Creek (Segment VAC-L66R-01), the allocation results in bacteria concentrations that are consistently below both the geometric mean and instantaneous standards for *E. coli*. A summary of the TMDL allocation plan loads for Cherrystone Creek (Segment VAC-L66R-01) is presented in **Table 5-11**.

Table 5-11: Cherrystone Creek (Segment VAC-L66R-01) TMDL Allocation Plan Loads (cfu/day) for *E. coli*

WLA (Point Sources)	LA (Nonpoint sources)	MOS (Margin of safety)	TMDL
1.60E+10	1.74E+11	IMPLICT	1.90E+11

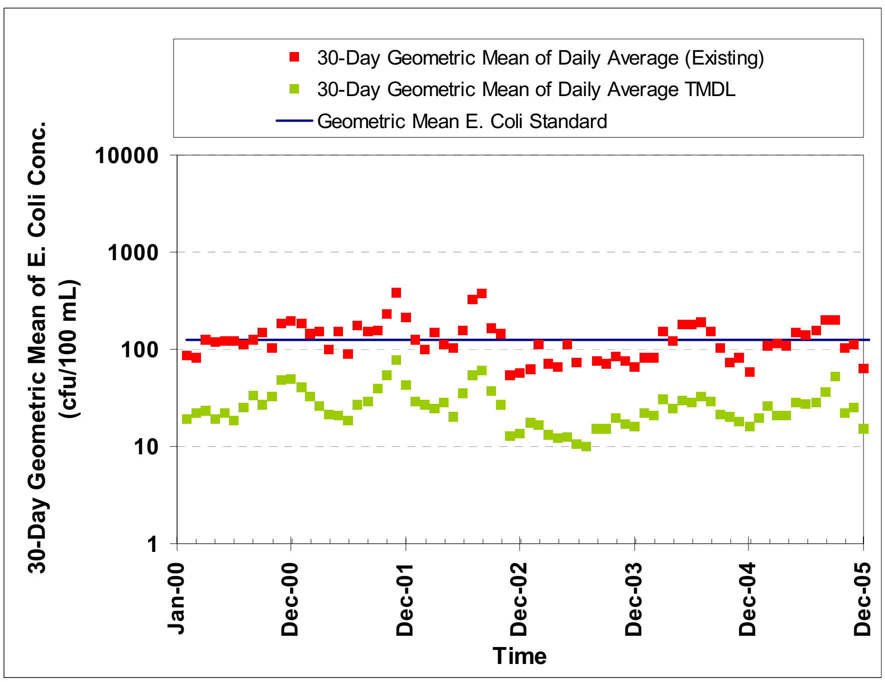

Figure 5-7: Cherrystone Creek (Segment VAC-L66R-01) Geometric Mean *E. coli* Concentrations under Existing Conditions and the Allocation Scenario

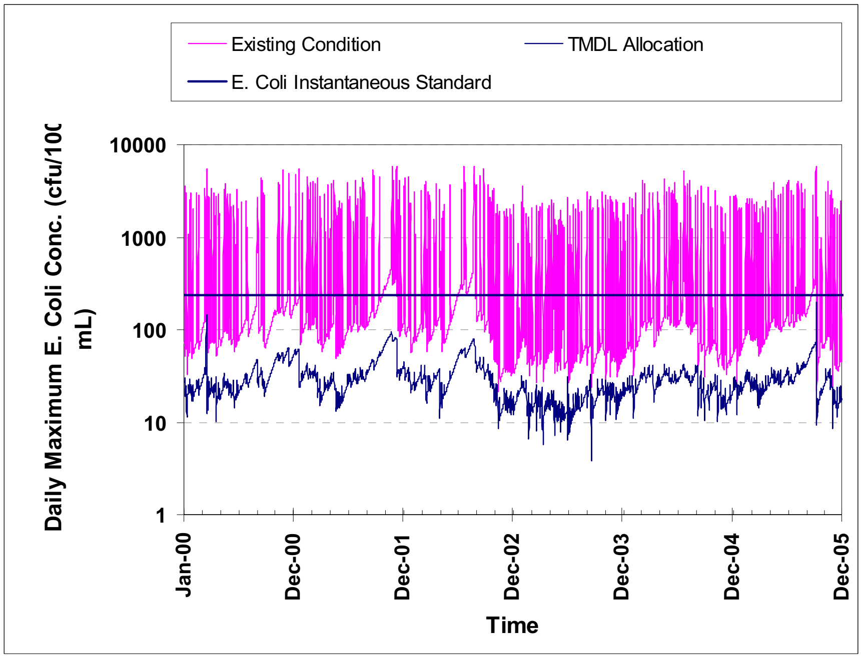

Figure 5-8: Cherrystone Creek (Segment VAC-L66R-01) Instantaneous *E. coli* Concentrations under Existing Conditions and the Allocation Scenario

5.10 Polecat Creek (Segment VAC-L71R-05)

5.10.1 Polecat Creek Segment Waste Load Allocation

There are no permitted faculties currently discharging bacteria to Polecat Creek (Segment VAC-L71R-05).

5.10.2 Polecat Creek Allocation Plan and TMDL Summary

The requirements to meet the calendar month *E. coli* geometric mean water quality standard of 126 cfu/100mL and the instantaneous water quality standard of 235 cfu/100mL for Polecat Creek (Segment VAC-L71R-05) are:

- 100 % reduction of the human sources (failed septic systems and straight pipes).
- 100 % reduction of the direct instream loading from livestock.
- 74 % reduction of bacteria loading from agricultural and urban nonpoint sources.
- 40% reduction of bacteria loading from direct deposition from wildlife
- No reductions from the forested land (wildlife indirect loads)

The coefficient of variation of the simulated daily loads for Polecat Creek (Segment AC-L71R-05) is 1.98.

Waste load allocations in watersheds where there are no individual VPDES permitted facilities containing bacteria effluent limitations are usually represented in the TMDL as 1% of the Total Maximum Daily Load. This 1% is then subtracted from the Load allocations. This is reflected in Table 5-12 which shows the *E. coli* TMDL allocation plan for Polecat Creek (Segment VAC-L71R-05).

Table 5-12: Polecat Creek (Segment VAC-L71R-05) Distribution of *E. coli* Load under Existing Conditions and TMDL Allocation

Land Use/Source	Annual Average *E. coli* Loads (cfu/yr)		Reduction (%)	Maximum Daily Loads (MDL) for Allocation
	Existing	Modeled Loads for Allocation		(cfu/day)
Forest	1.90E+11	1.90E+11	0.0%	1.87E+09
Cropland	6.18E+11	1.61E+11	74.0%	1.58E+09
Pasture	7.04E+12	1.83E+12	74.0%	1.80E+10
Low Density Residential/Pets	5.25E+12	1.36E+12	74.0%	1.34E+10
Medium Density Residential/Pets	1.88E+11	4.89E+10	74.0%	4.81E+08
High Density Residential/Pets	3.27E+11	8.50E+10	74.0%	8.37E+08
Commercial/Industrial	1.82E+12	4.72E+11	74.0%	4.65E+09
Cattle - Direct Deposition	3.47E+12	0.00E+00	100.0%	0.00E+00
Wildlife-Direct Deposition	7.08E+12	4.25E+12	40.0%	4.18E+10
Failed Septics & Straight Pipes	1.28E+08	0.00E+00	100.0%	0.00E+00
Point Source*	0.00E+00	8.40E+10	0.0%	2.30E+08
Total Loads/Overall Reductions	**2.60E+13**	**8.48E+12**	**67.3%**	**8.29E+10**

(*) there are no individual VPDES municipal point source dischargers; the WLA includes 1 percent of the total NPS allocations to account for future growth as well as allocated bacteria loads from the domestic sewage discharges

The resulting geometric mean and instantaneous *E. coli* concentrations under the TMDL allocation plan are presented in **Figure 5-9** and **Figure 5-10.** **Figure 5-9** shows the calendar month geometric mean *E. coli* concentrations for existing as well as allocation conditions. **Figure 5-10** shows the instantaneous *E. coli* concentrations under the allocations, as well as under existing conditions. For Polecat Creek (Segment VAC-

L71R-05), the allocation results in bacteria concentrations that are consistently below both the geometric mean and instantaneous standards for *E. coli*. A summary of the TMDL allocation plan loads for Polecat Creek (Segment VAC-L71R-05) is presented in **Table 5-13**.

Table 5-13: Polecat Creek (Segment VAC-L71R-05) TMDL Allocation Plan Loads (cfu/day) for *E. coli*

WLA (Point Sources)	LA (Nonpoint sources)	MOS (Margin of safety)	TMDL
2.30E+08	8.27E+10	IMPLICT	8.29E+10

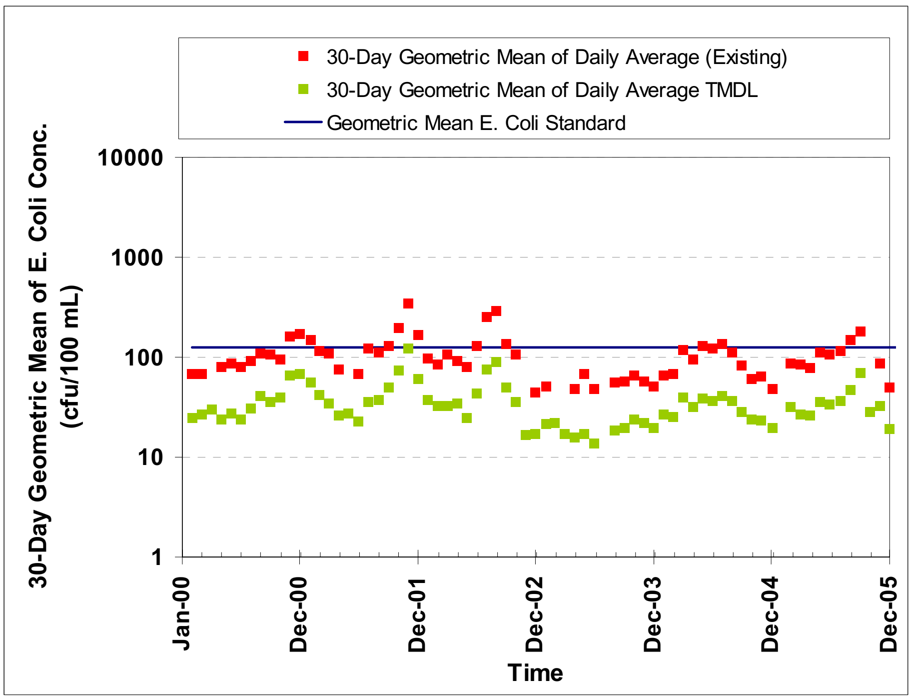

Figure 5-9: Polecat Creek (Segment VAC-L71R-05) Geometric Mean *E. coli* Concentrations under Existing Conditions and the Allocation Scenario

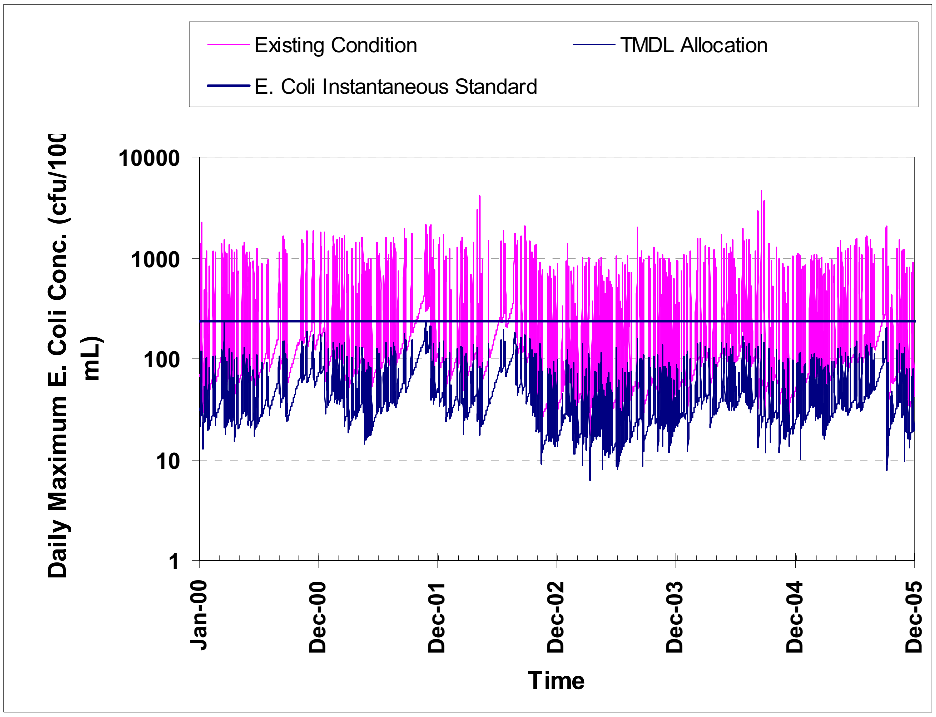

Figure 5-10: Polecat Creek (Segment VAC-L71R-05) Instantaneous *E. coli* Concentrations under Existing Conditions and the Allocation Scenario

5.11 Stinking River (Segment VAC-L69R-01)

5.11.1 Stinking River Waste Load Allocation

There are no domestic sewage permitted facilities currently discharging bacteria to Stinking River (Segment VAC-L69R-01).

5.11.2 Stinking River Allocation Plan and TMDL Summary

The requirements to meet the calendar month *E. coli* geometric mean water quality standard of 126 cfu/100mL and the instantaneous water quality standard of 235 cfu/100mL for Stinking River (Segment VAC-L69R-01) are:

- 100 % reduction of the human sources (failed septic systems and straight pipes).
- 100 % reduction of the direct instream loading from livestock.
- 83 % reduction of bacteria loading from agricultural and urban nonpoint sources.
- 35% reduction of bacteria loading from direct deposition from wildlife
- No reductions from the forested land (wildlife indirect loads)

The coefficient of variation of the daily simulated loads for Stinking River (Segment VAC-L69R-01) is 2.05. Waste load allocations in watersheds where there are no individual VPDES permitted facilities containing bacteria effluent limitations are usually represented in the TMDL as 1% of the Total Maximum Daily Load. This 1% is then subtracted from the Load allocations. This is reflected in **Table 5-14** which shows the *E. coli* TMDL allocation plan for Stinking River (Segment VAC-L69R-01).

Table 5-14: Stinking River (Segment VAC-L69R-01) Distribution of *E. coli* Load under Existing Conditions and TMDL Allocation

Land Use/Source	Annual Average *E. coli* Loads (cfu/yr)		Reduction (%)	Maximum Daily Loads (MDL) for Allocation
	Existing	Modeled Loads for Allocation		(cfu/day)
Forest	2.99E+11	2.99E+11	0.0%	2.97E+09
Cropland	2.49E+12	4.24E+11	83.0%	4.21E+09
Pasture	1.49E+13	2.53E+12	83.0%	2.51E+10
Low Density Residential/Pets	1.91E+13	3.24E+12	83.0%	3.22E+10
Medium Density Residential/Pets	8.18E+11	1.39E+11	83.0%	1.38E+09
High Density Residential/Pets	0.00E+00	0.00E+00	83.0%	0.00E+00
Commercial/Industrial	4.45E+12	7.57E+11	83.0%	7.52E+09
Cattle - Direct Deposition	9.17E+12	0.00E+00	100.0%	0.00E+00
Wildlife-Direct Deposition	1.17E+13	7.62E+12	35.0%	7.57E+10
Failed Septics & Straight Pipes	1.45E+08	0.00E+00	100.0%	0.00E+00
Point Source*	0.00E+00	1.50E+11	0.0%	4.11E+08
Total Loads/Overall Reductions	**6.29E+13**	**1.52E+13**	**75.9%**	**1.50E+11**

(*) there are no individual VPDES municipal point source dischargers; the WLA includes 1 percent of the total NPS allocations to account for future growth as well as allocated bacteria loads from the domestic sewage discharges

The resulting geometric mean and instantaneous *E. coli* concentrations under the TMDL allocation plan are presented in **Figure 5-11** and **Figure 5-12. Figure 5-11** shows the calendar month geometric mean *E. coli* concentrations for existing as well as allocation conditions. **Figure 5-12** shows the instantaneous *E. coli* concentrations under the allocations, as well as under existing conditions. For Stinking River (Segment VAC-L69R-01), the allocation results in bacteria concentrations that are consistently below both the geometric mean and instantaneous standards for *E. coli*. A summary of the

TMDL allocation plan loads for Stinking River (Segment VAC-L69R-01) is presented in **Table 5-15**.

Table 5-15: Stinking River (Segment VAC-L69R-01) TMDL Allocation Plan Loads (cfu/day) for *E. coli*			
WLA (Point Sources)	**LA (Nonpoint sources)**	**MOS (Margin of safety)**	**TMDL**
4.11E+08	1.49E+11	IMPLICT	1.50E+11

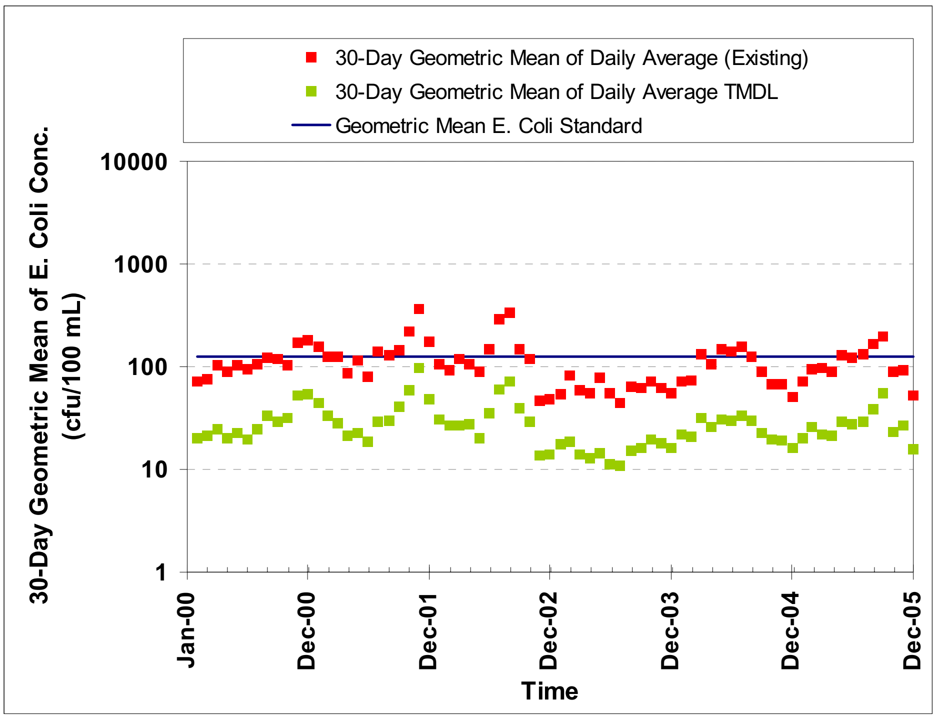

Figure 5-11: Stinking River (Segment VAC-L69R-01) Geometric Mean *E. coli* Concentrations under Existing Conditions and the Allocation Scenario

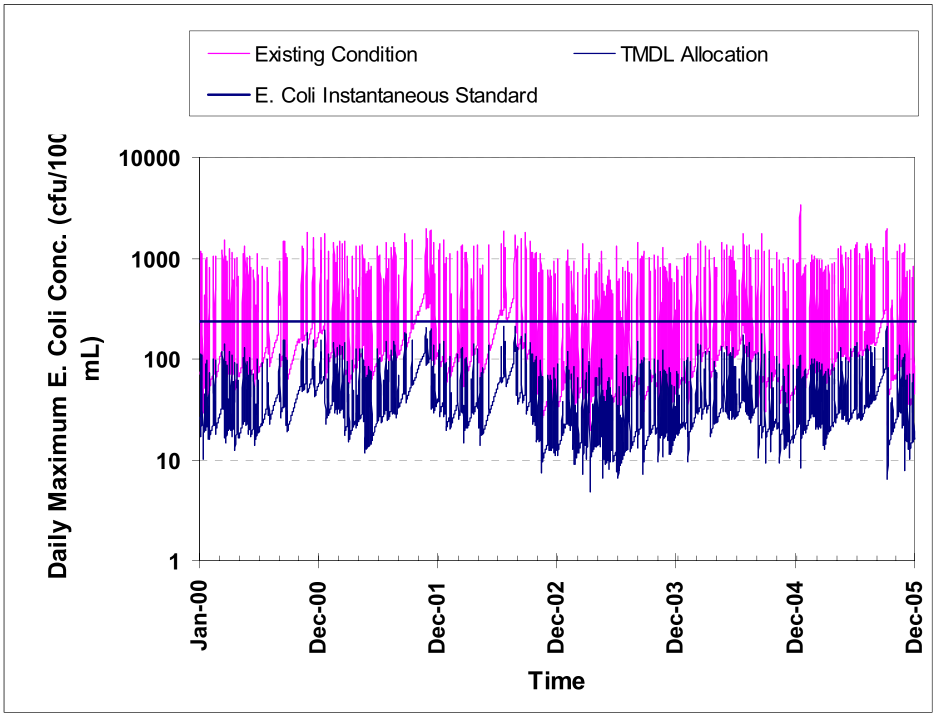

Figure 5-12: Stinking River (Segment VAC-L69R-01) Instantaneous E. coli Concentrations under Existing Conditions and the Allocation Scenario

5.12 Sandy Creek (Segment VAC-L70R-01)

5.12.1 Sandy Creek Waste Load Allocation

There are no domestic sewage permitted facilities discharging currently bacteria to Sandy Creek (Segment VAC-L70R-01).

5.12.2 Sandy Creek Allocation Plan and TMDL Summary

The requirements to meet the calendar month *E. coli* geometric mean water quality standard of 126 cfu/100mL and the instantaneous water quality standard of 235 cfu/100mL for Sandy Creek (Segment VAC-L70R-01) are **(Table 5-16)**:

- 100 % reduction of the human sources (failed septic systems and straight pipes).
- 100 % reduction of the direct instream loading from livestock.
- 85 % reduction of bacteria loading from agricultural and urban nonpoint sources.
- 40% reduction of bacteria loading from direct deposition from wildlife
- No reductions from the forested land (wildlife indirect loads)

The coefficient of variation of the simulated daily loads for Sandy Creek (Segment VAC-L70R-01) is 1.74.

Table 5-16: Sandy Creek (Segment VAC-L70R-01) Distribution of *E. coli* Load under Existing Conditions and TMDL Allocation

Land Use/Source	Annual Average *E. coli* Loads (cfu/yr)		Reduction (%)	Maximum Daily Loads (MDL) for Allocation
	Existing	Modeled Loads for Allocation		(cfu/day)
Forest	9.42E+11	9.42E+11	0.0%	8.96E+09
Cropland	4.89E+12	7.34E+11	85.0%	6.98E+09
Pasture	3.64E+13	5.46E+12	85.0%	5.20E+10
Low Density Residential/Pets	5.60E+13	8.40E+12	85.0%	7.99E+10
Medium Density Residential/Pets	9.11E+12	1.37E+12	85.0%	1.30E+10
High Density Residential/Pets	6.11E+11	9.16E+10	85.0%	8.72E+08
Commercial/Industrial	8.92E+12	1.34E+12	85.0%	1.27E+10
Cattle - Direct Deposition	1.81E+13	0.00E+00	100.0%	0.00E+00
Wildlife-Direct Deposition	3.52E+13	2.11E+13	40.0%	2.01E+11
Failed Septics & Straight Pipes	2.52E+09	0.00E+00	100.0%	0.00E+00
Point Source*	0.00E+00	3.94E+11	0.0%	1.08E+09
Total Loads/Overall Reductions	**1.70E+14**	**3.98E+13**	**76.6%**	**3.76E+11**

(*) there are no individual VPDES municipal point source dischargers; the WLA includes 1 percent of the total NPS allocations to account for future growth as well as allocated bacteria loads from the domestic sewage discharges

The resulting geometric mean and instantaneous *E. coli* concentrations under the TMDL allocation plan are presented in **Figure 5-13** and **Figure 5-14.** **Figure 5-13** shows the calendar month geometric mean *E. coli* concentrations for existing as well as allocation conditions. **Figure 5-14** shows the instantaneous *E. coli* concentrations under the allocations, as well as under existing conditions. For Sandy Creek (Segment VAC-L70R-01), the allocation results in bacteria concentrations that are consistently below both the geometric mean and instantaneous standards for *E. coli*. A summary of the TMDL allocation plan loads for Sandy Creek (Segment VAC-L70R-01) is presented in **Table 5-17**.

Table 5-17: Sandy Creek (Segment VAC-L70R-01) TMDL Allocation Plan Loads (cfu/day) for *E. coli*			
WLA (Point Sources)	LA (Nonpoint sources)	MOS (Margin of safety)	TMDL
1.08E+09	3.75E+11	IMPLICT	3.76E+11

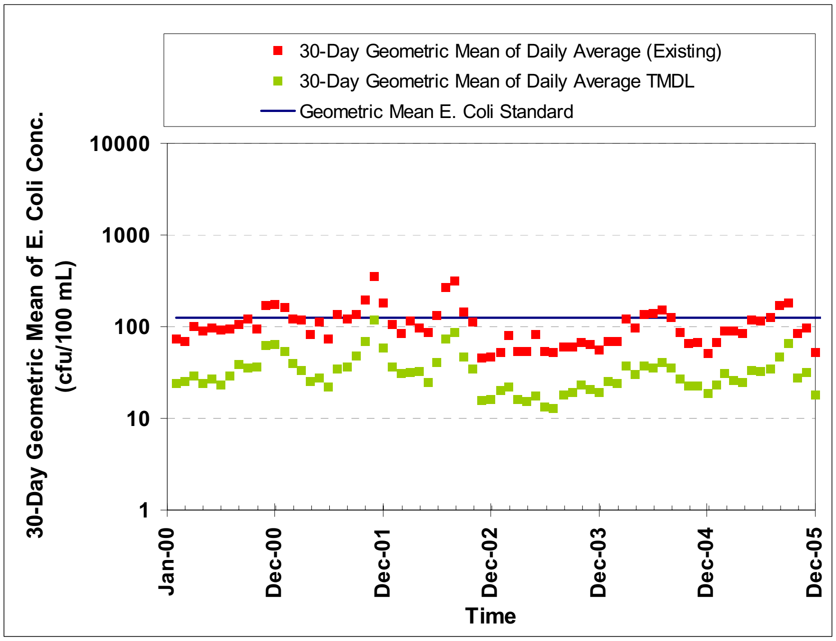

Figure 5-13: Sandy Creek (Segment VAC-L70R-01) Geometric Mean *E. coli* Concentrations under Existing Conditions and the Allocation Scenario

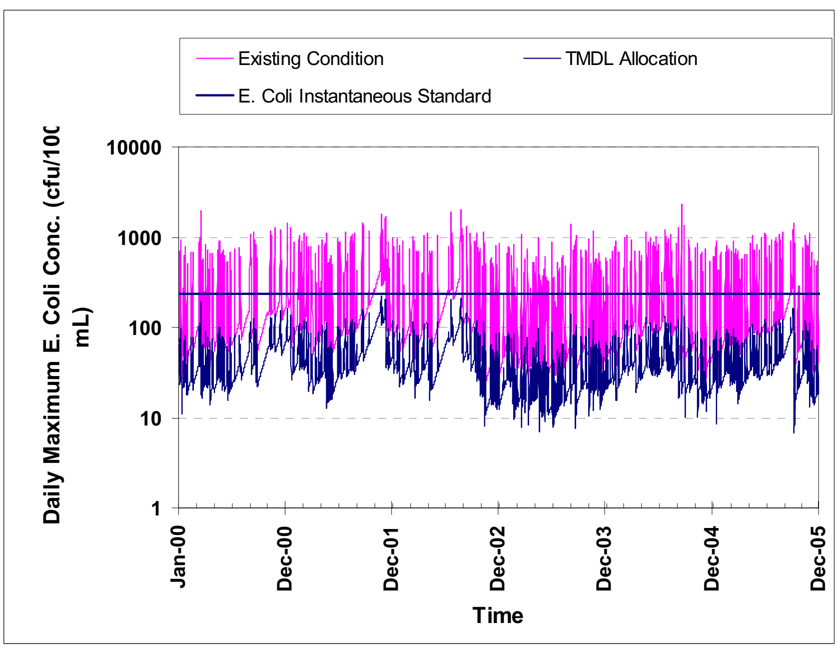

Figure 5-14: Sandy Creek (Segment VAC-L70R-01) Instantaneous E. coli Concentrations under Existing Conditions and the Allocation Scenario

5.13 Whitehorn Creek (Segment VAC-L68R-01)

5.13.1 Whitehorn Creek Waste Load Allocation

There is one municipal permitted facility discharging bacteria to Whitehorn Creek (Segment VAC-L68R-01). For this TMDL, following DEQ guidance the waste load allocation for such facilities is to assume the discharge at five-times the design flow limits and bacteria concentrations at the existing *E. coli* standard of 126 cfu/100mL. **Table 5-18** shows the existing and allocated loads from general domestic dischargers in Whitehorn Creek (Segment VAC-L68R-01).

Table 5-18: Whitehorn Creek (Segment VAC-L68R-01) Waste load Allocation for *E. coli*

Point Source	Facility Type	Existing Load (cfu/yr)	Allocated Load (cfu/yr)	Percent Reduction
VA0063843	Municipal	6.11E+11	3.06E+12	-
Total		**6.11E+11**	**3.06E+12**	-

5.13.2 Whitehorn Creek Allocation Plan and TMDL Summary

The requirements to meet the calendar month *E. coli* geometric mean water quality standard of 126 cfu/100mL and the instantaneous water quality standard of 235 cfu/100mL for Whitehorn Creek (Segment VAC-L68R-01) are (**Table 5-19**):

- 100 % reduction of the human sources (failed septic systems and straight pipes).
- 100 % reduction of the direct instream loading from livestock.
- 94 % reduction of bacteria loading from agricultural and urban nonpoint sources.
- 30% reduction of bacteria loading from direct deposition from wildlife
- No reductions from the forested land (wildlife indirect loads)

The coefficient of variation of the simulated daily loads for Whitehorn Creek (Segment VAC-L68R-01) is 1.65.

Table 5-19: Whitehorn Creek (Segment VAC-L68R-01) Distribution of *E. coli* Load under Existing Conditions and TMDL Allocation

Land Use/Source	Annual Average *E. coli* Loads (cfu/yr)		Reduction (%)	Maximum Daily Loads (MDL) for Allocation
	Existing	Modeled Loads for Allocation		(cfu/day)
Forest	4.75E+11	4.75E+11	0.0%	4.45E+09
Cropland	3.60E+12	2.16E+11	94.0%	2.02E+09
Pasture	3.06E+13	1.84E+12	94.0%	1.72E+10
Low Density Residential/Pets	1.01E+14	6.04E+12	94.0%	5.66E+10
Medium Density Residential/Pets	1.75E+13	1.05E+12	94.0%	9.85E+09
High Density Residential/Pets	9.22E+12	5.53E+11	94.0%	5.18E+09
Commercial/Industrial	8.93E+12	5.36E+11	94.0%	5.02E+09
Cattle - Direct Deposition	1.87E+13	0.00E+00	100.0%	0.00E+00
Wildlife-Direct Deposition	2.07E+13	1.45E+13	30.0%	1.36E+11
Failed Septics & Straight Pipes	2.54E+09	0.00E+00	100.0%	0.00E+00
Point Source	6.11E+11	3.06E+12	0.0%	8.37E+09
Total Loads/Overall Reductions	**2.11E+14**	**2.82E+13**	**86.6%**	**2.44E+11**

The resulting geometric mean and instantaneous *E. coli* concentrations under the TMDL allocation plan are presented in **Figure 5-15** and **Figure 5-16.** **Figure 5-15** shows the calendar month geometric mean *E. coli* concentrations for existing as well as allocation conditions. **Figure 5-16** shows the instantaneous *E. coli* concentrations under the allocations, as well as under existing conditions. For Whitehorn Creek (Segment VAC-L68R-01), the allocation results in bacteria concentrations that are consistently below both the geometric mean and instantaneous standards for *E. coli*. A summary of the TMDL allocation plan loads for Whitehorn Creek (Segment VAC-L68R-01) is presented in **Table 5-20**.

Table 5-20:Whitehorn Creek (Segment VAC-L68R-01) TMDL Allocation Plan Loads (cfu/day) for *E. coli*

WLA (Point Sources)	LA (Nonpoint sources)	MOS (Margin of safety)	TMDL
8.37E+09	2.36E+11	IMPLICT	2.44E+11

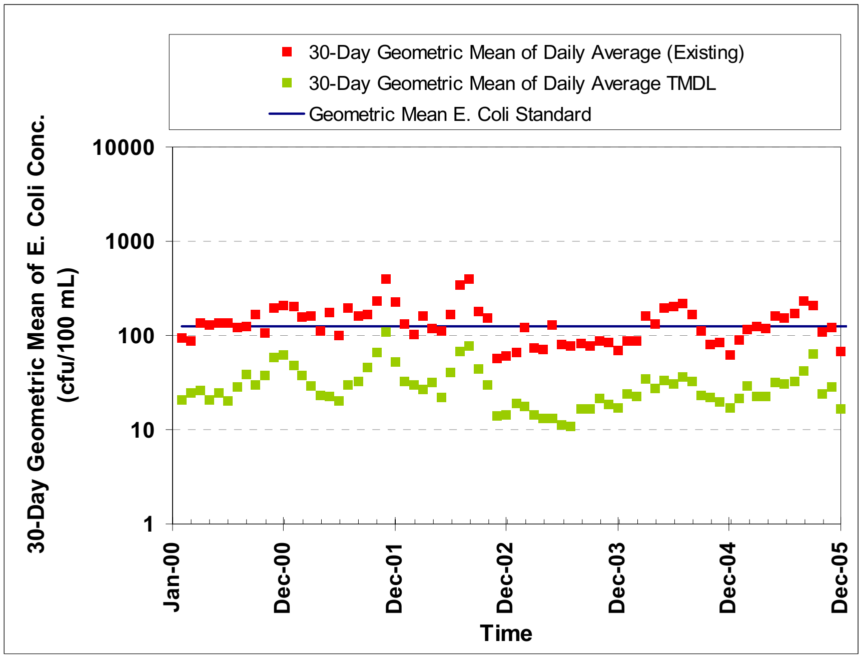

Figure 5-15: Whitehorn Creek (Segment VAC-L68R-01) Geometric Mean *E. coli* Concentrations under Existing Conditions and the Allocation Scenario

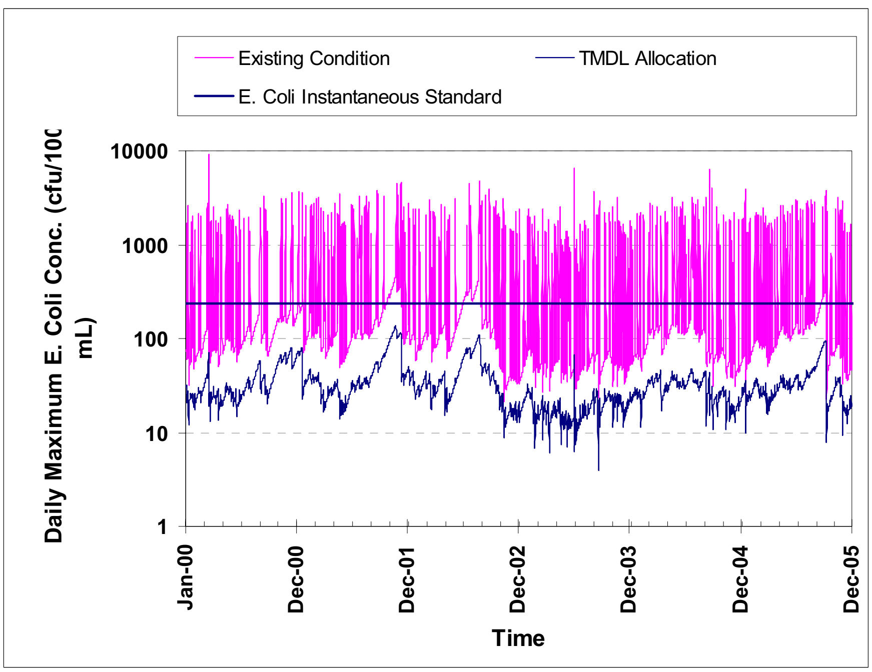

Figure 5-16: Whitehorn Creek (Segment VAC-L68R-01) Instantaneous E. coli Concentrations under Existing Conditions and the Allocation Scenario

6.0 TMDL Implementation

Once a TMDL has been approved by EPA, measures must be taken to reduce pollution levels from both point and non point sources in the stream (see section 7.4.2). For point sources, all new or revised VPDES/NPDES permits must be consistent with the TMDL WLA pursuant to 40 CFR '122.44 (d)(1)(vii)(B) and must be submitted to EPA for approval. The measures for non point 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 implementation plan. The process for developing an implementation plan has been described in the "TMDL Implementation Plan Guidance Manual", published in July 2003 and available upon request from the DEQ and DCR TMDL project staff or at http://www.deq.virginia.gov/tmdl/implans/ipguide.pdf. 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.

6.1 Staged Implementation

In general, Virginia intends for the required bacteria reductions to be implemented in an iterative process that first addresses those sources with the largest impact on water quality. For example, in agricultural areas of the watershed, the most promising management practice is livestock exclusion from streams. This has been shown to be very effective in lowering bacteria concentrations in streams, both by reducing the cattle deposits themselves and by providing additional riparian buffers.

Additionally, in both urban and rural areas, reducing the human bacteria loading from failing septic systems should be a primary implementation focus because of its health implications. This component could be implemented through education on septic tank pump-outs as well as a septic system repair/replacement program and the use of alternative waste treatment systems.

In urban areas, reducing the human bacteria loading from leaking sewer lines could be accomplished through a sanitary sewer inspection and management program. Other BMPs that might be appropriate for controlling urban wash-off from parking lots and roads and that could be readily implemented may include more restrictive ordinances to reduce fecal loads from pets, improved garbage collection and control, and improved street cleaning.

The iterative implementation of BMPs in the watershed has several benefits:

1. It enables tracking of water quality improvements following BMP 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 BMP implementation 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.

Watershed stakeholders will have opportunity to participate in the development of the TMDL implementation plan. While specific goals for BMP implementation will be established as part of the implementation plan development, the following stage 1 scenarios are targeted at controllable, anthropogenic bacteria sources and can serve as starting points for targeting BMP implementation activities.

6.2 Stage 1 Scenarios

The goal of the stage 1 scenarios is to reduce the bacteria loadings from controllable sources (excluding wildlife) such that violations of the single sample maximum criterion (235 cfu/100mL) are less than 10 percent. The stage 1 scenarios were generated with the same model setup as was used for the TMDL allocation scenarios. A margin of safety was not used in determining the stage 1 scenarios. It was estimated for modeling purposes that there are 19 straight pipes in the watershed. Should any be found during the implementation process, they should be eliminated as soon as possible since they would be illegally discharging fecal bacteria into Bacteria TMDLs for Banister River, Bearskin Creek, Cherrystone Creek, Polecat Creek, Stinking River, Sandy Creek, and Whitehorn Creek watersheds and their tributaries.

Three allocation scenarios are presented in **Tables 6-1 to 6-9** for Bacteria TMDLs for Banister River, Bearskin Creek, Cherrystone Creek, Polecat Creek, Stinking River, Sandy Creek, and Whitehorn Creek Watersheds respectively. Scenario 1 represents the required load reduction that will not exceed the instantaneous standard by more than 10% violation. Scenarios 2 and 3 represent the implementation of BMPs and management strategies such as livestock exclusion from streams, alternative water, manure storage, riparian buffers, and pet waste control that can be readily put in place in the watershed.

Table 6-1: Banister River (Segment VAC-L65R-01) Watershed Stage 1 Scenarios

Scenario	Failed Septics & Pipes	Direct Livestock	NPS (Agricultural)	NPS (Urban)	Direct Wildlife	violation of GM standard 126 #/100ml	violation of Inst. standard 235 #/100ml
1	100%	100%	77%	77%	35%	0%	3%
2	100%	50%	50%	50%	0%	14%	33%
3	100%	75%	75%	75%	0%	8%	20%

Table 6-2: Banister River (Segment VAC-L67R-01) Watershed Stage 1 Scenarios

Scenario	Failed Septics & Pipes	Direct Livestock	NPS (Agricultural)	NPS (Urban)	Direct Wildlife	violation of GM standard 126 #/100ml	violation of Inst. standard 235 #/100ml
1	100%	100%	92%	92%	35%	0%	3%
2	100%	50%	50%	50%	0%	19%	47%
3	100%	75%	75%	75%	0%	10%	27%

Table 6-3: Bearskin Creek (Segment VAC-L65R-02) Watershed Stage 1 Scenarios

Scenario	Failed Septics & Pipes	Direct Livestock	NPS (Agricultural)	NPS (Urban)	Direct Wildlife	violation of GM standard 126 #/100ml	violation of Inst. standard 235 #/100ml
1	100%	100%	69%	69%	40%	0%	3%
2	100%	50%	50%	50%	0%	17%	57%
3	100%	75%	75%	75%	0%	12%	33%

Table 6-4: Cherrystone Creek (Segment VAC-L66R-01) Watershed Stage 1 Scenarios

Scenario	Failed Septics & Pipes	Direct Livestock	NPS (Agricultural)	NPS (Urban)	Direct Wildlife	violation of GM standard 126 #/100ml	violation of Inst. standard 235 #/100ml
1	100%	100%	78%	78%	25%	0%	10%
2	100%	50%	50%	50%	0%	24%	42%
3	100%	75%	75%	75%	0%	12%	20%

Table 6-5: Polecat Creek (Segment VAC-L71R-05) Watershed Stage 1 Scenarios

Scenario	Failed Septics & Pipes	Direct Livestock	NPS (Agricultural)	NPS (Urban)	Direct Wildlife	violation of GM standard 126 #/100ml	violation of Inst. standard 235 #/100ml
1	100%	100%	73%	73%	40%	0%	3%
2	100%	50%	50%	50%	0%	14%	37%
3	100%	75%	75%	75%	0%	8%	23%

Table 6-6: Stinking River (Segment VAC-L69R-01) Watershed Stage 1 Scenarios

Scenario	Failed Septics & Pipes	Direct Livestock	NPS (Agricultural)	NPS (Urban)	Direct Wildlife	violation of GM standard 126 #/100ml	violation of Inst. standard 235 #/100ml
1	100%	100%	83%	83%	35%	0%	0%
2	100%	50%	50%	50%	0%	15%	37%
3	100%	75%	75%	75%	0%	8%	20%

Table 6-7: Sandy Creek (Segment VAC-L70R-01) Watershed Stage 1 Scenarios

Scenario	Failed Septics & Pipes	Direct Livestock	NPS (Agricultural)	NPS (Urban)	Direct Wildlife	violation of GM standard 126 #/100ml	violation of Inst. standard 235 #/100ml
1	100%	100%	62%	62%	40%	0%	7%
2	100%	50%	50%	50%	0%	16%	50%
3	100%	75%	75%	75%	0%	9%	37%

Table 6-8: Whitehorn Creek (Segment VAC-L68R-01) Watershed Stage 1 Scenarios

Scenario	Failed Septics & Pipes	Direct Livestock	NPS (Agricultural)	NPS (Urban)	Direct Wildlife	violation of GM standard 126 #/100ml	violation of Inst. standard 235 #/100ml
1	100%	100%	83%	83%	30%	0%	7%
2	100%	50%	50%	50%	0%	21%	35%
3	100%	75%	75%	75%	0%	12%	19%

6.3 Link to Ongoing Restoration Efforts

The town of Halifax is in the final phase of adopting its Comprehensive Plan. Several sections of the plan pertain to water quality and the Banister River TMDL study.

The Natural and Environmental Resources section of the report states resources should be protected and preserved for present and future generations. A specific policy and action strategy under this section states "Banister Lake and the Banister River and its tributaries should be protected as natural community assets and enhanced for recreation and tourism." The plan states this policy and action strategy will be implemented through "Partnering with DEQ to assist in meeting TMDLs established for Banister Lake and Banister River through the Banister River Steering Committee. Include DCR, DGIF, DOF, and the Dan River Basin Association."

For more information on the Town of Halifax's Comprehensive Plan, please contact Carl Espy, IV, Town Manager at (434) 476-2343 or halifaxtm@adelphia.net.

6.4 Reasonable Assurance for Implementation

6.4.1 Follow-Up Monitoring

Following the development of the TMDL, the Department of Environmental Quality (DEQ) will continue to monitor the impaired stream in accordance with its ambient monitoring program. DEQ'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. The purpose, location, parameters, frequency, and duration of the monitoring will be determined by the DEQ staff, in cooperation with DCR 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 DEQ Regional Office. Other agency personnel, watershed stakeholders, etc. may provide input on the Annual Water Monitoring Plan. These recommendations must be made to the DEQ regional TMDL coordinator by September 30 of each year.

DEQ staff, in cooperation with DCR 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 DEQ's standard monitoring plan. Ancillary monitoring by citizens', 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 DEQ 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 TMDL Implementation Plan has been completed), DEQ 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.

6.4.2 Regulatory Framework

While section 303(d) of the Clean Water Act and current EPA regulations do not require the development of TMDL implementation plans as part of the TMDL process, they do require reasonable assurance that the load and wasteload allocations can and will be implemented. EPA also requires that all new or revised National Pollutant Discharge Elimination System (NPDES) permits must be consistent with the TMDL WLA pursuant to 40 CFR §122.44 (d)(1)(vii)(B). All such permits should be submitted to EPA for review.

Additionally, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (the "Act") directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters" (Section 62.1-44.19.7). The Act also establishes that the implementation plan shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments. EPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process." 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.

For the implementation of the WLA component of the TMDL, the Commonwealth intends to utilize the Virginia NPDES (VPDES) program, which typically includes consideration of the WQMIRA requirements during the permitting process. Requirements of the permit process should not be duplicated in the TMDL process, and with the exception of stormwater related permits, permitted sources are not usually addressed during the development of a TMDL implementation plan.

For the implementation of the TMDL's LA component, a TMDL implementation plan addressing at a minimum the WQMIRA requirements will be developed.

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

In response to a Memorandum of Understanding (MOU) between EPA and DEQ, DEQ also submitted a draft Continuous Planning Process to EPA in which DEQ commits to regularly updating the WQMPs. Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

DEQ staff will present both EPA-approved TMDLs and TMDL implementation plans to the State Water Control Board 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.

DEQ 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 is 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 the public participation guidelines referenced above and can be found on DEQ's web site under http://www.deq.state.va.us/tmdl/pdf/ppp.pdf

6.4.3 Stormwater Permits

It is the intention of the Commonwealth that the TMDL will be implemented using existing regulations and programs. One of these regulations is the Virginia Stormwater Management Program (VSMP) Permit Regulation (4 VAC 50-60-10 et. seq). Section 4VAC 50-60-380 describes the requirements for stormwater discharges. Also, federal regulations state in 40 CFR §122.44(k) that NPDES permit conditions may consist of "Best management practices to control or abate the discharge of pollutants when:…(2) Numeric effluent limitations are infeasible,…". Information on Virginia's Stormwater Management program and a downloadable menu of Best Management Practices and Measurable Goals Guidance can be found at http://www.dcr.virginia.gov/sw/stormwat.htm.

6.4.4 Implementation Funding Sources

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". Potential sources for implementation may include the U.S. Department of Agriculture's Conservation Reserve Enhancement and Environmental Quality Incentive Programs, EPA Section 319 funds, the Virginia State Revolving Loan Program, Virginia Agricultural Best Management Practices Cost-Share Programs, the Virginia Water Quality Improvement Fund, tax credits and landowner contributions. The TMDL Implementation Plan Guidance Manual contains additional information on funding sources, as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

6.4.5 Attainability of Primary Contact Recreation Use

In some streams for which TMDLs have been developed, water quality modeling indicates that even after removal of all bacteria sources (other than wildlife), the stream will not attain standards under all flow regimes at all times. These streams may not be able to attain standards without some reduction in wildlife load. **Virginia and EPA are not proposing the elimination of wildlife to allow for the attainment of water quality standards.** While managing overpopulations of wildlife remains as an option to local stakeholders, the reduction of wildlife or changing a natural background condition is not the intended goal of a TMDL. Additionally, other factors may prevent the stream from attaining the primary contact recreation use.

To address this issue, Virginia proposed during its latest triennial water quality standards review a new "secondary contact" category for protecting the recreational use in state waters. On March 25, 2003, the Virginia State Water Control Board adopted criteria for "secondary contact recreation" which means "a water-based form of recreation, the practice of which has a low probability for total body immersion or ingestion of waters (examples include but are not limited to wading, boating and fishing)". These new criteria became effective on February 12, 2004 and can be found at http://www.deq.virginia.gov/wqs/rule.html.

In order for the new criteria to apply to a specific stream segment, the primary contact recreational use must be removed. To remove a designated use, the state must demonstrate 1) that the use is not an existing use, 2) that downstream uses are protected, and 3) that the source of contamination is natural and uncontrollable by effluent limitations and by implementing cost-effective and reasonable best management practices for nonpoint source control (9 VAC 25-260-10). This and other information is collected through a special study called a Use Attainability Analysis (UAA). All site-specific criteria or designated use changes must be adopted as amendments to the water quality standards regulations. Watershed stakeholders and EPA will be able to provide comment during this process. Additional information can be obtained at http://www.deq.virginia.gov/wqs/WQS03AUG.pdf

The process to address potentially unattainable reductions based on the above is as follows: First is the development of a stage 1 scenario such as those presented previously in this chapter. The pollutant reductions in the stage 1 scenario are targeted only at the controllable, anthropogenic bacteria sources identified in the TMDL, setting aside control strategies for wildlife except for cases of nuisance overpopulations. During the implementation of the stage 1 scenario, all controllable sources would be reduced to the maximum extent practicable using the iterative approach described in Section 6-2 above. DEQ will re-assess water quality in the stream during and subsequent to the implementation of the stage 1 scenario to determine if the water quality standard is attained. This effort will also evaluate if the modeling assumptions were correct. If water quality standards are not being met, and no additional cost-effective and reasonable best management practices can be identified, a UAA may be initiated with the goal of re-designating the stream for secondary contact recreation.

7.0 Public Participation

The development of the Banister River, Bearskin Creek, Cherrystone Creek, Polecat Creek, Stinking River, Sandy Creek, and Whitehorn Creek bacteria TMDLs would not have been possible without public participation. Two technical advisory committee (TAC) meetings and two public meetings were held within the watershed. The following is a summary of the meetings.

TAC Meeting No. 1: The first TAC meeting was held on January 27, 2007 at the Mary Bethune Office Complex in Halifax, Virginia to present and review the steps and the data used in the development of the bacteria TMDLs for the Banister River, Bearskin Creek, Cherrystone Creek, Polecat Creek, Stinking River, Sandy Creek, and Whitehorn Creek listed segments.

TAC Meeting No. 2: The second TAC meeting was held on March 12, 2007 at the USDA Center, Chatham Virginia to discuss the preliminary source assessment for the Banister River, Bearskin Creek, Cherrystone Creek, Polecat Creek, Stinking River, Sandy Creek, and Whitehorn Creek watersheds.

Public Meeting No. 1: The first public meeting was held in on March 20, 2007 at the USDA Center, Chatham Virginia to present the process for TMDL development, the Banister River, Bearskin Creek, Cherrystone Creek, Polecat Creek, Stinking River, Sandy Creek, and Whitehorn Creek bacteria impaired segments, data that caused the segments to be on the 303(d) list and identify data and information needed for TMDL development. Nineteen people added the meeting. Copies of the presentation were available for public distribution. This meeting was publicly noticed in the *Virginia Register*. No written comments were received during the 30-day comment period.

Public Meeting No. 2: The second public meeting was held on May 8, 1007 in Halifax, Virginia. The meeting was public noticed in *The Virginia Register of Regulations.*

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APPENDIX A:
Discharge Monitoring Report Data

Table A-1: Discharge Monitoring Report Data Summary

Permit No		VA0006513	VA0020524	VA0022721	VA0022730	VA0027707	VA0027715	VA0051951	VA0063843
Flow (mgd) (Quantity Average)	No of Samples	68	68	4	68	59	58	1	68
	Permit Limit	No limit	0.45	0.0051	0.0051	0.005	0.006	No limit	No limit
	Min	0.015	0.167	0	0.0008	0.001	0.0011	0.00432	0.04
	Max	0.2	0.43	0	0.0035	0.0041	0.018	0.00432	0.386
	Exceedances of Permit Limit	-	0	0	0	0	2	-	-
Chlorine (CL2) Instantaneous Tech Limit (mg/L)	No of Samples	-	68	-	68	60	60	-	44
	Permit min	-	0.6	0.6	0.6	0.6	0.6	-	0.6
	Min of Concentration Minimum	-	1	-	0.1	0	1.5	-	0.6
	Max of Concentration Minimum	-	1.57	-	3.5	2.2	1.75	-	1.5
	Exceedances of minimum	-	0	-	1	1	0	-	0

APPENDIX B:
Livestock and Wildlife Inventories by Subwatershed

Table B-1: Livestock Inventory by Subwatershed:

Subwatershed	Beef Cows	Milk cows	Hogs and pigs inventory	Sheep and lambs inventory	Chickens	Horses
1	151	0	87	1	0	13
2	201	0	115	1	0	17
3	401	0	230	2	0	34
4	624	0	358	3	0	52
5	145	0	83	1	0	12
6	278	0	159	1	0	23
7	135	0	77	1	0	11
8	42	0	24	0	0	3
9	364	0	209	2	0	30
10	62	0	36	0	0	5
11	340	0	195	2	0	28
12	106	0	61	1	0	9
13	255	0	124	1	20,000	24
14	0	0	0	0	0	0
15	319	0	54	2	34,000	43
16	216	0	19	1	0	31
17	285	0	26	2	0	41
18	524	0	47	4	0	76
19	373	0	33	3	0	54
20	361	0	32	2	0	53
21	392	0	35	3	0	57
22	160	0	14	1	0	23
23	6	0	1	0	0	1
24	11	0	1	0	0	2
25	206	0	19	1	0	30
26	0	0	0	0	0	0
27	329	0	29	2	0	48
28	545	0	49	4	0	79
29	155	0	14	1	0	23
30	313	0	28	2	0	45
31	627	0	56	4	0	91
32	850	0	76	6	0	123
33	512	0	46	4	0	74
34	140	0	13	1	0	20
35	313	700	28	2	0	46
36	3	0	0	0	0	1
37	334	0	30	2	0	49
38	320	3,000	29	2	0	46
39	1,011	0	91	7	0	147
40	403	0	36	3	0	59
41	339	0	30	2	17,000	49
42	331	0	30	2	0	48
43	757	0	68	5	0	110
44	1,275	400	114	9	68,000	185

Subwatershed	Beef Cows	Milk cows	Hogs and pigs inventory	Sheep and lambs inventory	Chickens	Horses
45	121	0	11	1	0	18
46	231	0	21	2	0	34
47	623	0	56	4	0	90
48	670	0	60	5	0	97
49	799	0	72	5	0	116
50	294	0	26	2	0	43
51	259	0	58	2	0	33
52	280	0	25	2	0	41
53	368	0	202	2	0	32
54	217	0	124	1	0	18
55	365	0	198	2	0	32
56	242	0	32	2	34,000	34
57	460	0	84	3	0	61
58	301	0	27	2	0	44
59	200	0	18	1	0	29
60	716	0	64	5	0	104
61	746	0	67	5	0	108
62	247	0	142	1	0	21
63	362	0	208	2	0	30
Total	**22,018**	**4,100**	**4,301**	**141**	**173,000**	**2,902**

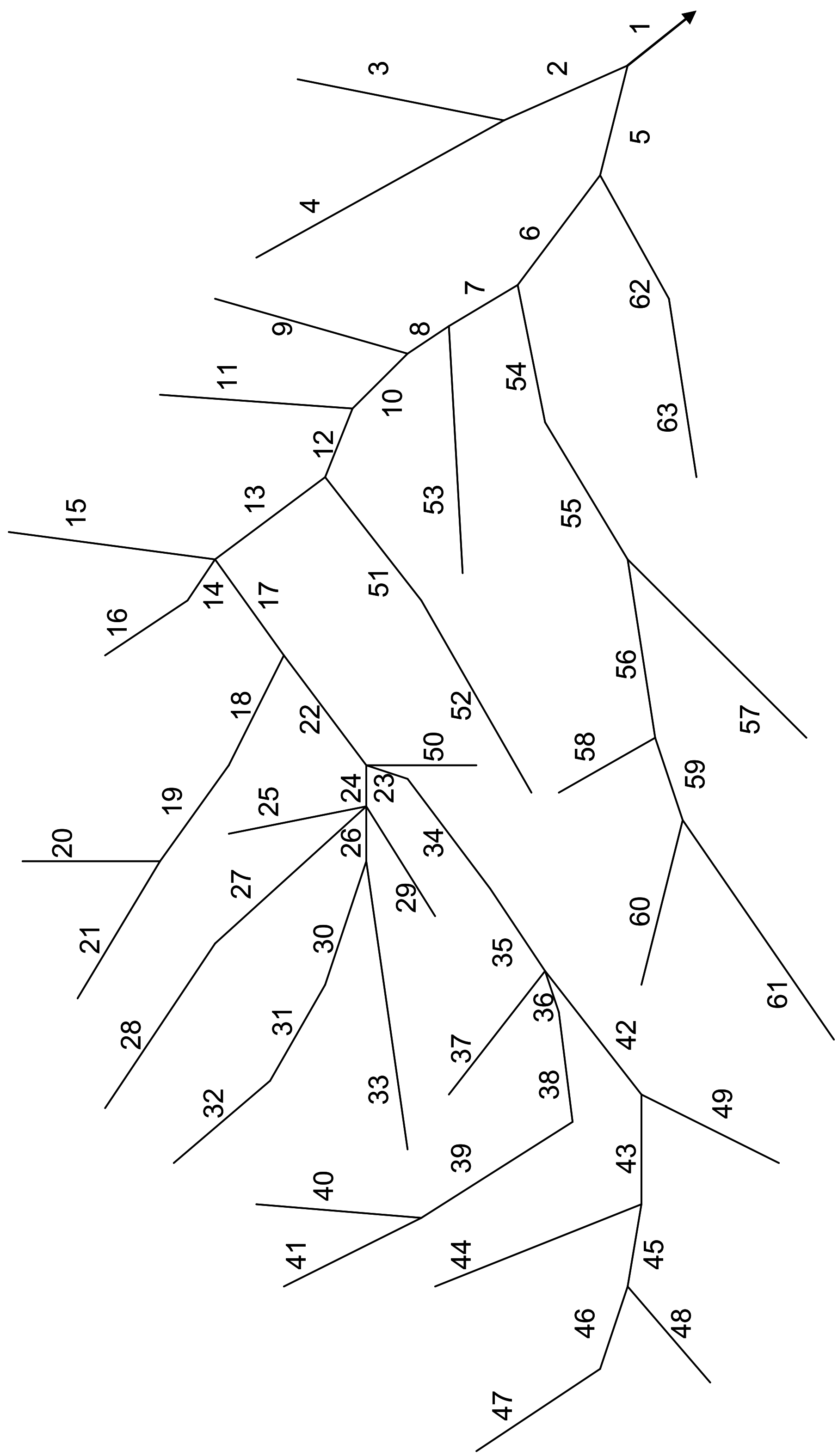
Table B-2: Wildlife Inventory

Subwatershed	Deer	Raccoon	Muskrat	Beaver	Wild Turkey	Goose	Mallard	Wood duck
1	259	259	1,121	122	41	54	9	9
2	294	289	1,250	136	51	62	10	10
3	434	403	1,741	190	72	91	14	14
4	455	399	1,725	188	66	95	13	13
5	266	233	1,006	110	47	56	8	8
6	270	293	1,265	138	43	57	10	10
7	141	135	585	64	23	30	5	5
8	66	54	233	25	12	14	2	2
9	335	285	1,231	134	52	70	10	10
10	119	127	547	60	22	25	4	4
11	232	230	994	108	33	49	8	8
12	122	112	483	53	21	26	4	4
13	350	346	1,495	163	61	73	12	12
14	1	2	10	1	0	0	0	0
15	311	297	1,285	140	50	65	10	10
16	203	184	794	87	32	42	6	6
17	250	271	1,171	128	39	52	9	9
18	372	358	1,546	169	53	78	12	12
19	220	164	708	77	28	46	6	6
20	212	189	816	89	28	44	6	6

Subwatershed	Deer	Raccoon	Muskrat	Beaver	Wild Turkey	Goose	Mallard	Wood duck
21	235	191	824	90	30	49	6	6
22	111	85	367	40	16	23	3	3
23	17	7	31	3	3	4	0	0
24	7	10	44	5	1	2	0	0
25	179	130	563	61	29	38	4	4
26	1	4	17	2	0	0	0	0
27	183	154	664	72	23	38	5	5
28	341	273	1,181	129	40	71	9	9
29	96	86	372	41	13	20	3	3
30	156	155	668	73	19	33	5	5
31	313	277	1,197	131	35	66	9	9
32	364	253	1,094	119	33	76	9	9
33	332	304	1,315	143	45	69	10	10
34	152	122	528	58	26	32	4	4
35	314	285	1,231	134	52	66	10	10
36	5	8	36	4	1	1	0	0
37	173	161	694	76	20	36	5	5
38	194	161	696	76	22	41	5	5
39	589	478	2,064	225	72	123	16	16
40	201	155	670	73	23	42	5	5
41	204	150	646	71	27	43	5	5
42	263	252	1,090	119	38	55	9	9
43	357	268	1,158	126	40	75	9	9
44	649	554	2,395	261	77	136	19	19
45	90	66	286	31	13	19	2	2
46	120	110	476	52	15	25	4	4
47	407	370	1,597	174	56	85	12	12
48	432	357	1,543	168	59	91	12	12
49	471	340	1,468	160	60	99	11	11
50	292	297	1,284	140	47	61	10	10
51	303	265	1,146	125	52	64	9	9
52	367	291	1,256	137	63	77	10	10
53	321	284	1,226	134	50	67	10	10
54	285	263	1,137	124	50	60	9	9
55	415	372	1,610	176	69	87	13	13
56	286	226	979	107	49	60	8	8
57	533	481	2,078	227	89	112	16	16
58	208	188	812	89	30	44	6	6
59	202	182	786	86	33	42	6	6
60	479	511	2,207	241	67	100	17	17
61	564	531	2,294	250	82	118	18	18
62	257	244	1,055	115	42	54	8	8
63	324	301	1,299	142	50	68	10	10
Total	**16,700**	**14,831**	**64,093**	**6,992**	**2,433**	**3,500**	**500**	**500**

Appendix C

Model Representation of Stream Reach Networks



Model Representation of Banister River Model Stream Network

Appendix D

Monthly Fecal Coliform Build-up Rates

Table D-1: Monthly Build-up Rates cfu/ac/day (January to June)						
Land use	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**
Forest	4.45E+06	4.45E+06	4.45E+06	4.45E+06	4.45E+06	4.45E+06
Cropland	2.70E+07	1.10E+09	1.10E+09	2.40E+09	9.00E+08	2.00E+09
Pasture	7.00E+08	7.20E+08	7.30E+08	7.50E+08	7.30E+08	7.50E+08
Commercial/Industrial	2.31E+08	2.31E+08	2.31E+08	2.31E+08	2.31E+08	2.31E+08
Low Intensity Residential	2.09E+10	2.09E+10	2.09E+10	2.09E+10	2.09E+10	2.09E+10
Medium Intensity Residential	2.09E+10	2.09E+10	2.09E+10	2.09E+10	2.09E+10	2.09E+10
High Intensity Residential	2.09E+10	2.09E+10	2.09E+10	2.09E+10	2.09E+10	2.09E+10

Table D-2: Monthly Build-up Rates cfu/ac/day (July to December)						
Land use	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**
Forest	4.45E+06	4.45E+06	4.45E+06	4.45E+06	4.45E+06	4.45E+06
Cropland	2.70E+07	1.10E+09	1.10E+09	2.40E+09	9.00E+08	2.00E+09
Pasture	7.00E+08	7.20E+08	7.30E+08	7.50E+08	7.30E+08	7.50E+08
Commercial/Industrial	2.31E+08	2.31E+08	2.31E+08	2.31E+08	2.31E+08	2.31E+08
Low Intensity Residential	2.09E+10	2.09E+10	2.09E+10	2.09E+10	2.09E+10	2.09E+10
Medium Intensity Residential	2.09E+10	2.09E+10	2.09E+10	2.09E+10	2.09E+10	2.09E+10
High Intensity Residential	2.09E+10	2.09E+10	2.09E+10	2.09E+10	2.09E+10	2.09E+10

Table D-3: Banister River (VAC-L67R-01)Monthly Direct Deposition Rates (cfu/ac/day)			
Month	**Direct Cattle**	**Direct Wildlife**	**Failed Septic**
1	2.60E+12	8.18E+12	2.37E+09
2	3.59E+12	7.48E+12	2.17E+09
3	5.26E+12	8.18E+12	2.37E+09
4	5.09E+12	7.92E+12	2.30E+09
5	6.59E+12	8.18E+12	2.37E+09
6	6.37E+12	7.92E+12	2.30E+09
7	6.59E+12	8.18E+12	2.37E+09
8	5.26E+12	8.18E+12	2.37E+09
9	3.80E+12	7.92E+12	2.30E+09
10	3.93E+12	8.18E+12	2.37E+09
11	2.51E+12	7.92E+12	2.30E+09
12	2.60E+12	8.18E+12	2.37E+09

Table D-4: Banister River (VAC-L65R-01)Monthly Direct Deposition Rates (cfu/ac/day)			
Month	Direct Cattle	Direct Wildlife	Failed Septic
1	7.01E+11	1.59E+12	4.20E+07
2	9.61E+11	1.45E+12	3.84E+07
3	1.40E+12	1.59E+12	4.20E+07
4	1.36E+12	1.54E+12	4.07E+07
5	1.75E+12	1.59E+12	4.20E+07
6	1.70E+12	1.54E+12	4.07E+07
7	1.75E+12	1.59E+12	4.20E+07
8	1.40E+12	1.59E+12	4.20E+07
9	1.02E+12	1.54E+12	4.07E+07
10	1.05E+12	1.59E+12	4.20E+07
11	6.79E+11	1.54E+12	4.07E+07
12	7.01E+11	1.59E+12	4.20E+07

Table D-5: Bearskin Creek (VAC-L65R-02) Monthly Direct Deposition Rates (cfu/ac/day)			
Month	Direct Cattle	Direct Wildlife	Failed Septic
1	5.80E+11	9.76E+11	1.96E+07
2	8.16E+11	8.92E+11	1.79E+07
3	1.20E+12	9.76E+11	1.96E+07
4	1.16E+12	9.45E+11	1.89E+07
5	1.51E+12	9.76E+11	1.96E+07
6	1.46E+12	9.45E+11	1.89E+07
7	1.51E+12	9.76E+11	1.96E+07
8	1.20E+12	9.76E+11	1.96E+07
9	8.64E+11	9.45E+11	1.89E+07
10	8.93E+11	9.76E+11	1.96E+07
11	5.62E+11	9.45E+11	1.89E+07
12	5.80E+11	9.76E+11	1.96E+07

Table D-6: Cherrystone Creek (VAC-L66R-01) Monthly Direct Deposition Rates (cfu/ac/day)			
Month	Direct Cattle	Direct Wildlife	Failed Septic
1	1.30E+12	1.99E+12	4.48E+07
2	1.91E+12	1.82E+12	4.10E+07
3	2.89E+12	1.99E+12	4.48E+07
4	2.80E+12	1.93E+12	4.34E+07
5	3.68E+12	1.99E+12	4.48E+07
6	3.56E+12	1.93E+12	4.34E+07
7	3.68E+12	1.99E+12	4.48E+07
8	2.89E+12	1.99E+12	4.48E+07
9	2.03E+12	1.93E+12	4.34E+07
10	2.10E+12	1.99E+12	4.48E+07
11	1.26E+12	1.93E+12	4.34E+07
12	1.30E+12	1.99E+12	4.48E+07

Table D-7: Polecat Creek (VAC-L71R-05) Monthly Direct Deposition Rates (cfu/ac/day)			
Month	**Direct Cattle**	**Direct Wildlife**	**Failed Septic**
1	2.60E+11	9.28E+11	1.68E+07
2	3.56E+11	8.48E+11	1.53E+07
3	5.19E+11	9.28E+11	1.68E+07
4	5.03E+11	8.98E+11	1.62E+07
5	6.50E+11	9.28E+11	1.68E+07
6	6.29E+11	8.98E+11	1.62E+07
7	6.50E+11	9.28E+11	1.68E+07
8	5.19E+11	9.28E+11	1.68E+07
9	3.77E+11	8.98E+11	1.62E+07
10	3.89E+11	9.28E+11	1.68E+07
11	2.52E+11	8.98E+11	1.62E+07
12	2.60E+11	9.28E+11	1.68E+07

Table D-8: Stinking River (VAC-L69R-01) Monthly Direct Deposition Rates (cfu/ac/day)			
Month	**Direct Cattle**	**Direct Wildlife**	**Failed Septic**
1	7.75E+11	1.75E+12	1.96E+07
2	1.06E+12	1.60E+12	1.79E+07
3	1.55E+12	1.75E+12	1.96E+07
4	1.50E+12	1.70E+12	1.89E+07
5	1.94E+12	1.75E+12	1.96E+07
6	1.88E+12	1.70E+12	1.89E+07
7	1.94E+12	1.75E+12	1.96E+07
8	1.55E+12	1.75E+12	1.96E+07
9	1.12E+12	1.70E+12	1.89E+07
10	1.16E+12	1.75E+12	1.96E+07
11	7.50E+11	1.70E+12	1.89E+07
12	7.75E+11	1.75E+12	1.96E+07

Table D-9: Sandy Creek (VAC-L70R-01) Monthly Direct Deposition Rates (cfu/ac/day)			
Month	**Direct Cattle**	**Direct Wildlife**	**Failed Septic**
1	1.38E+12	4.71E+12	3.38E+08
2	1.90E+12	4.30E+12	3.09E+08
3	2.77E+12	4.71E+12	3.38E+08
4	2.68E+12	4.56E+12	3.27E+08
5	3.46E+12	4.71E+12	3.38E+08
6	3.35E+12	4.56E+12	3.27E+08
7	3.46E+12	4.71E+12	3.38E+08
8	2.77E+12	4.71E+12	3.38E+08
9	2.01E+12	4.56E+12	3.27E+08
10	2.08E+12	4.71E+12	3.38E+08
11	1.34E+12	4.56E+12	3.27E+08
12	1.38E+12	4.71E+12	3.38E+08

Table D-10: Whitehorn Creek (VAC-L68R-01) Monthly Direct Deposition Rates (cfu/ac/day)			
Month	**Direct Cattle**	**Direct Wildlife**	**Failed Septics**
1	1.51E+12	2.93E+12	3.58E+08
2	2.07E+12	2.67E+12	3.28E+08
3	3.02E+12	2.93E+12	3.58E+08
4	2.93E+12	2.83E+12	3.47E+08
5	3.78E+12	2.93E+12	3.58E+08
6	3.66E+12	2.83E+12	3.47E+08
7	3.78E+12	2.93E+12	3.58E+08
8	3.02E+12	2.93E+12	3.58E+08
9	2.19E+12	2.83E+12	3.47E+08
10	2.27E+12	2.93E+12	3.58E+08
11	1.46E+12	2.83E+12	3.47E+08
12	1.51E+12	2.93E+12	3.58E+08

Appendix E

Water Quality Calibration and Validation Plots

E.1 Banister River Segment (VAC-L65R-01)

Figure E-1: Fecal Coliform Calibration Banister River (VAC-L65R-01)

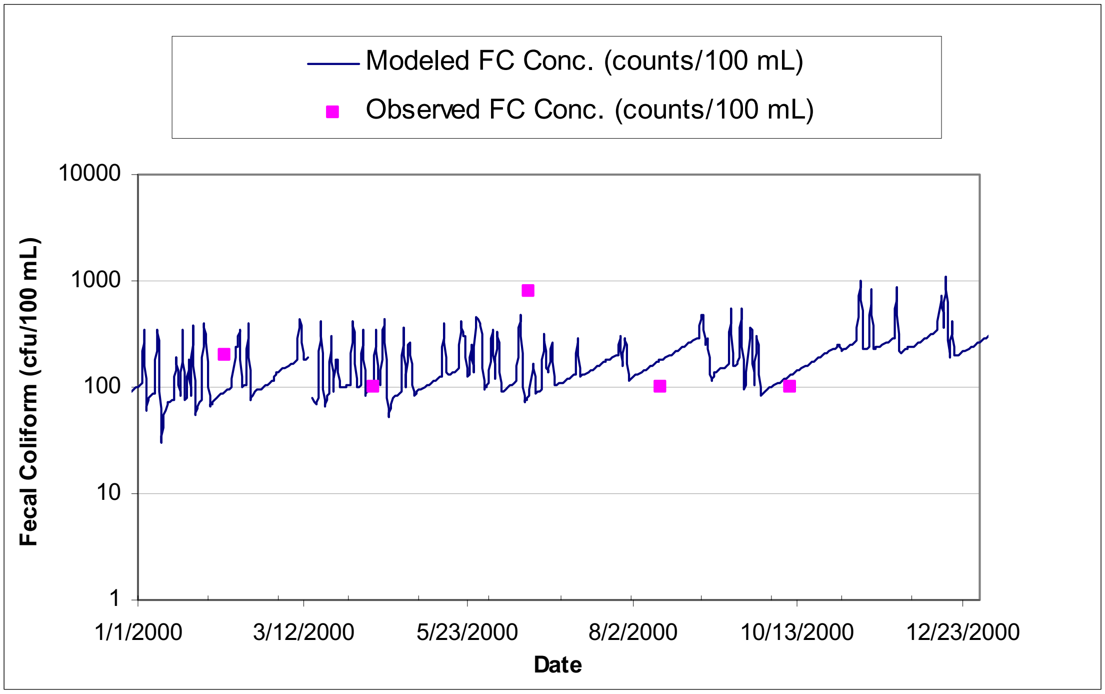
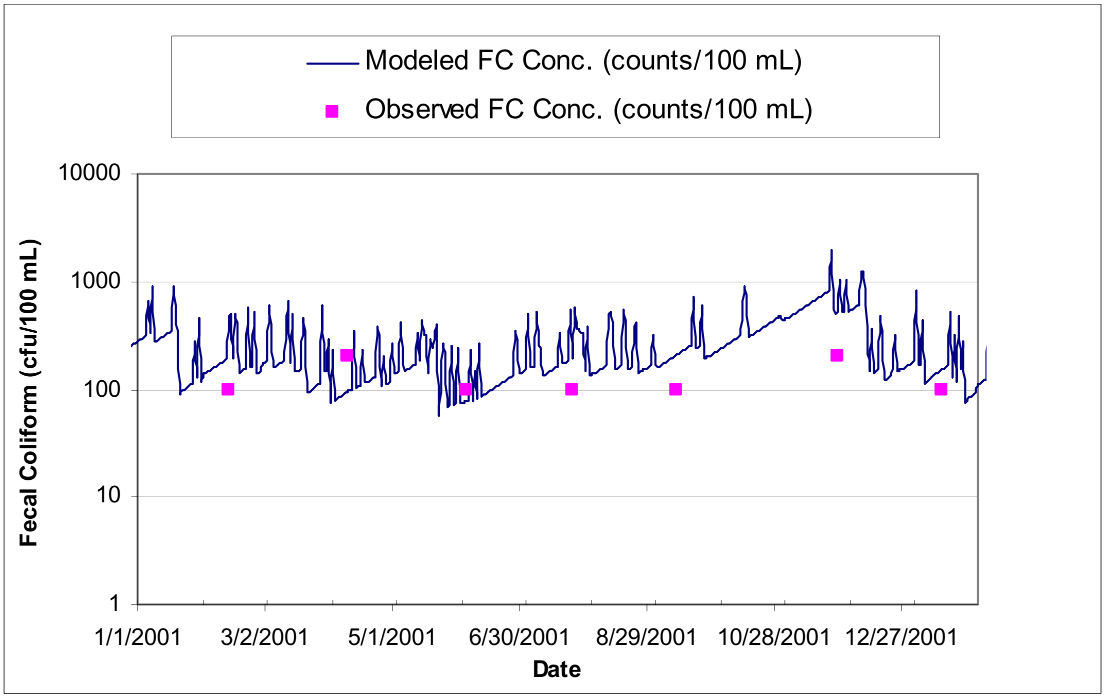


Figure E-2: Fecal Coliform Validation Banister River (Segment VAC-L65R-01)



E.2 Banister River Segment (VAC-L67R-01)

Figure E-3: Fecal Coliform Calibration Banister River (VAC-L67R-01)

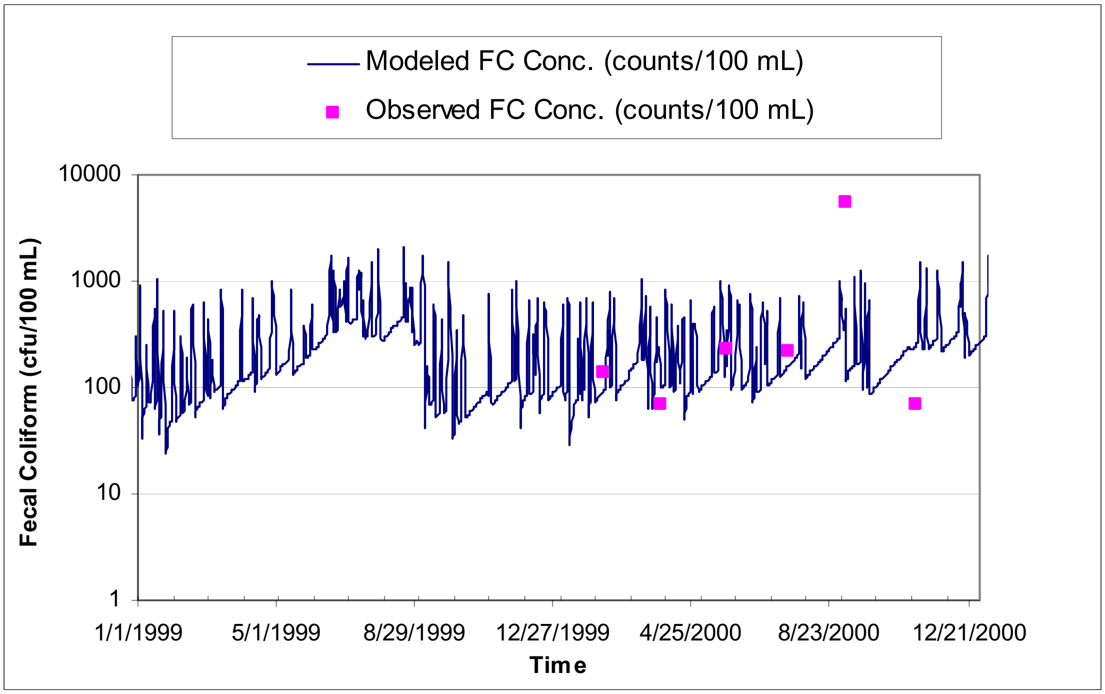
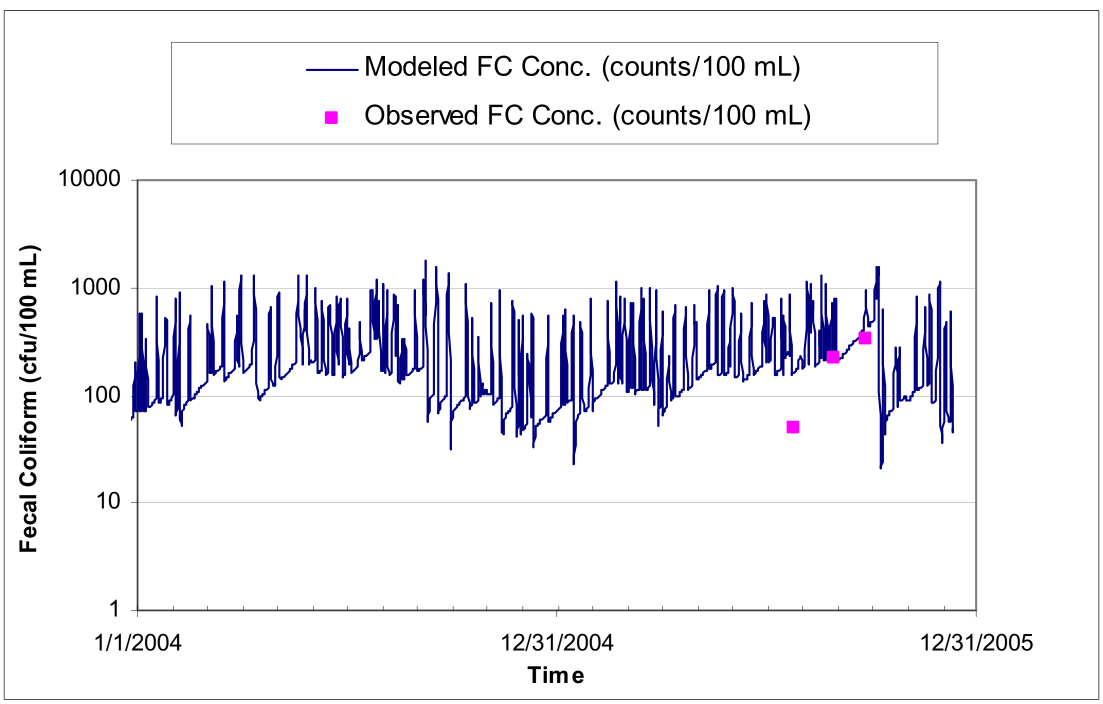
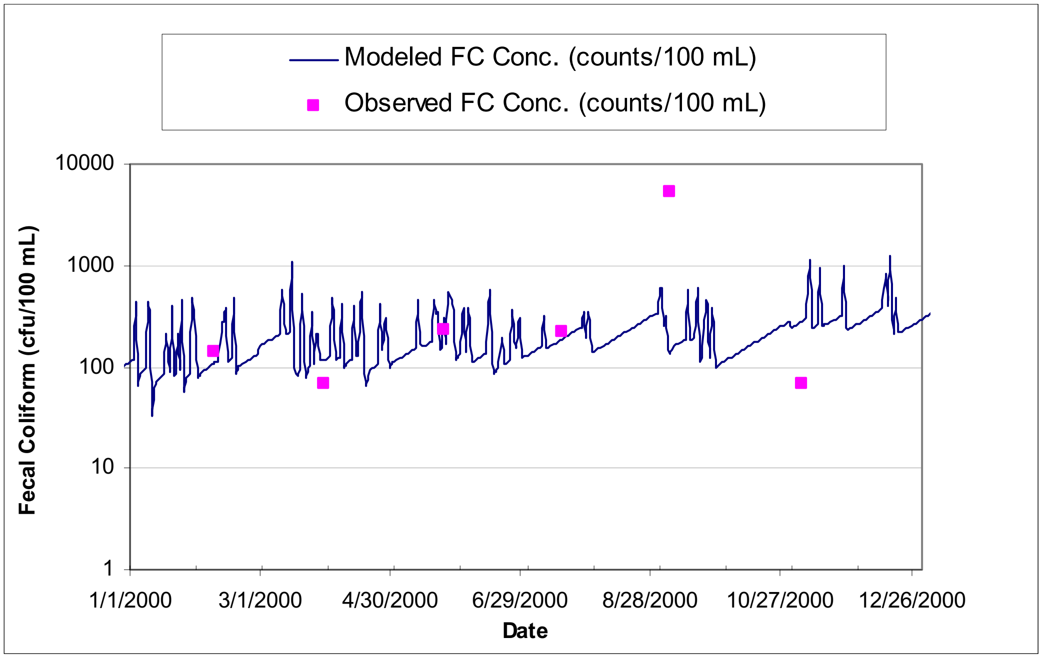


Figure E-4: Fecal Coliform Validation Banister River (VAC-L67R-01)



E.3 Bearskin Creek Segment (VAC-L65R-02)

Figure E-5: Fecal Coliform Calibration Bearskin Creek Segment (VAC-L65R-02)



Note: Data for Bearskin Creek was available in 2000 and solely used for the calibration.

E.4 Cherrystone Creek Segment (VAC-L66R-01)

Figure E-6: Fecal Coliform Calibration Cherrystone Creek Segment (VAC-L66R-01)

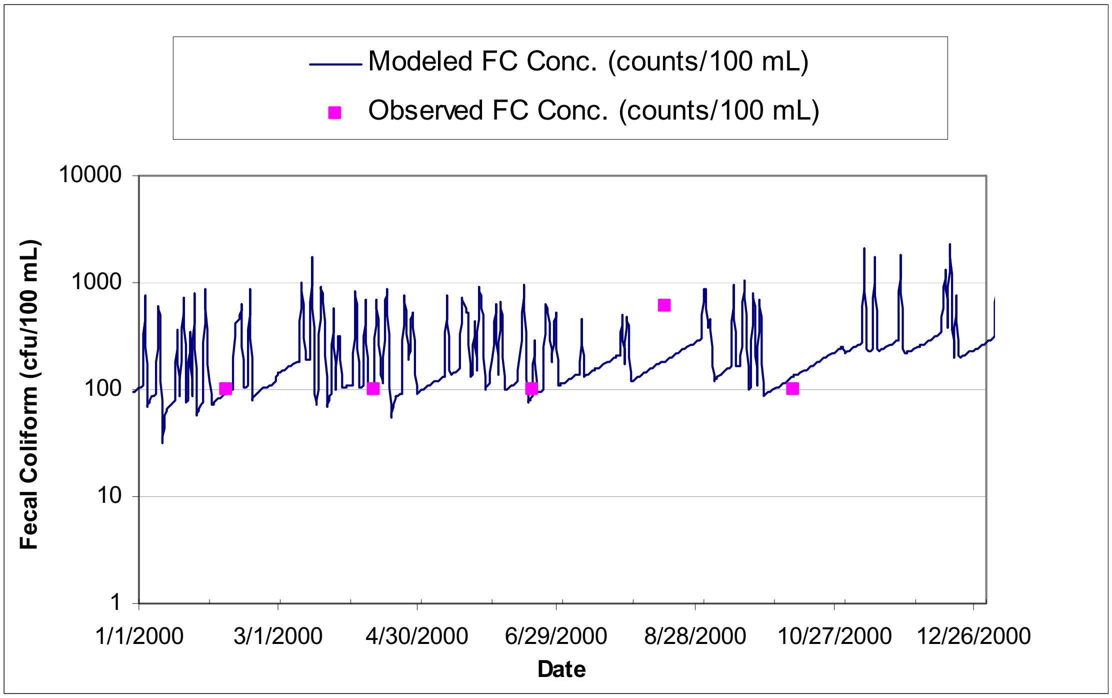
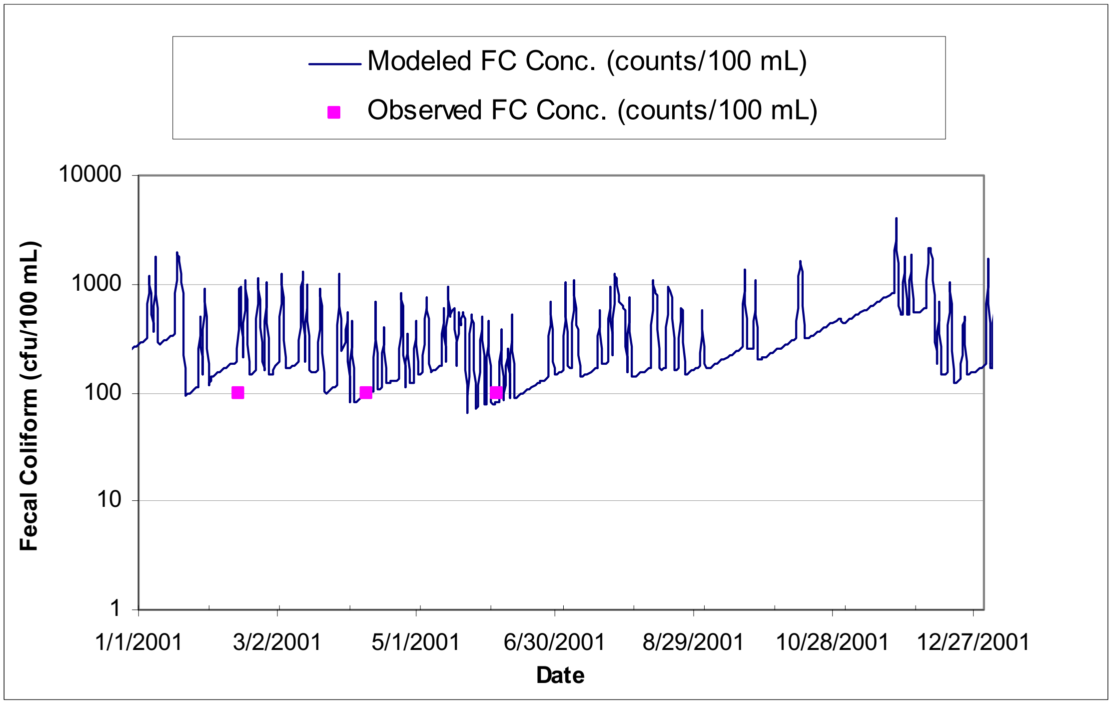


Figure E-7: Fecal Coliform Validation Cherrystone Creek Segment (VAC-L66R-01)



E.5 Polecat Creek Segment (VAC-L71R-01)

Figure E-8: Fecal Coliform Calibration Polecat Creek Segment (VAC-L71R-01)

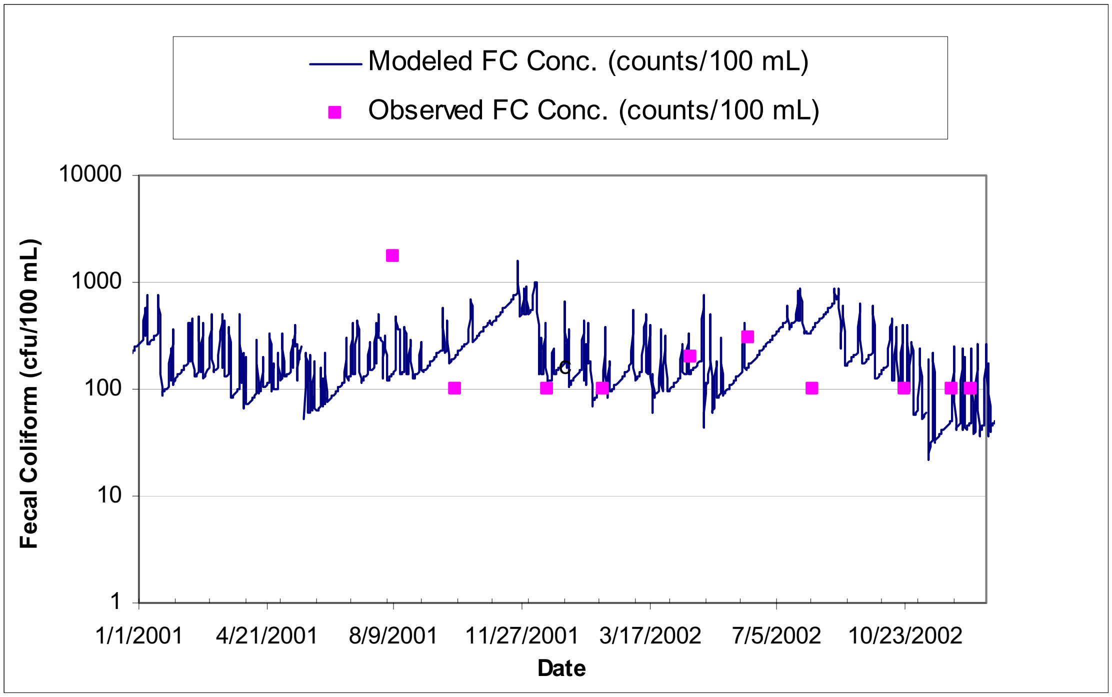
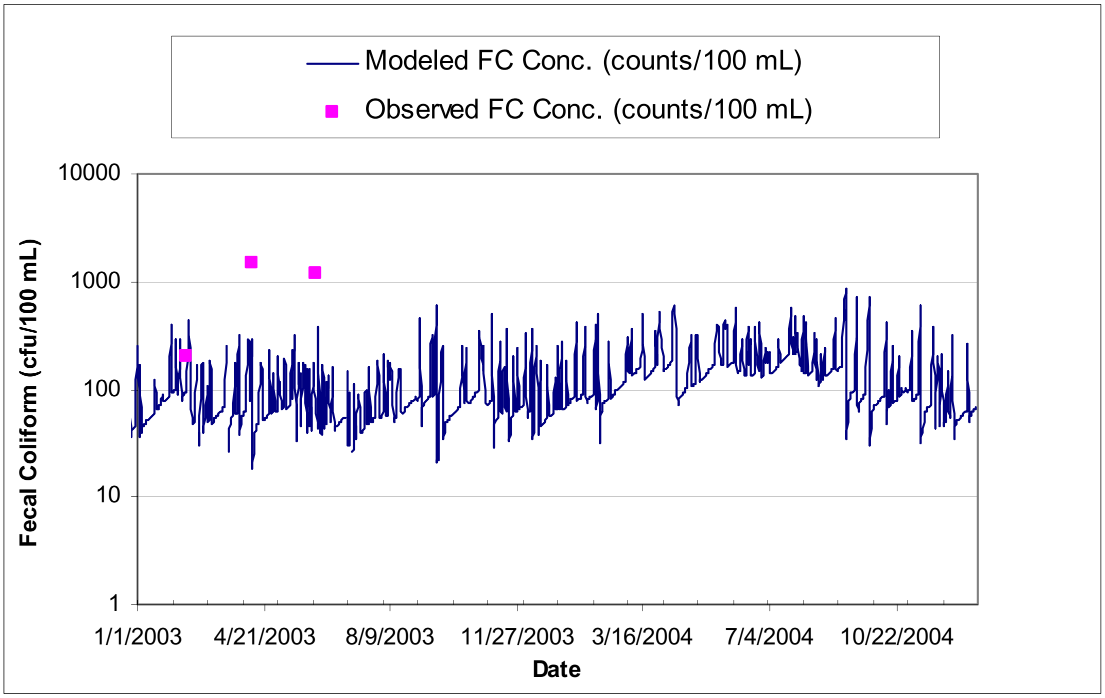
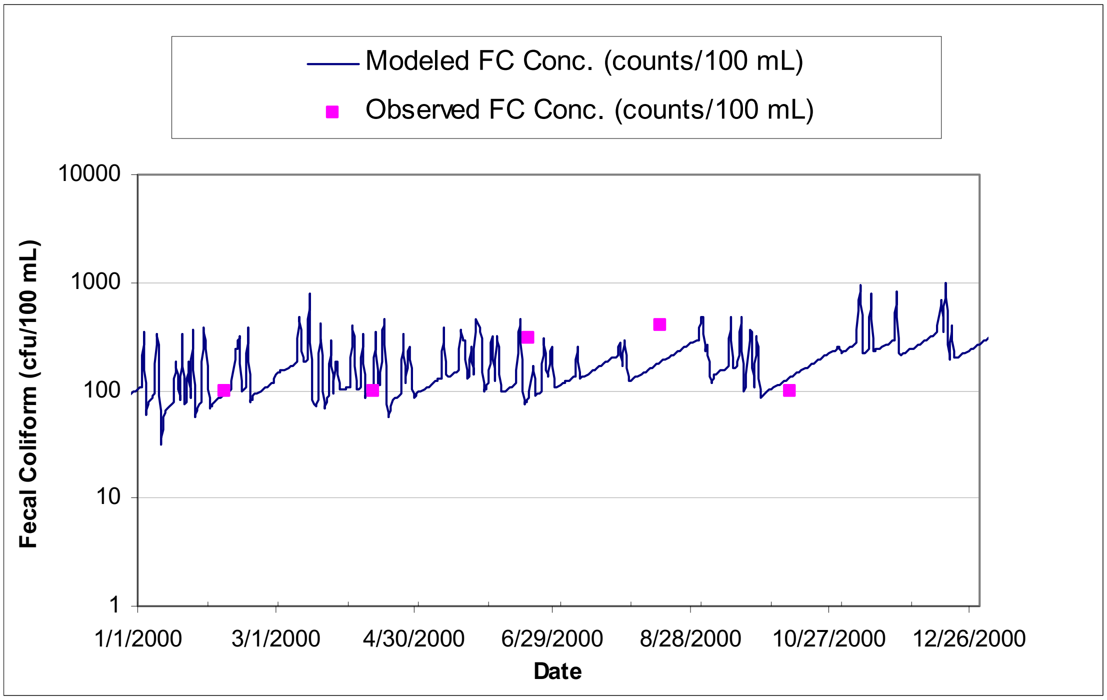


Figure E-9: Fecal Coliform Validation Polecat Creek Segment (VAC-L71R-01)



E.6 Stinking River (Segment VAC-L69R-01)

Figure E-10: Fecal Coliform Calibration Stinking River (Segment VAC-L69R-01)



Note: Data for Stinking River was available in 2000 and solely used for the calibration.

E.7 Sandy Creek (Segment VAC-L70R-01)

Figure E-11: Fecal Coliform Calibration Sandy Creek (Segment VAC-L70R-01)

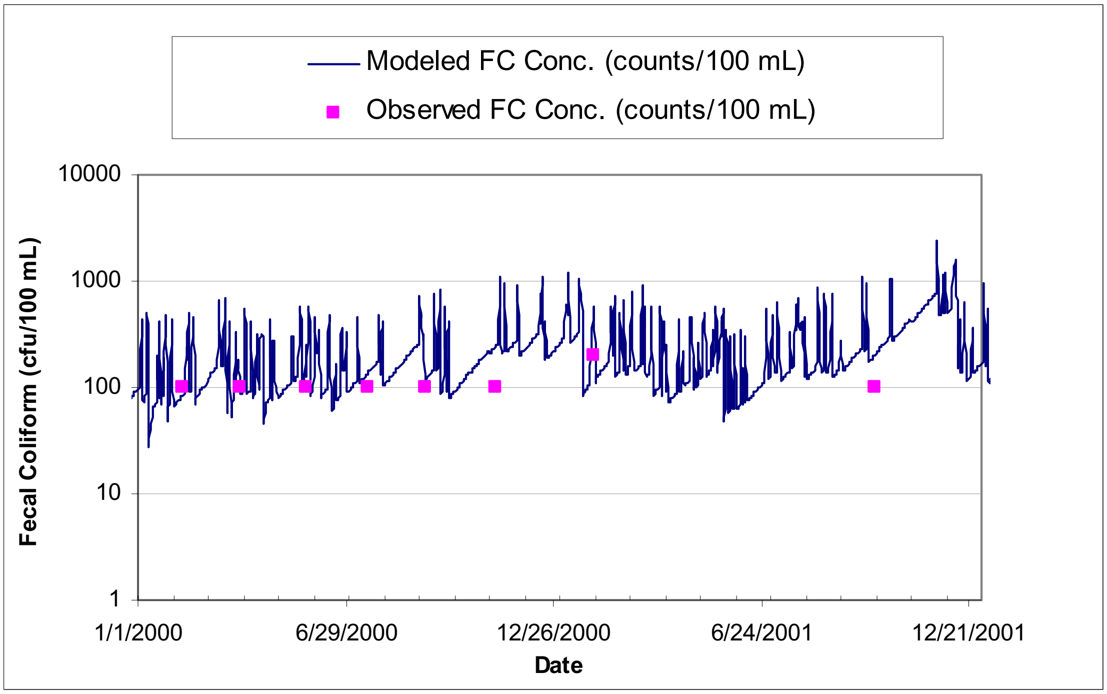
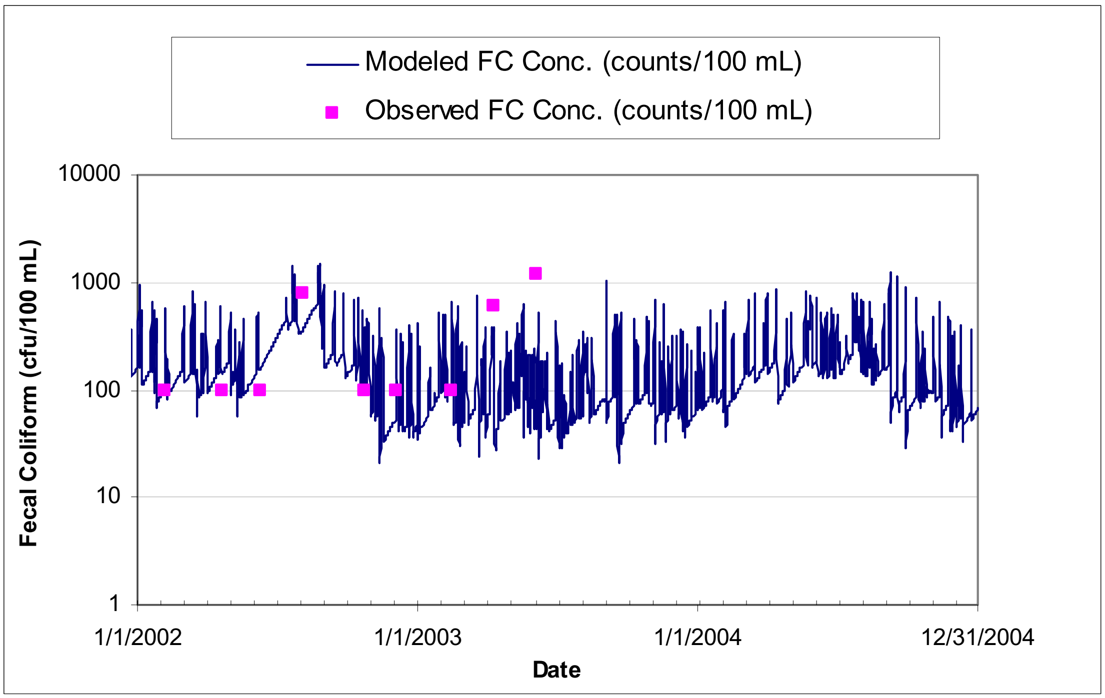
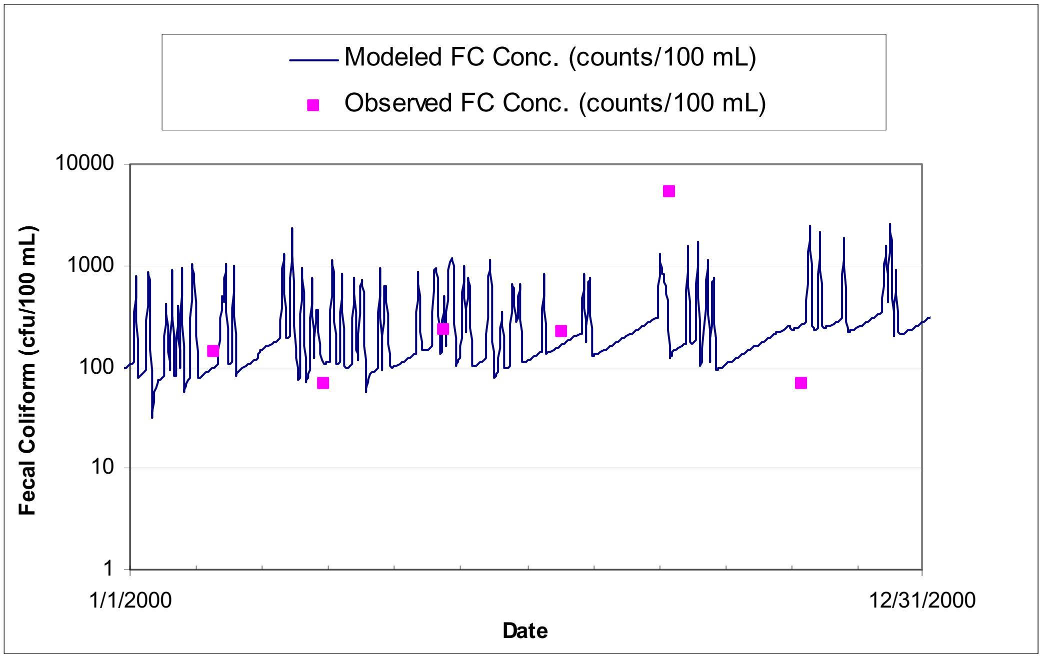


Figure E-12: Fecal Coliform Validation Sandy Creek (Segment VAC-L70R-01)



E.8 Whitehorn Creek (Segment VAC-L68R-01)

Figure E-13: Fecal Coliform Calibration Whitehorn Creek (Segment VAC-L68R-01)



Note: Data for Whitehorn Creek was available in 2000 and solely used for the calibration.

Appendix F

Fecal Coliform and *E. coli* Geometric Mean and Instantaneous Concentrations under Existing Conditions

F.1 Banister River (Segment VAC-L65R-01)

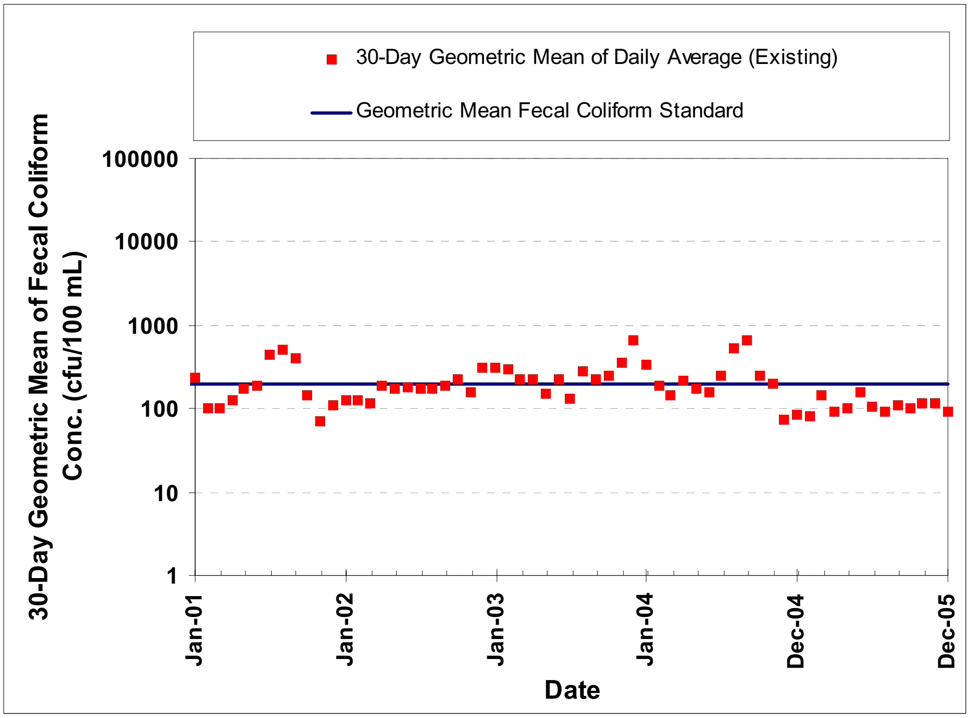


Figure F-1:Banister River (Segment VAC-L65R-01) Fecal Coliform Geometric Mean Existing Conditions

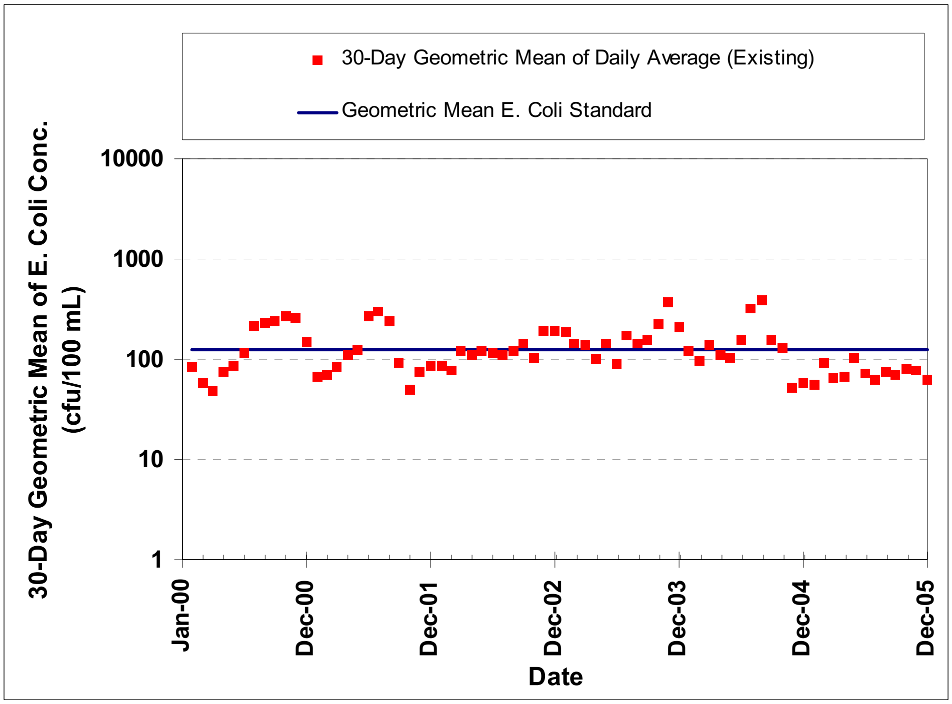


Figure F-2: Banister River (Segment VAC-L65R-01) E. coli Geometric Mean Existing Conditions

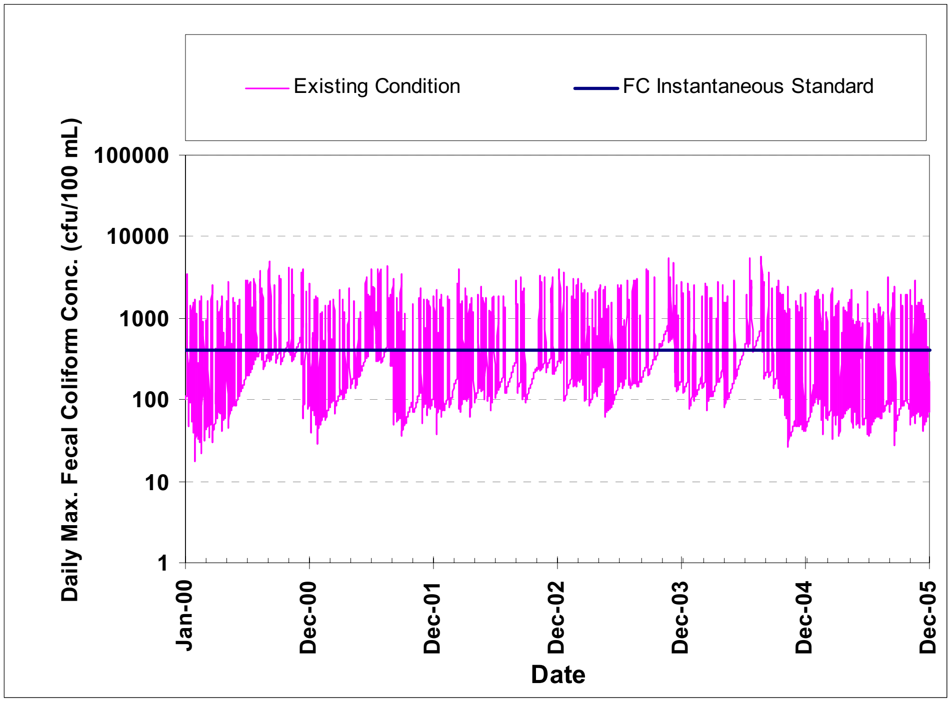


Figure F-3: Banister River (Segment VAC-L65R-01) Fecal Coliform Instantaneous Existing Conditions

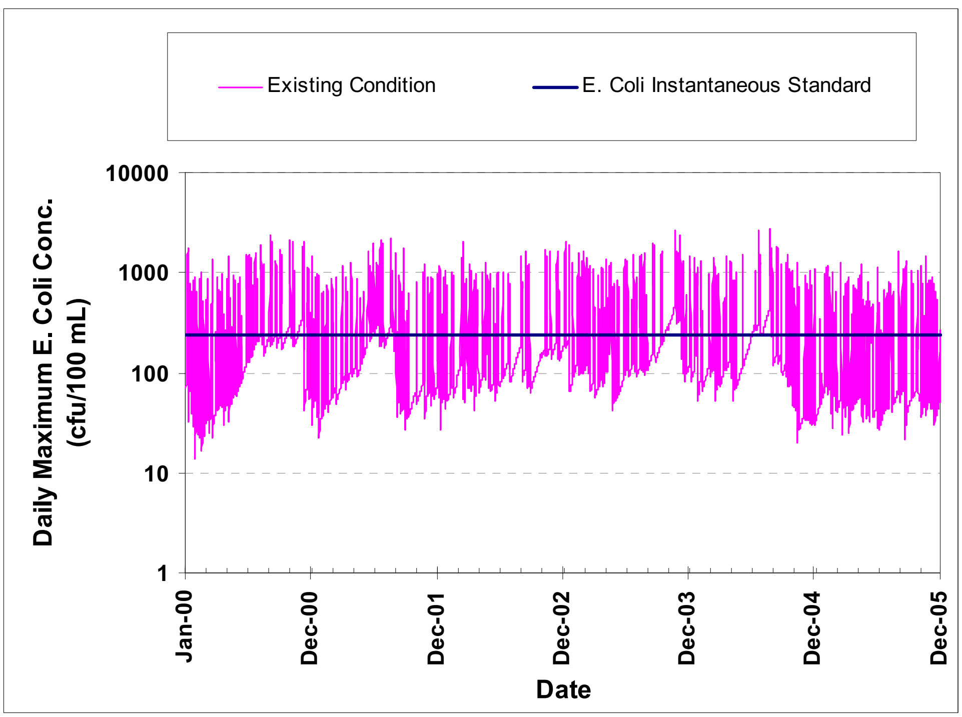


Figure F-4: Banister River (Segment VAC-L65R-01) E. coli Instantaneous Existing Conditions

F.2 Banister River (Segment VAC-L67R-01)

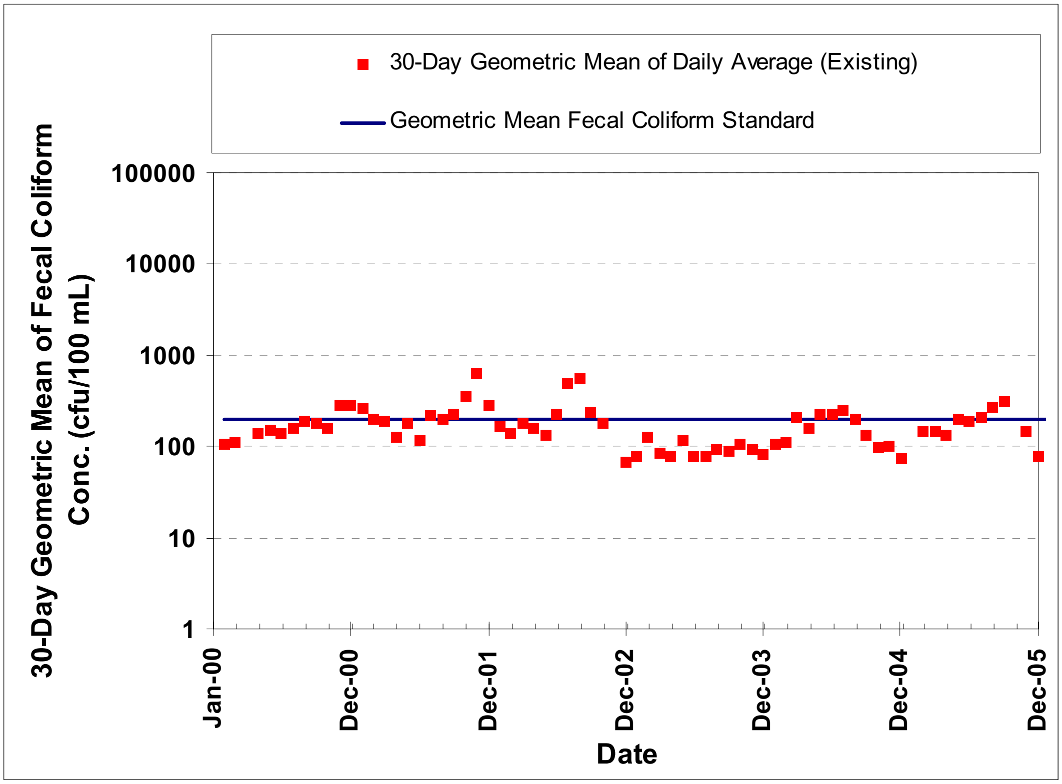


Figure F-5: Banister River (Segment VAC-L67R-01) Fecal Coliform Geometric Mean Existing Conditions

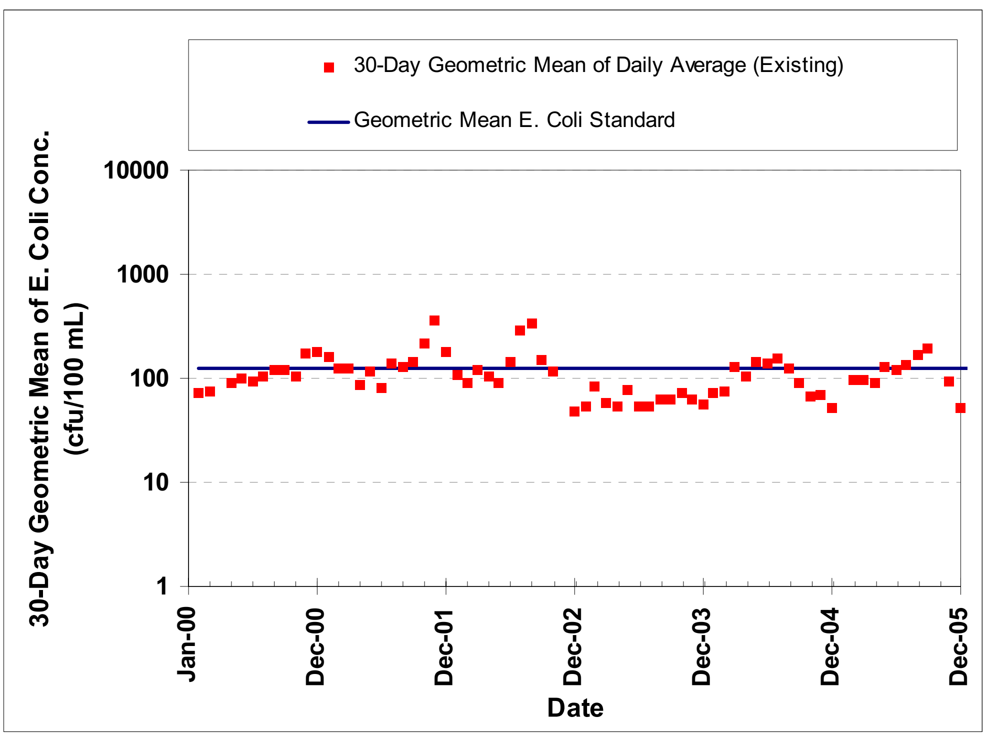


Figure F-6: Banister River (Segment VAC-L67R-01) E. coli Geometric Mean Existing Conditions

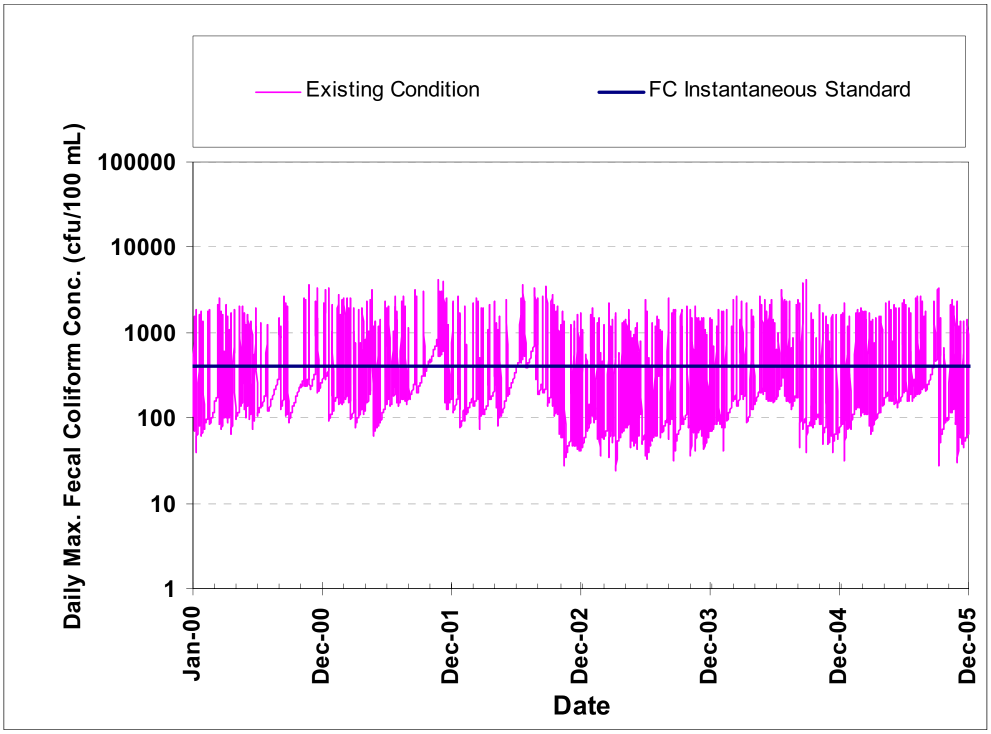


Figure F-7: Banister River (Segment VAC-L67R-01) Fecal Coliform Instantaneous Existing Conditions

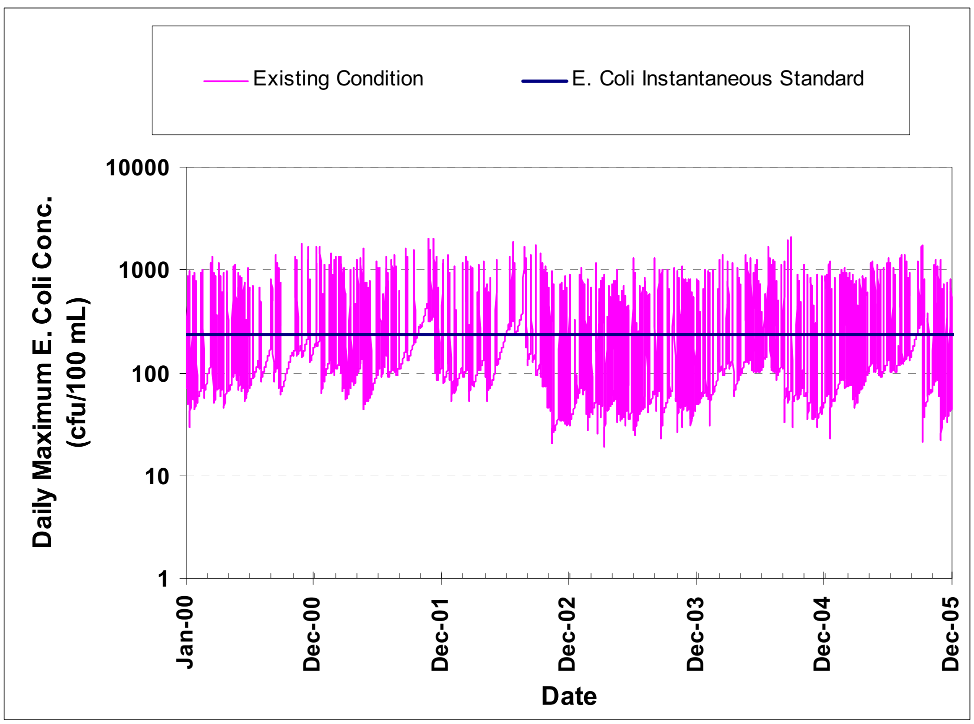


Figure F-8: Banister River (Segment VAC-L67R-01) E. coli Instantaneous Existing Conditions

F.3 Bearskin Creek Segment (VAC-L65R-02)

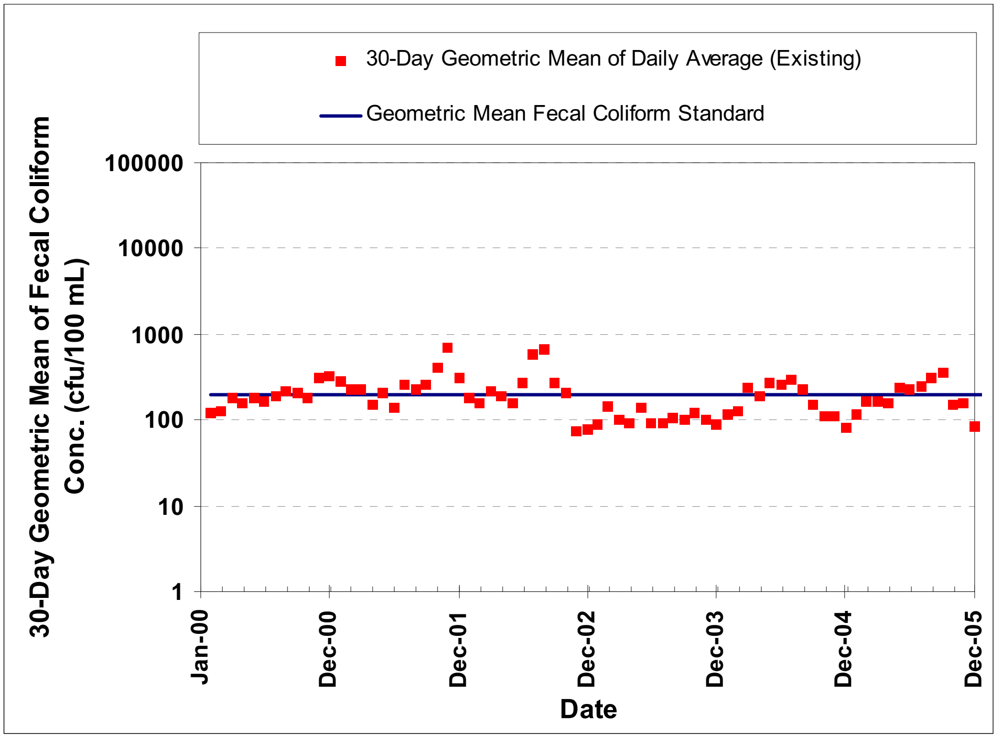


Figure F-9: Bearskin Creek Segment (VAC-L65R-02) Fecal Coliform Geometric Mean Existing Conditions

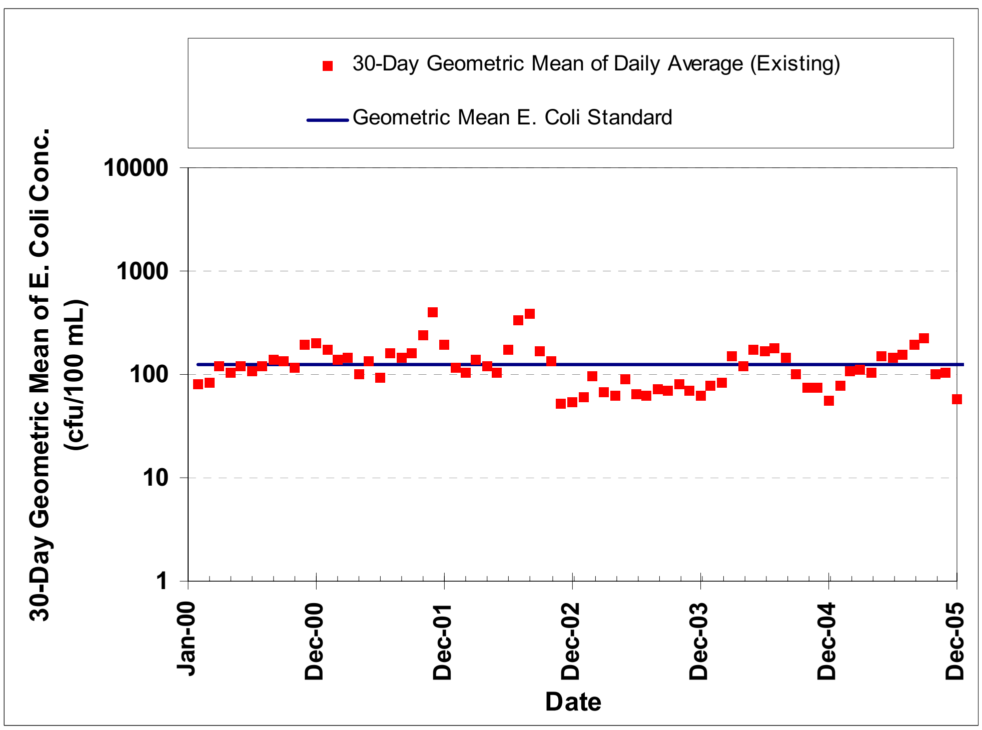


Figure F-10: Bearskin Creek Segment (VAC-L65R-02) E. coli Geometric Mean Existing Conditions

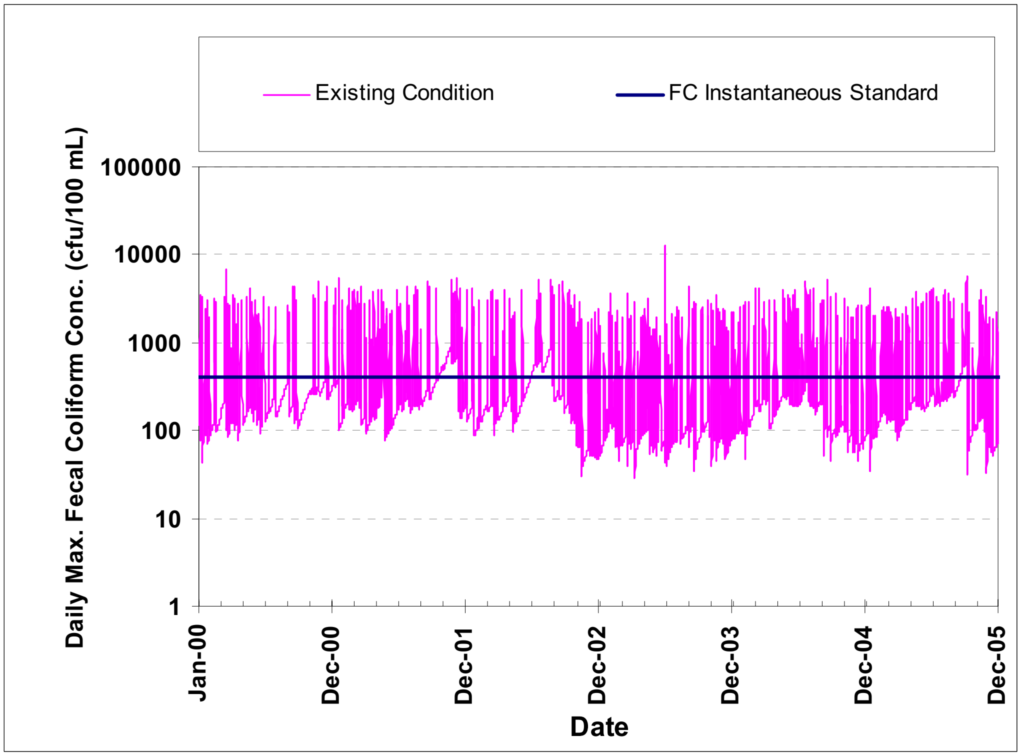


Figure F-11:Bearskin Creek Segment (VAC-L65R-02) Fecal Coliform Instantaneous Existing Conditions

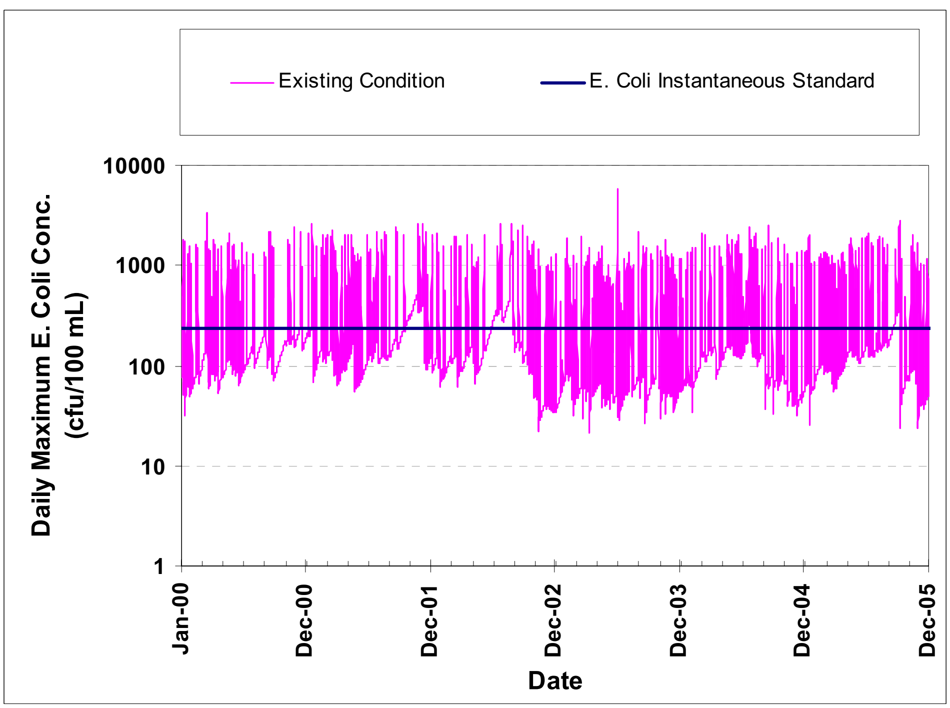


Figure F-12: Bearskin Creek Segment (VAC-L65R-02) E. coli Instantaneous Existing Conditions

F.5 Cherrystone Creek Segment (VAC-L66R-01)

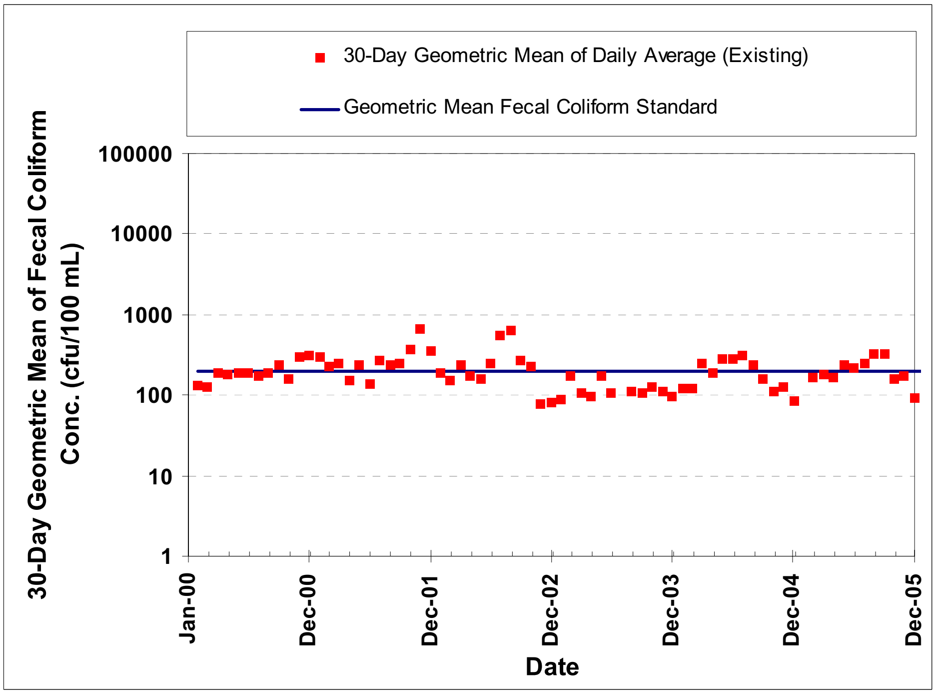


Figure F-13: Cherrystone Creek Segment (VAC-L66R-01) Fecal Coliform Geometric Mean Existing Conditions

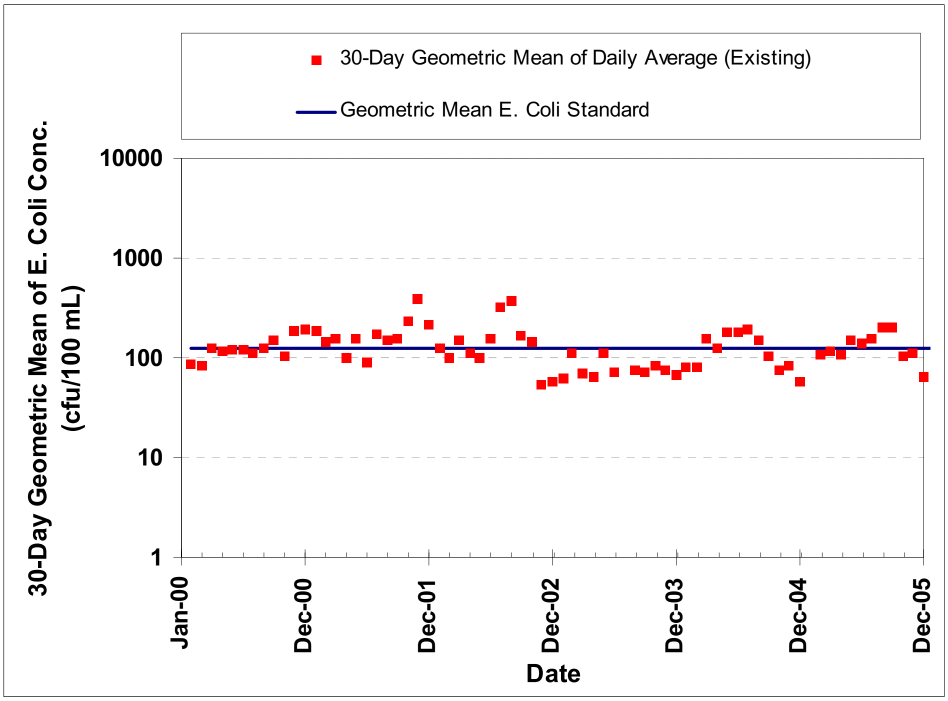


Figure F-14: Cherrystone Creek Segment (VAC-L66R-01) E. coli Geometric Mean Existing Conditions

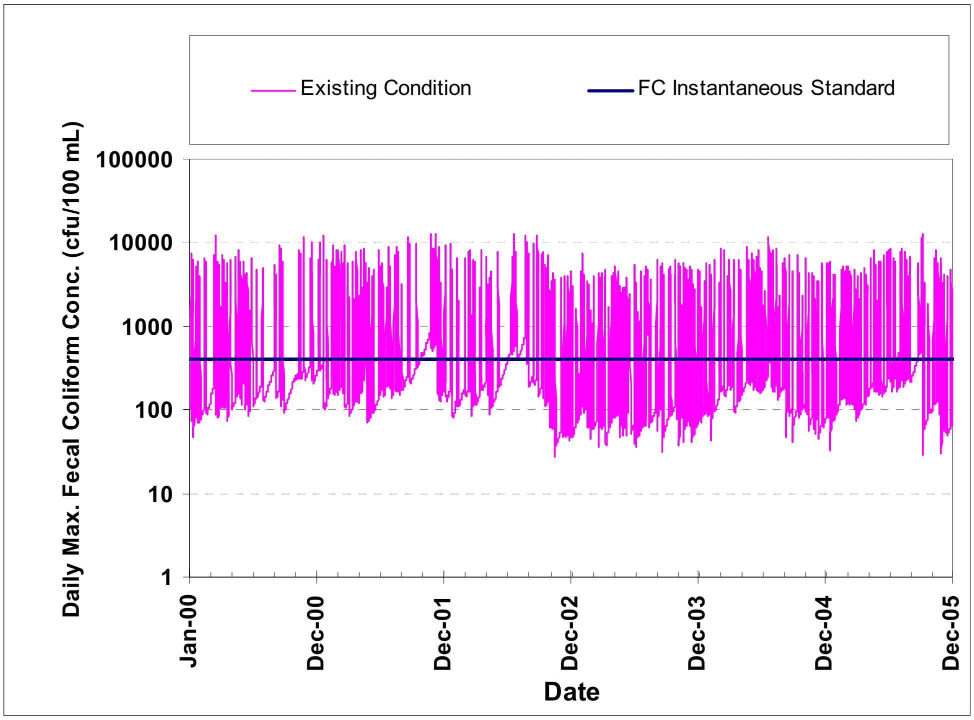


Figure F-15: Cherrystone Creek Segment (VAC-L66R-01) Fecal Coliform Instantaneous Existing Conditions

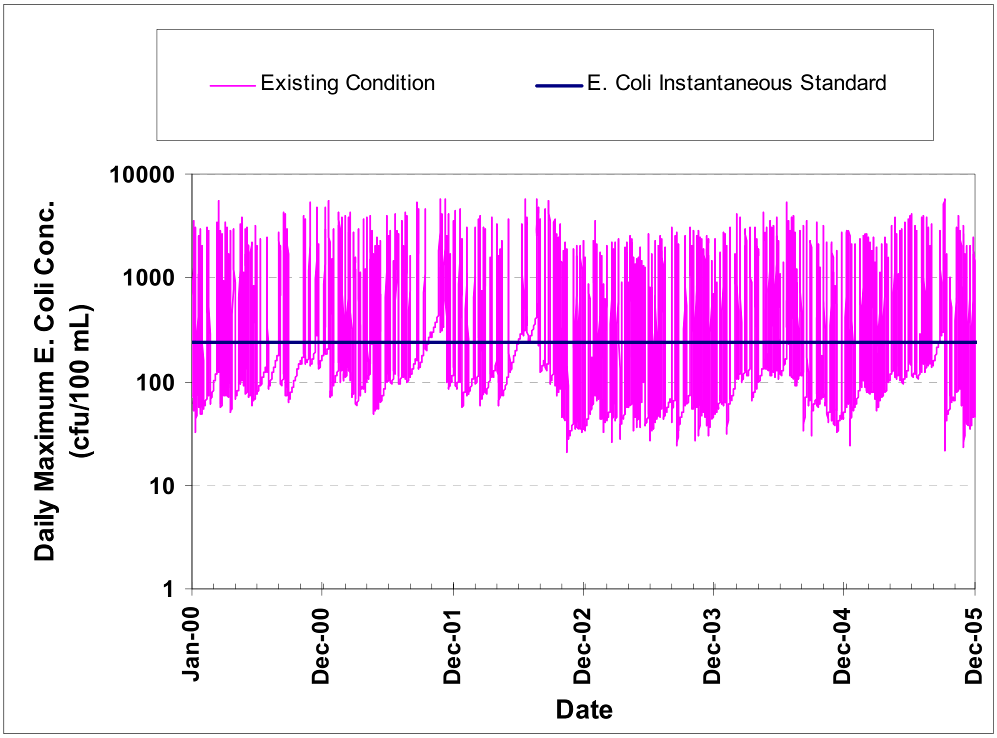


Figure F-16: Cherrystone Creek Segment (VAC-L66R-01) E. coli Instantaneous Existing Conditions

F.9 Polecat Creek Segment (VAC-L71R-01)

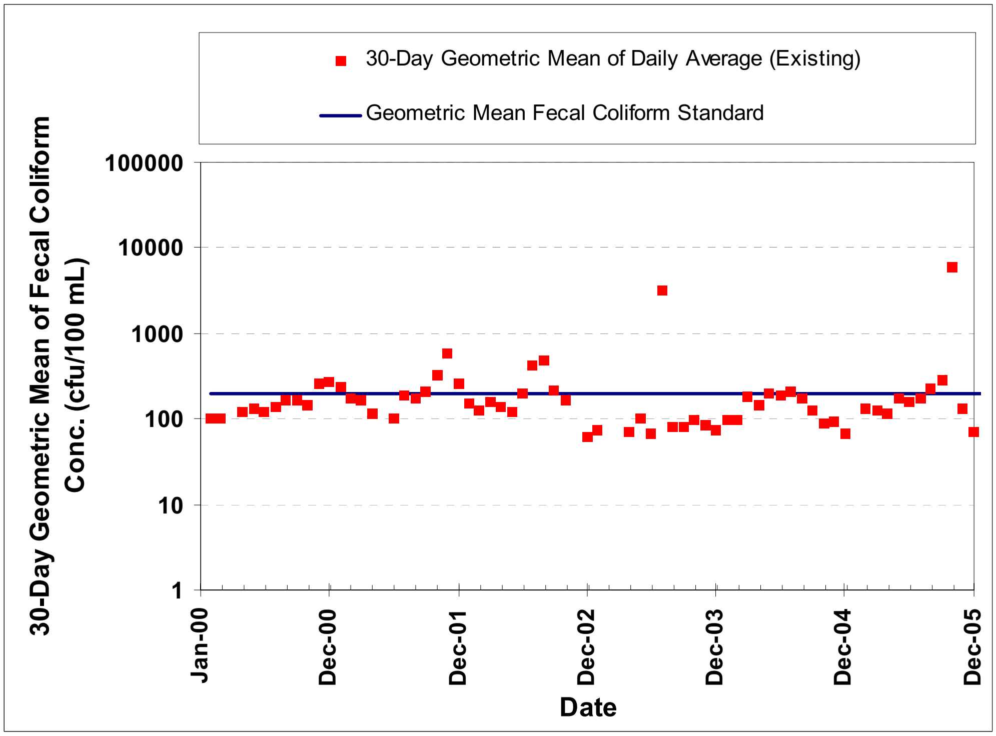


Figure F-17: Polecat Creek Segment (VAC-L71R-01) Fecal Coliform Geometric Mean Existing Conditions

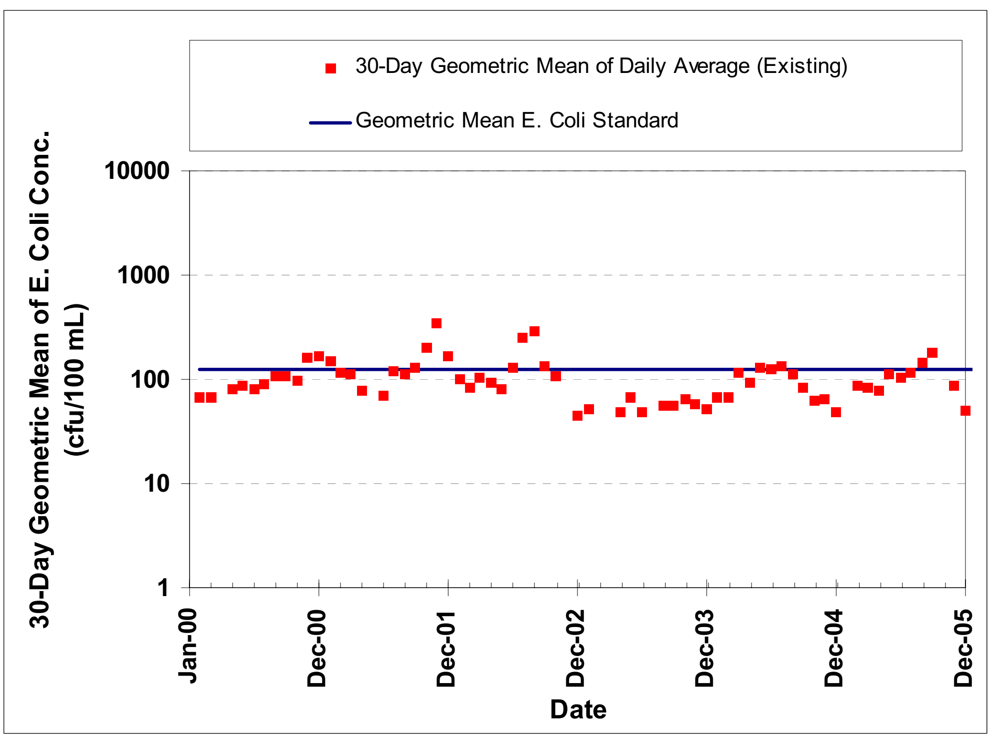


Figure F-18: Polecat Creek Segment (VAC-L71R-01) E. coli Geometric Mean Existing Conditions

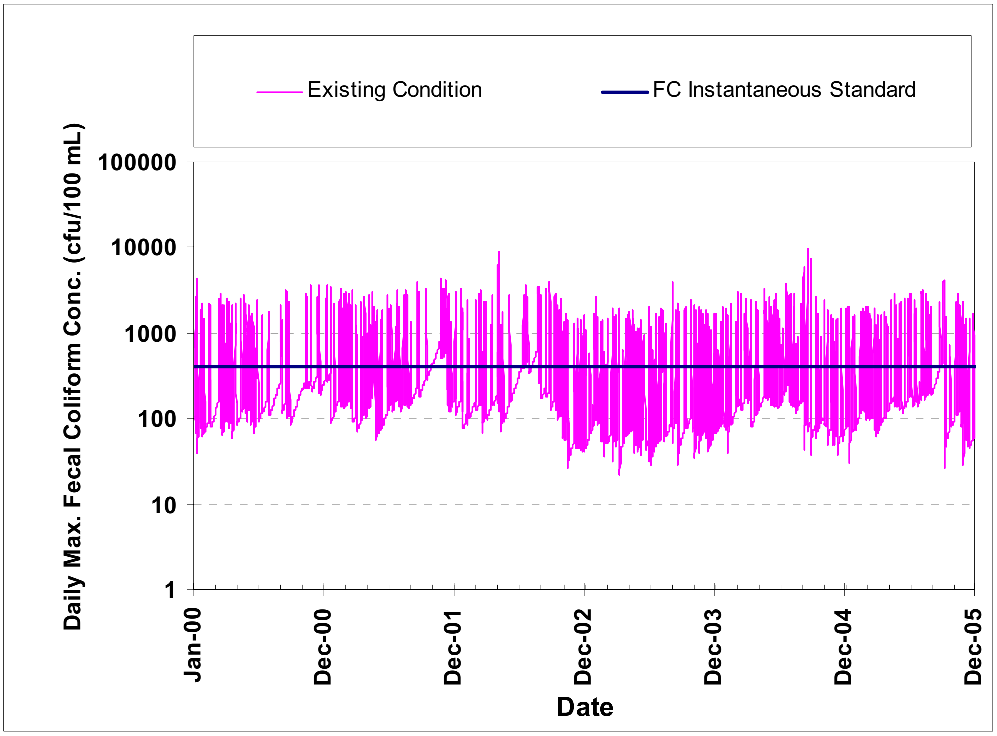


Figure F-19: Polecat Creek Segment (VAC-L71R-01) Fecal Coliform Instantaneous Existing Conditions

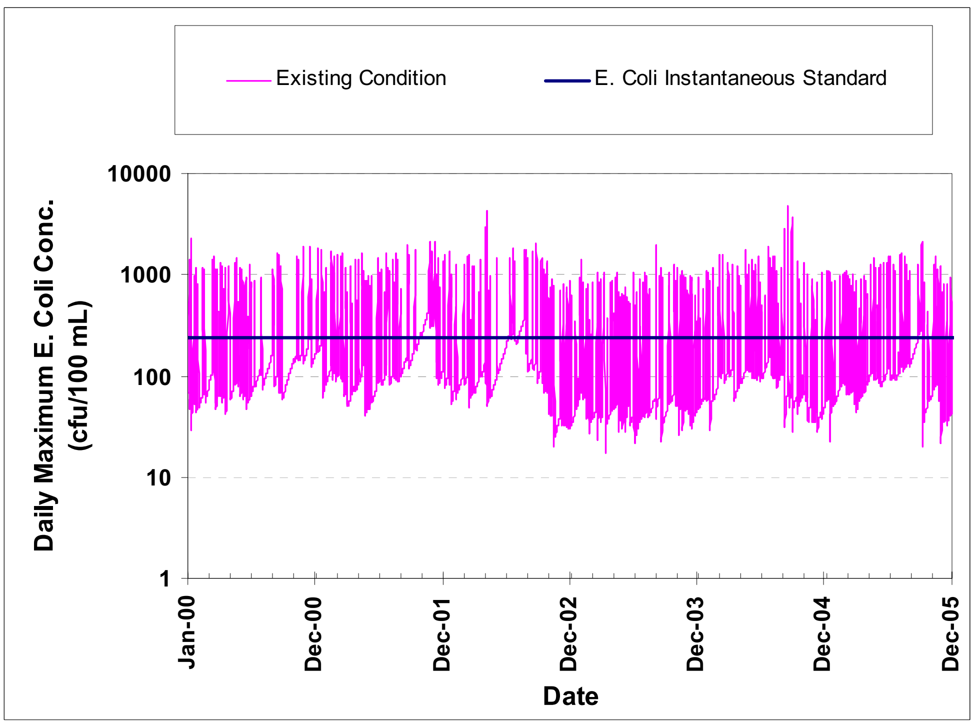


Figure F-20: Polecat Creek Segment (VAC-L71R-01) E. coli Instantaneous Existing Conditions

F.8 Stinking River (Segment VAC-L69R-01)

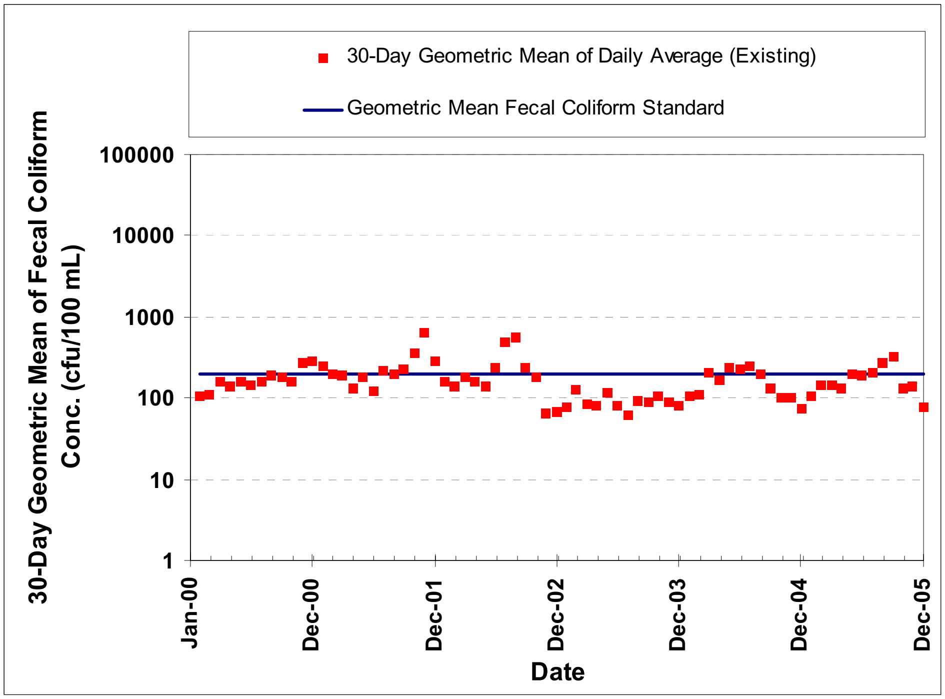


Figure F-21: Stinking River (Segment VAC-L69R-01) Fecal Coliform Geometric Mean Existing Conditions

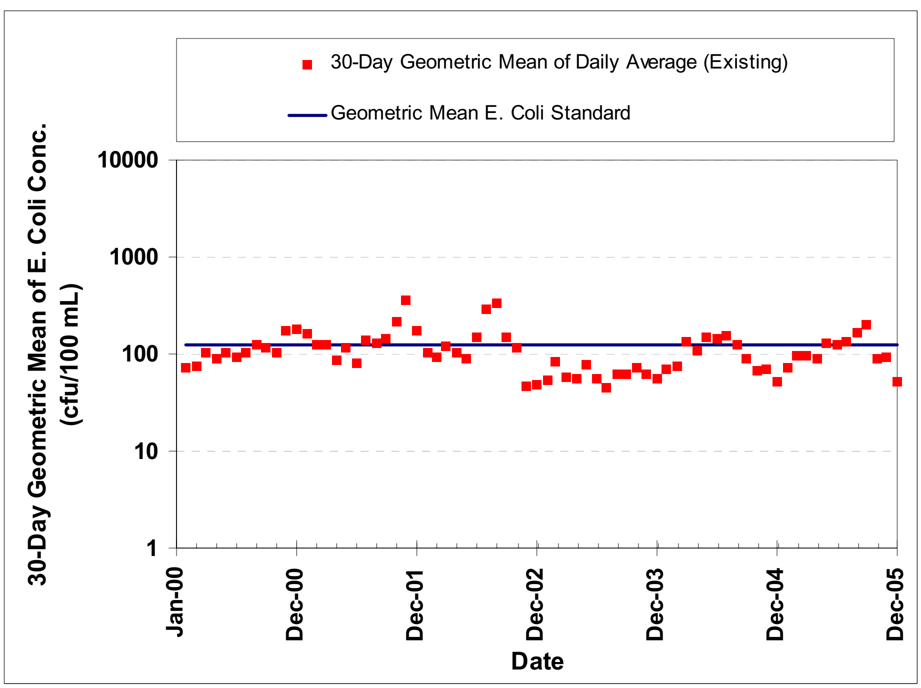


Figure F-22: Stinking River (Segment VAC-L69R-01) E. coli Geometric Mean Existing Conditions

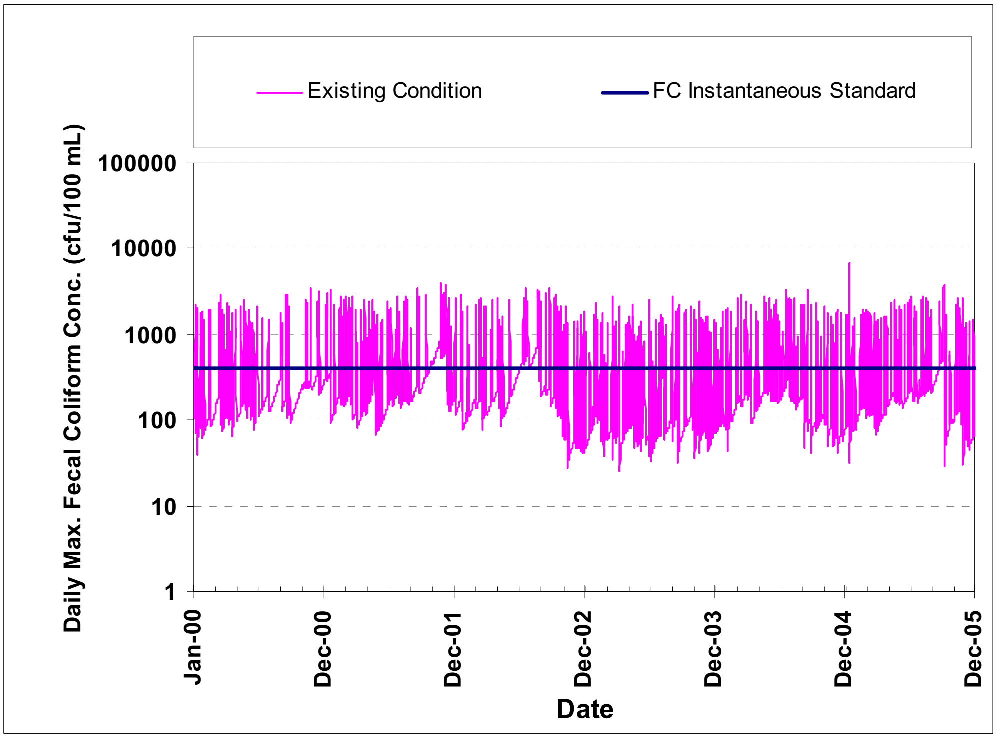


Figure F-23:Stinking River (Segment VAC-L69R-01) Fecal Coliform Instantaneous Existing Conditions

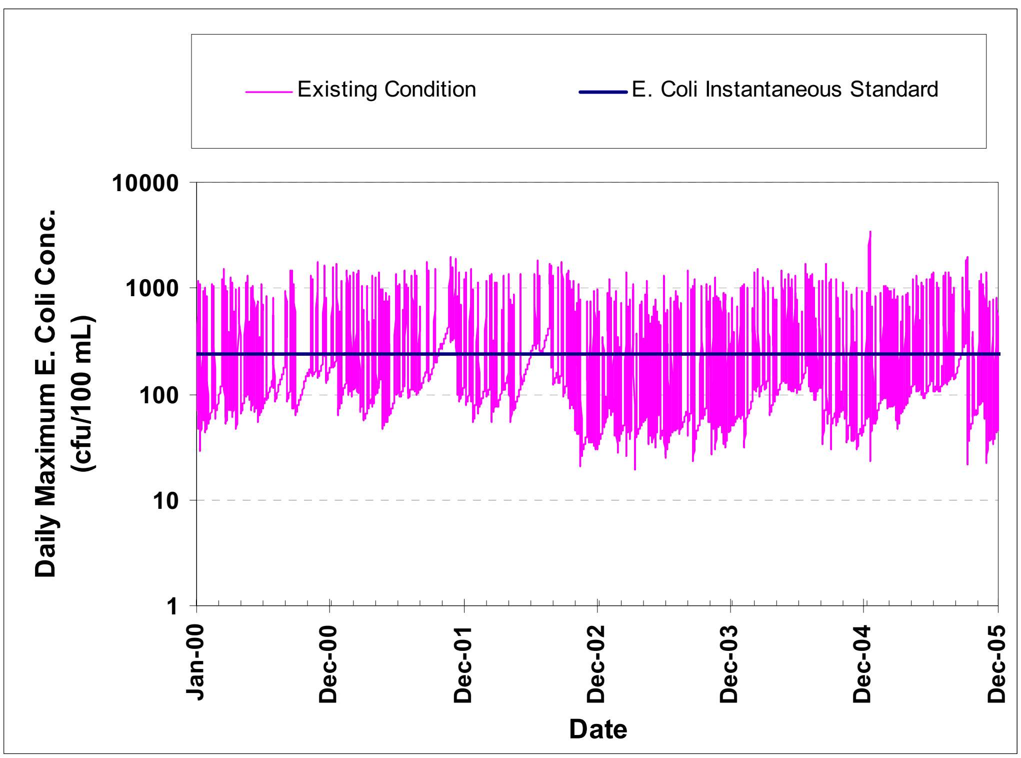


Figure F-24: Stinking River (Segment VAC-L69R-01) E. coli Instantaneous Existing Conditions

F.6 Sandy Creek (Segment VAC-L70R-01)

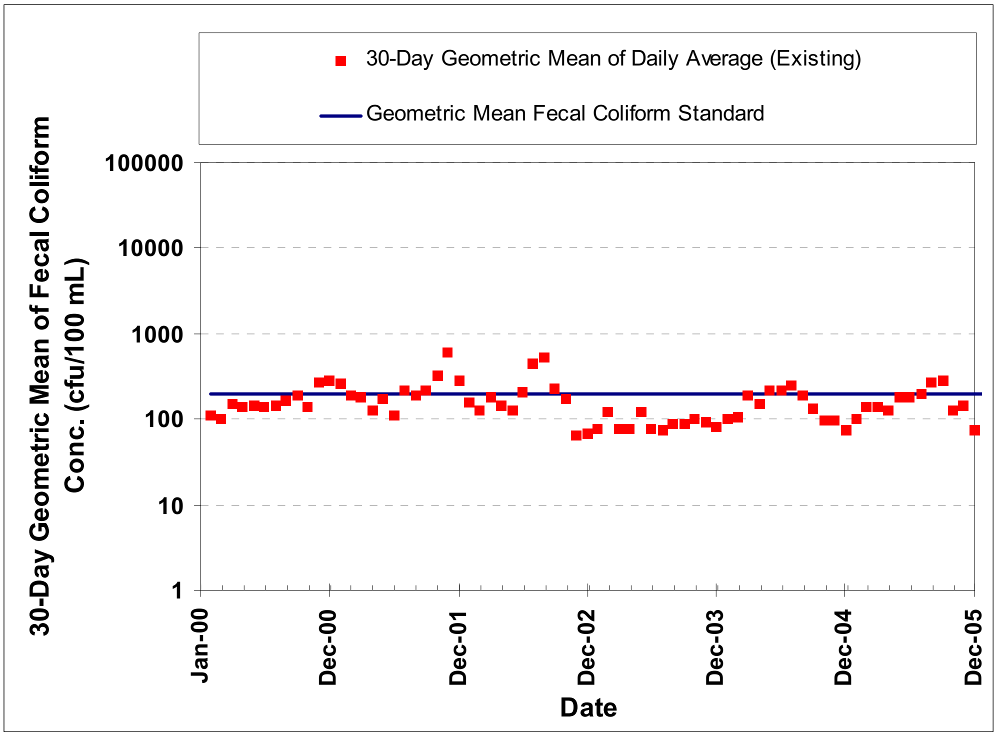


Figure F-25: Sandy Creek (Segment VAC-L70R-01) Fecal Coliform Geometric Mean Existing Conditions

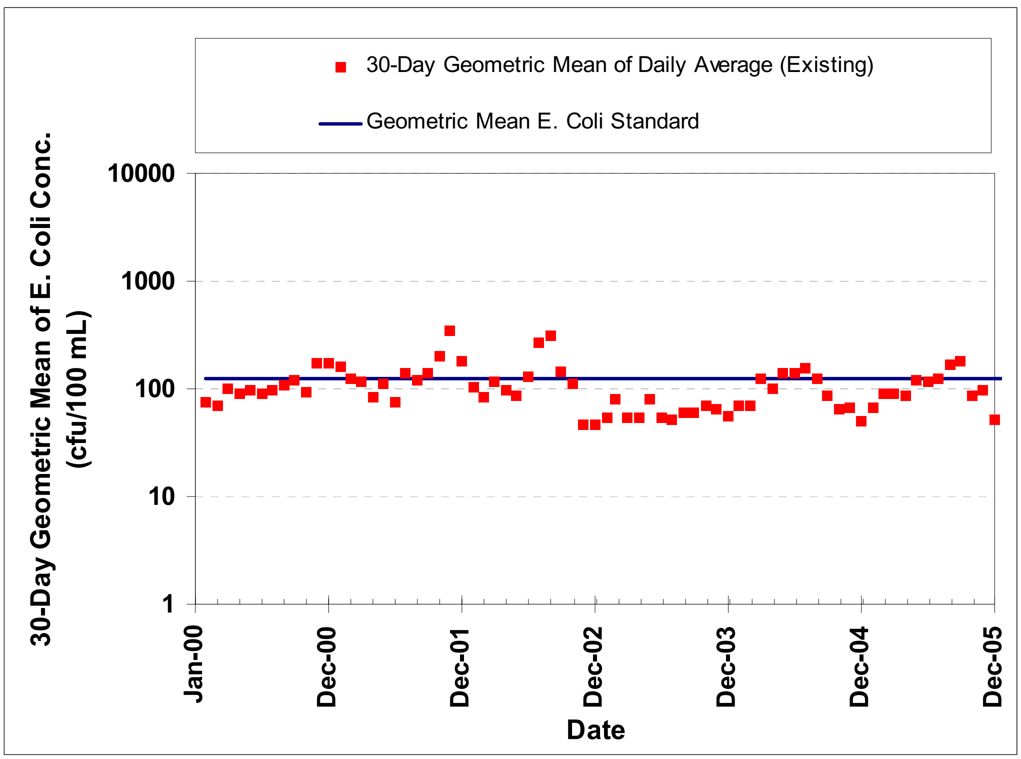


Figure F-26: Sandy Creek (Segment VAC-L70R-01) E. coli Geometric Mean Existing Conditions

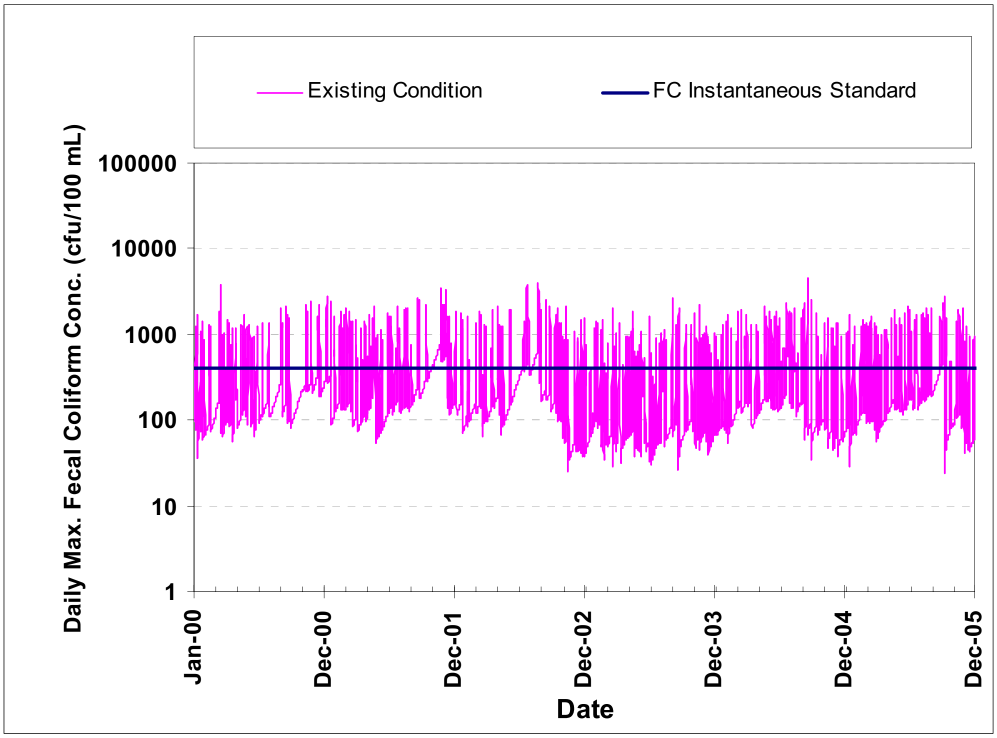


Figure F-27: Sandy Creek (Segment VAC-L70R-01) Fecal Coliform Instantaneous Existing Conditions

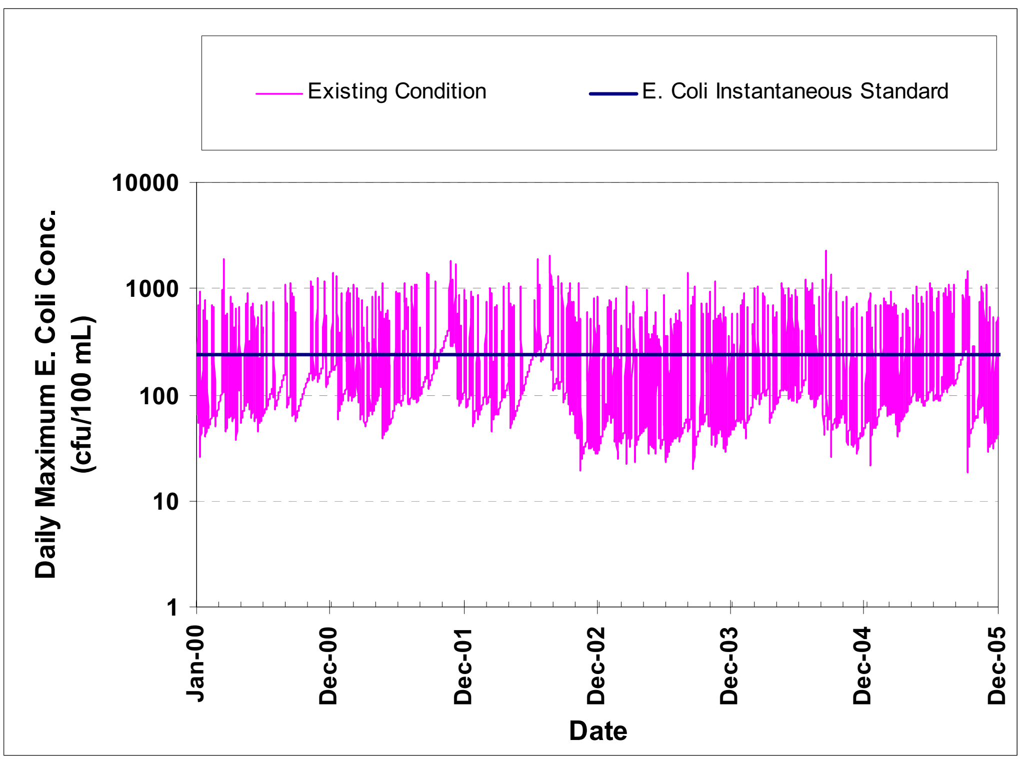


Figure F-28: Sandy Creek (Segment VAC-L70R-01) E. coli Instantaneous Existing Conditions

F.4 Whitehorn Creek (Segment VAC-L68R-01)

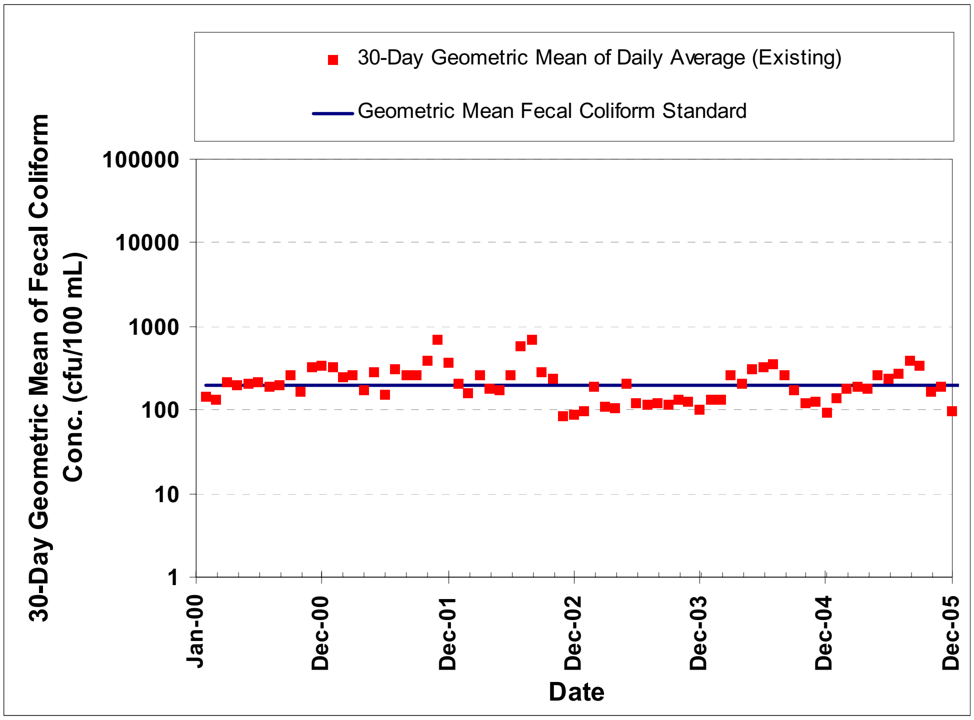


Figure F-29: Whitehorn Creek (Segment VAC-L68R-01) Fecal Coliform Geometric Mean Existing Conditions

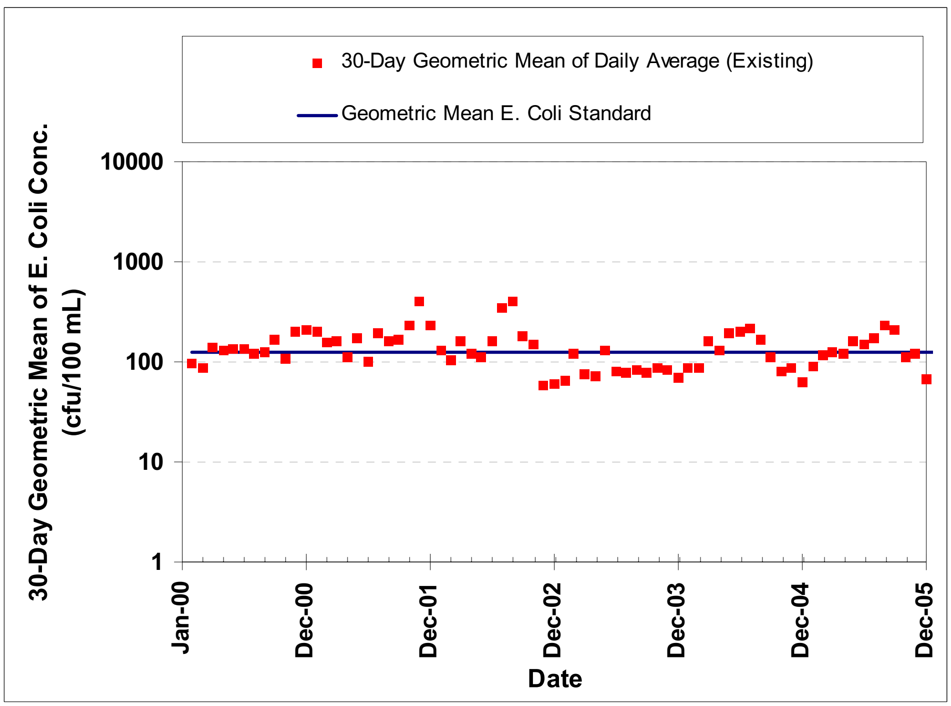


Figure F-30: Whitehorn Creek (Segment VAC-L68R-01) E. coli Geometric Mean Existing Conditions

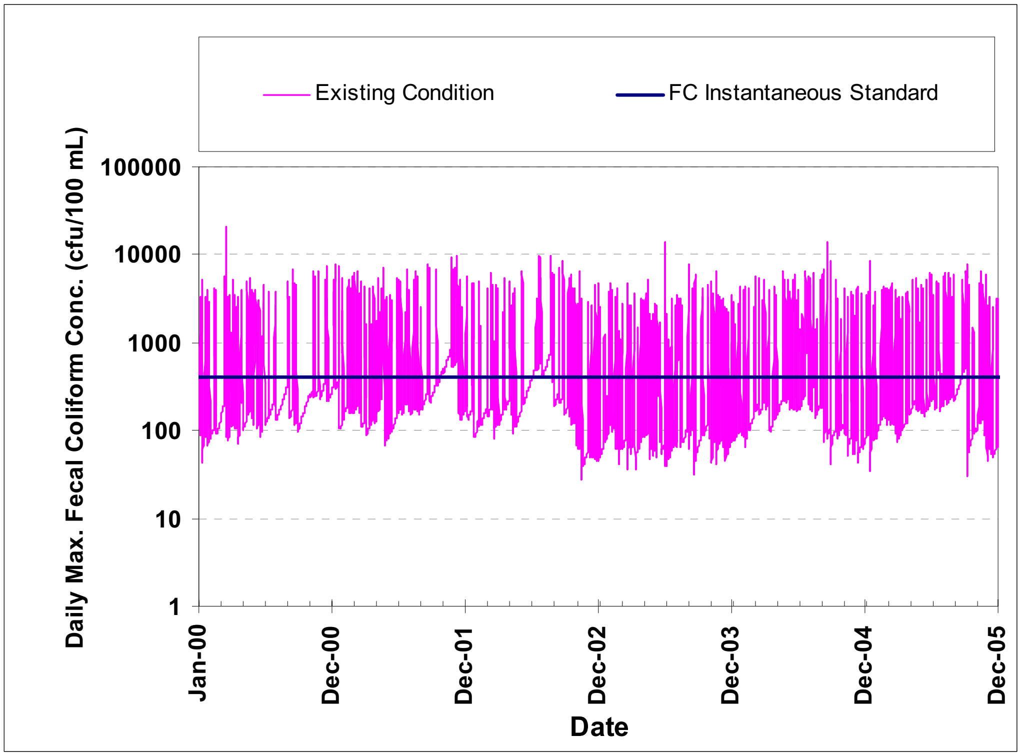


Figure F-31:Whitehorn Creek (Segment VAC-L68R-01) Fecal Coliform Instantaneous Existing Conditions

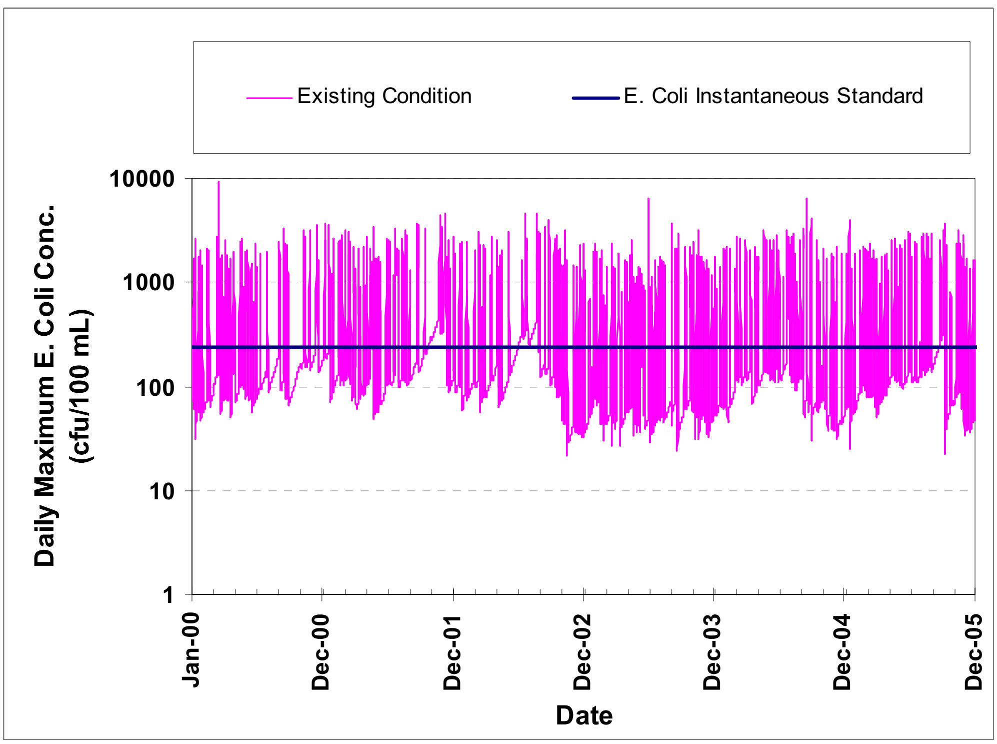


Figure F-32: Whitehorn Creek (Segment VAC-L68R-01) E. coli Instantaneous Existing Conditions

Appendix G

Sensitivity Analysis

Sensitivity Analysis

The sensitivity analysis of the fecal coliform loadings and the waterbody response provides a better understanding of the watershed conditions that lead to the water quality standard violation and provides insight and direction in developing the TMDL allocation and implementation. Potential sources of fecal coliform include non-point (land-based) sources such as runoff from livestock grazing, manure and biosolids land application, residential waste from failed septic systems or straight pipes, and wildlife. Some of these sources are dry weather driven and others are wet weather driven.

The objective of the sensitivity analysis was to assess the impacts of variation of model calibration parameters on the simulation of flow and the violation of the fecal coliform standard in the nine impairments. For the January 1992 to December 1994 period, the model was run with 110 percent and 90 percent of calibrated values of the parameters. The scenarios that were analyzed include the following:

- 10 percent increase in LZSN
- 10 percent decrease in LZSN
- 10 percent increase in INFILT
- 10 percent decrease in INFILT
- 10 percent increase in AGWRC
- 10 percent decrease in AGWRC
- 10 percent increase in UZSN
- 10 percent decrease in UZSN
- 10 percent increase in INTFW
- 10 percent decrease in INTFW
- 10 percent increase in IRC
- 10 percent decrease in IRC
- 10 percent increase in LZETP
- 10 percent decrease in LZETP

The modeled flows for different sensitivity runs were compared with observed flows at the gage and the coefficients of determination of the hydrologic sensitivity analysis are presented in **Table G-1**. Based on these tables it can be seen that the calibration parameters affect the coefficient of determination in the decreasing order of AGWRC, INFILT, INTFW, IRC, UZSN, LZSN and LZETP.

The sensitivity analysis was also performed for two water quality parameters, WSQOP and FSTDEC, by simulating the fecal coliform concentrations for 120 percent and 80 percent of their calibrated values. The rate of violation of the Monthly Geometric Mean Water Quality Standard was determined for each scenario and compared with the rate of violation under the water quality calibration run. The changes in the rate of violation are presented in **Table G-2**. The results of the sensitivity analysis show that at the calibrated values of WSQOP and FSTDEC there is no significant effect on the violation of the water quality standards.

Table G-1: Sensitivity Analysis: Variation in Coefficient of Determination With Respect to Variation in Parameters For Simulation Period 1992-1994

Parameter	Coefficient of Determination	
	+10% change in parameter	-10% change in parameter
LZSN	0.845	0.849
INFILT	0.851	0.842
AGWRC	0.802	0.834
UZSN	0.858	0.850
INTFW	0.860	0.847
IRC	0.852	0.857
LZETP	0.855	0.855
Calibrated Parameters 0.847		

Table G-2: Sensitivity Analysis: Change in Violation Rate From 20% Change in Calibration Parameter Values

	WSQOP		FSTDEC	
Segment #	20%	-20%	20%	-20%
Banister River (VAC-L65R-01)	0.0%	0.0%	0.0%	0.0%
Banister River (VAC-L67R-01)	0.0%	0.0%	0.0%	0.0%
Bearskin Creek (VAC-L65R-02)	0.0%	0.0%	0.0%	0.0%
Cherrystone Creek (VAC-L66R-01)	0.0%	0.0%	0.0%	0.0%
Polecat Creek (VAC-L71R-05)	0.0%	0.0%	0.0%	0.0%
Stinking River (VAC-L69R-01)	0.0%	0.0%	0.0%	0.0%
Sandy Creek (VAC-L70R-01)	0.0%	0.0%	0.0%	0.0%
Whitehorn Creek (VAC-L68R-01)	0.0%	0.0%	0.0%	0.0%

Appendix H
Load Reduction Scenarios under Calendar Month Geometric Mean and Instantaneous Standards for *E. coli*

Table H-1:Banister River (VAC-L65R-01) Load Reduction Scenario under Calendar Month Geometric Mean and Instantaneous Standards for E. *coli*

Scenario	Septics & Pipes (%)	Direct Cattle (%)	NPS-Agriculture (%)	NPS-Urban (%)	Direct Wildlife (%)	Exceedence of Geometric Mean E. *coli* Standard (%)	Exceedence of Instantaneous E. *coli* Standard (%)
0	0	0	0	0	0	27%	70%
1	100	0	0	0	0	15%	35%
2	100	50	0	0	0	18%	37%
3	100	100	0	0	0	8%	23%
4	100	100	100	100	0	2%	0%
5	100	100	0	0	50	0%	16%
6	100	100	0	0	75	0%	16%
7	100	100	95	95	50	0%	0%
8 (TMDL)	**100**	**100**	**81**	**81**	**35**	**0%**	**0%**

Table H-1: Banister River (VAC-L67R-01) Load Reduction Scenarios under Calendar Month Geometric Mean and Instantaneous Standards for E. *coli*

Scenario	Septics & Pipes (%)	Direct Cattle (%)	NPS-Agriculture (%)	NPS-Urban (%)	Direct Wildlife (%)	Exceedence of Geometric Mean E. *coli* Standard (%)	Exceedence of Instantaneous E. *coli* Standard (%)
0	0	0	0	0	0	39%	77%
1	100	0	0	0	0	23%	40%
2	100	50	0	0	0	23%	43%
3	100	100	0	0	0	15%	33%
4	100	100	100	100	0	3%	3%
5	100	100	0	0	50	0%	33%
6	100	100	0	0	75	0%	33%
7	100	100	95	95	50	0%	0%
8 (TMDL)	**100**	**100**	**92**	**92**	**35**	**0%**	**0%**

Table H-3: Bearskin Creek (VAC-L65R-02)Load Reduction Scenario under Calendar Month Geometric Mean and Instantaneous Standards for E. *coli*

Scenario	Septics & Pipes (%)	Direct Cattle (%)	NPS-Agriculture (%)	NPS-Urban (%)	Direct Wildlife (%)	Exceedence of Geometric Mean E. *coli* Standard (%)	Exceedence of Instantaneous E. *coli* Standard (%)
0	0	0	0	0	0	42%	100%
1	100	0	0	0	0	26%	68%
2	100	50	0	0	0	20%	57%
3	100	100	0	0	0	7%	23%
4	100	100	100	100	0	3%	7%
5	100	100	0	0	50	0%	20%
6	100	100	0	0	75	0%	17%
7	100	100	95	95	50	0%	0%
8 (TMDL)	**100**	**100**	**83**	**83**	**40**	**0%**	**0%**

Table H-4: Cherrystone Creek (VAC-L66R-01) Load Reduction Scenario under Calendar Month Geometric Mean and Instantaneous Standards for E. *coli*

Scenario	Septics & Pipes (%)	Direct Cattle (%)	NPS-Agriculture (%)	NPS-Urban (%)	Direct Wildlife (%)	Exceedence of Geometric Mean E. *coli* Standard (%)	Exceedence of Instantaneous E. *coli* Standard (%)
0	0	0	0	0	0	55%	94%
1	100	0	0	0	0	45%	65%
2	100	50	0	0	0	37%	42%
3	100	100	0	0	0	12%	42%
4	100	100	100	100	0	1%	0%
5	100	100	0	0	50	0%	42%
6	100	100	0	0	75	0%	42%
7	100	100	95	95	50	0%	0%
8 (TMDL)	**100**	**100**	**94**	**94**	**25**	**0%**	**0%**

Table H-5: Polecat Creek (VAC-L71R-05) Load Reduction Scenario under Calendar Month Geometric Mean and Instantaneous Standards for E. *coli*

Scenario	Septics & Pipes (%)	Direct Cattle (%)	NPS-Agriculture (%)	NPS-Urban (%)	Direct Wildlife (%)	Exceedence of Geometric Mean E. *coli* Standard (%)	Exceedence of Instantaneous E. *coli* Standard (%)
0	0	0	0	0	0	19%	57%
1	100	0	0	0	0	10%	20%
2	100	50	0	0	0	16%	40%
3	100	100	0	0	0	6%	17%
4	100	100	100	100	0	3%	10%
5	100	100	0	0	50	0%	13%
6	100	100	0	0	75	0%	10%
7	100	100	95	95	50	0%	0%
8 (TMDL)	**100**	**100**	**74**	**74**	**40**	**0%**	**0%**

Table H-6: Stinking River (VAC-L69R-01) Load Reduction Scenario under Calendar Month Geometric Mean and Instantaneous Standards for E. *coli*

Scenario	Septics & Pipes (%)	Direct Cattle (%)	NPS-Agriculture (%)	NPS-Urban (%)	Direct Wildlife (%)	Exceedence of Geometric Mean E. *coli* Standard (%)	Exceedence of Instantaneous E. *coli* Standard (%)
0	0	0	0	0	0	28%	73%
1	100	0	0	0	0	17%	35%
2	100	50	0	0	0	19%	40%
3	100	100	0	0	0	7%	23%
4	100	100	100	100	0	3%	0%
5	100	100	0	0	50	0%	19%
6	100	100	0	0	75	0%	17%
7	100	100	95	95	50	0%	0%
8 (TMDL)	**100**	**100**	**83**	**83**	**35**	**0%**	**0%**

Table H-7: Sandy Creek (VAC-L70R-01) Load Reduction Scenario under Calendar Month Geometric Mean and Instantaneous Standards for E. *coli*

Scenario	Septics & Pipes (%)	Direct Cattle (%)	NPS-Agriculture (%)	NPS-Urban (%)	Direct Wildlife (%)	Exceedence of Geometric Mean E. *coli* Standard (%)	Exceedence of Instantaneous E. *coli* Standard (%)
0	0	0	0	0	0	25%	80%
1	100	0	0	0	0	14%	33%
2	100	50	0	0	0	19%	53%
3	100	100	0	0	0	14%	30%
4	100	100	100	100	0	3%	20%
5	100	100	0	0	50	1%	26%
6	100	100	0	0	75	0%	26%
7	100	100	95	95	50	0%	0%
8 (TMDL)	**100**	**100**	**85**	**85**	**40**	**0%**	**0%**

Table H-8: Whitehorn Creek (VAC-L68R-01) Load Reduction Scenario under Calendar Month Geometric Mean and Instantaneous Standards for E. *coli*

Scenario	Septics & Pipes (%)	Direct Cattle (%)	NPS-Agriculture (%)	NPS-Urban (%)	Direct Wildlife (%)	Exceedence of Geometric Mean E. *coli* Standard (%)	Exceedence of Instantaneous E. *coli* Standard (%)
0	100	100	0	0	0	44%	74%
1	100	100	0	0	0	35%	45%
2	100	100	0	0	0	31%	45%
3	100	100	0	0	0	15%	45%
4	100	100	100	100	0	1%	0%
5	100	100	0	0	50	0%	45%
6	100	100	0	0	75	0%	42%
7	100	100	95	95	50	0%	0%
8 (TMDL)	**100**	**100**	**94**	**94**	**30**	**0%**	**0%**

Appendix I

Monthly Distribution of Fecal Coliform Loading Under Existing and Allocated Conditions

H.1 Fecal Coliform Monthly Loads- Existing Conditions

Table I-1: Banister River (VAC-L65R-01) Fecal Coliform Load: Existing Condition (counts/ month)

Month	Commercial/ Industrial	Cropland	Forest	High Density Residential	Medium Density Residential	Low Density Residential	Pasture
1	5.52E+11	5.43E+10	5.07E+10	6.47E+10	8.61E+10	2.52E+12	2.54E+12
2	4.01E+11	7.73E+10	3.32E+10	4.69E+10	6.05E+10	1.66E+12	1.25E+12
3	6.52E+11	2.35E+11	4.50E+10	7.64E+10	1.02E+11	2.99E+12	2.71E+12
4	4.60E+11	1.35E+11	3.99E+10	5.39E+10	6.78E+10	1.79E+12	1.38E+12
5	6.68E+11	1.62E+11	4.51E+10	7.90E+10	9.83E+10	2.62E+12	2.16E+12
6	4.93E+11	1.09E+11	3.38E+10	5.84E+10	6.93E+10	1.72E+12	1.02E+12
7	5.23E+11	1.27E+11	4.69E+10	6.26E+10	7.68E+10	2.12E+12	2.17E+12
8	3.70E+11	6.74E+10	1.74E+10	4.44E+10	4.93E+10	1.12E+12	4.38E+11
9	6.13E+11	2.63E+11	5.45E+10	7.03E+10	1.08E+11	3.57E+12	3.47E+12
10	3.98E+11	1.86E+11	4.23E+10	4.67E+10	6.57E+10	2.09E+12	2.25E+12
11	5.83E+11	7.56E+10	4.96E+10	6.73E+10	9.73E+10	3.03E+12	2.85E+12
12	4.73E+11	2.13E+09	3.57E+10	5.49E+10	6.92E+10	1.76E+12	9.66E+11

Table I-2: Banister River (VAC-L67R-01) Fecal Coliform Load: Existing Condition (counts/ month)

Month	Commercial/Industrial	Cropland	Forest	High Density Residential	Medium Density Residential	Low Density Residential	Pasture
1	7.60E+12	1.33E+12	6.94E+11	6.66E+12	1.22E+13	5.40E+13	3.38E+13
2	5.52E+12	1.89E+12	4.54E+11	4.83E+12	8.55E+12	3.55E+13	1.66E+13
3	8.97E+12	5.75E+12	6.16E+11	7.86E+12	1.44E+13	6.40E+13	3.62E+13
4	6.34E+12	3.31E+12	5.46E+11	5.55E+12	9.59E+12	3.84E+13	1.84E+13
5	9.21E+12	3.96E+12	6.17E+11	8.14E+12	1.39E+13	5.62E+13	2.88E+13
6	6.79E+12	2.68E+12	4.63E+11	6.03E+12	9.80E+12	3.68E+13	1.36E+13
7	7.21E+12	3.10E+12	6.42E+11	6.46E+12	1.09E+13	4.54E+13	2.90E+13
8	5.10E+12	1.65E+12	2.38E+11	4.58E+12	6.97E+12	2.40E+13	5.84E+12
9	8.45E+12	6.44E+12	7.46E+11	7.21E+12	1.53E+13	7.64E+13	4.63E+13
10	5.48E+12	4.56E+12	5.79E+11	4.80E+12	9.29E+12	4.48E+13	3.00E+13
11	8.03E+12	1.85E+12	6.79E+11	6.91E+12	1.38E+13	6.49E+13	3.81E+13
12	6.52E+12	5.21E+10	4.88E+11	5.66E+12	9.78E+12	3.76E+13	1.29E+13

Table I-3: Bearskin Creek (VAC-L65R-02) Fecal Coliform Load: Existing Condition (counts/ month)							
Month	Commercial/ Industrial	Cropland	Forest	High Density Residential	Medium Density Residential	Low Density Residential	Pasture
1	4.10E+11	3.41E+10	2.68E+10	0.00E+00	3.43E+10	1.87E+12	1.99E+12
2	2.98E+11	4.86E+10	1.75E+10	0.00E+00	2.40E+10	1.23E+12	9.80E+11
3	4.85E+11	1.47E+11	2.38E+10	0.00E+00	4.06E+10	2.21E+12	2.13E+12
4	3.42E+11	8.49E+10	2.11E+10	0.00E+00	2.69E+10	1.33E+12	1.08E+12
5	4.97E+11	1.02E+11	2.38E+10	0.00E+00	3.90E+10	1.94E+12	1.70E+12
6	3.66E+11	6.87E+10	1.79E+10	0.00E+00	2.74E+10	1.27E+12	7.99E+11
7	3.89E+11	7.96E+10	2.48E+10	0.00E+00	3.05E+10	1.57E+12	1.71E+12
8	2.75E+11	4.23E+10	9.20E+09	0.00E+00	1.94E+10	8.30E+11	3.44E+11
9	4.56E+11	1.65E+11	2.88E+10	0.00E+00	4.34E+10	2.64E+12	2.73E+12
10	2.96E+11	1.17E+11	2.24E+10	0.00E+00	2.62E+10	1.55E+12	1.77E+12
11	4.33E+11	4.75E+10	2.62E+10	0.00E+00	3.89E+10	2.24E+12	2.24E+12
12	3.52E+11	1.34E+09	1.89E+10	0.00E+00	2.74E+10	1.30E+12	7.59E+11

Table I-4 Cherrystone Creek (VAC-L66R-01) Fecal Coliform Load: Existing Condition (counts/ month)							
Month	Commercial/ Industrial	Cropland	Forest	High Density Residential	Medium Density Residential	Low Density Residential	Pasture
1	9.58E+11	6.96E+10	5.72E+10	1.98E+12	3.25E+12	1.01E+13	3.80E+12
2	6.96E+11	9.91E+10	3.74E+10	1.44E+12	2.28E+12	6.63E+12	1.87E+12
3	1.13E+12	3.01E+11	5.07E+10	2.34E+12	3.86E+12	1.20E+13	4.07E+12
4	7.99E+11	1.73E+11	4.50E+10	1.65E+12	2.56E+12	7.17E+12	2.07E+12
5	1.16E+12	2.07E+11	5.08E+10	2.42E+12	3.71E+12	1.05E+13	3.24E+12
6	8.56E+11	1.40E+11	3.81E+10	1.79E+12	2.62E+12	6.87E+12	1.52E+12
7	9.09E+11	1.63E+11	5.29E+10	1.92E+12	2.90E+12	8.49E+12	3.26E+12
8	6.42E+11	8.64E+10	1.96E+10	1.36E+12	1.86E+12	4.49E+12	6.57E+11
9	1.07E+12	3.37E+11	6.15E+10	2.14E+12	4.09E+12	1.43E+13	5.21E+12
10	6.91E+11	2.39E+11	4.77E+10	1.43E+12	2.48E+12	8.38E+12	3.37E+12
11	1.01E+12	9.69E+10	5.59E+10	2.05E+12	3.68E+12	1.21E+13	4.28E+12
12	8.22E+11	2.73E+09	4.02E+10	1.68E+12	2.61E+12	7.03E+12	1.45E+12

Table I-5: Polecat Creek (VAC-L71R-05) Fecal Coliform Load: Existing Condition (counts/ month)							
Month	**Commercial/ Industrial**	**Cropland**	**Forest**	**High Density Residential**	**Medium Density Residential**	**Low Density Residential**	**Pasture**
1	2.50E+11	3.47E+10	3.01E+10	4.50E+10	2.63E+10	7.57E+11	1.19E+12
2	1.82E+11	4.94E+10	1.97E+10	3.27E+10	1.84E+10	4.97E+11	5.85E+11
3	2.95E+11	1.50E+11	2.67E+10	5.31E+10	3.12E+10	8.97E+11	1.27E+12
4	2.09E+11	8.64E+10	2.37E+10	3.75E+10	2.07E+10	5.38E+11	6.46E+11
5	3.03E+11	1.03E+11	2.67E+10	5.50E+10	3.00E+10	7.88E+11	1.01E+12
6	2.24E+11	6.99E+10	2.01E+10	4.08E+10	2.11E+10	5.15E+11	4.77E+11
7	2.37E+11	8.10E+10	2.78E+10	4.37E+10	2.34E+10	6.37E+11	1.02E+12
8	1.68E+11	4.31E+10	1.03E+10	3.10E+10	1.49E+10	3.37E+11	2.05E+11
9	2.78E+11	1.68E+11	3.23E+10	4.86E+10	3.33E+10	1.07E+12	1.63E+12
10	1.80E+11	1.19E+11	2.51E+10	3.24E+10	2.01E+10	6.29E+11	1.05E+12
11	2.64E+11	4.83E+10	2.94E+10	4.66E+10	2.98E+10	9.11E+11	1.34E+12
12	2.15E+11	1.36E+09	2.11E+10	3.83E+10	2.11E+10	5.28E+11	4.53E+11

Table I-6: Stinking River (VAC-L69R-01) Fecal Coliform Load: Existing Condition (counts/ month)							
Month	**Commercial/ Industrial**	**Cropland**	**Forest**	**High Density Residential**	**Medium Density Residential**	**Low Density Residential**	**Pasture**
1	6.30E+11	1.44E+11	4.86E+10	0.00E+00	1.17E+11	2.82E+12	2.58E+12
2	4.58E+11	2.05E+11	3.18E+10	0.00E+00	8.24E+10	1.85E+12	1.27E+12
3	7.44E+11	6.22E+11	4.31E+10	0.00E+00	1.39E+11	3.34E+12	2.76E+12
4	5.25E+11	3.58E+11	3.83E+10	0.00E+00	9.25E+10	2.01E+12	1.40E+12
5	7.63E+11	4.28E+11	4.32E+10	0.00E+00	1.34E+11	2.94E+12	2.20E+12
6	5.63E+11	2.90E+11	3.24E+10	0.00E+00	9.45E+10	1.92E+12	1.03E+12
7	5.97E+11	3.36E+11	4.50E+10	0.00E+00	1.05E+11	2.38E+12	2.21E+12
8	4.22E+11	1.78E+11	1.67E+10	0.00E+00	6.72E+10	1.26E+12	4.46E+11
9	7.00E+11	6.96E+11	5.23E+10	0.00E+00	1.48E+11	3.99E+12	3.53E+12
10	4.54E+11	4.94E+11	4.06E+10	0.00E+00	8.96E+10	2.34E+12	2.29E+12
11	6.65E+11	2.00E+11	4.75E+10	0.00E+00	1.33E+11	3.39E+12	2.90E+12
12	5.40E+11	5.64E+09	3.42E+10	0.00E+00	9.43E+10	1.97E+12	9.82E+11

Table I-7:Sandy Creek (VAC-L70R-01) Fecal Coliform Load: Existing Condition (counts/ month)							
Month	Commercial/ Industrial	Cropland	Forest	High Density Residential	Medium Density Residential	Low Density Residential	Pasture
1	1.26E+12	2.81E+11	1.53E+11	8.59E+10	1.30E+12	8.26E+12	6.28E+12
2	9.13E+11	4.00E+11	9.97E+10	6.23E+10	9.14E+11	5.43E+12	3.09E+12
3	1.48E+12	1.21E+12	1.35E+11	1.01E+11	1.54E+12	9.79E+12	6.72E+12
4	1.05E+12	6.98E+11	1.20E+11	7.16E+10	1.03E+12	5.87E+12	3.42E+12
5	1.52E+12	8.35E+11	1.36E+11	1.05E+11	1.49E+12	8.60E+12	5.36E+12
6	1.12E+12	5.65E+11	1.02E+11	7.78E+10	1.05E+12	5.62E+12	2.52E+12
7	1.19E+12	6.55E+11	1.41E+11	8.33E+10	1.16E+12	6.95E+12	5.39E+12
8	8.42E+11	3.48E+11	5.23E+10	5.91E+10	7.45E+11	3.67E+12	1.09E+12
9	1.40E+12	1.36E+12	1.64E+11	9.30E+10	1.64E+12	1.17E+13	8.60E+12
10	9.05E+11	9.63E+11	1.27E+11	6.19E+10	9.93E+11	6.86E+12	5.57E+12
11	1.33E+12	3.91E+11	1.49E+11	8.92E+10	1.47E+12	9.93E+12	7.07E+12
12	1.08E+12	1.10E+10	1.07E+11	7.30E+10	1.05E+12	5.76E+12	2.39E+12

Table I-8: Whitehorn Creek (VAC-L68R-01) Fecal Coliform Load: Existing Condition (counts/ month)							
Month	Commercial/ Industrial	Cropland	Forest	High Density Residential	Medium Density Residential	Low Density Residential	Pasture
1	1.33E+12	2.18E+11	8.13E+10	1.37E+12	2.65E+12	1.57E+13	5.57E+12
2	9.64E+11	3.10E+11	5.31E+10	9.94E+11	1.86E+12	1.03E+13	2.74E+12
3	1.57E+12	9.42E+11	7.21E+10	1.62E+12	3.14E+12	1.86E+13	5.97E+12
4	1.11E+12	5.42E+11	6.40E+10	1.14E+12	2.08E+12	1.11E+13	3.03E+12
5	1.61E+12	6.49E+11	7.22E+10	1.67E+12	3.02E+12	1.63E+13	4.75E+12
6	1.19E+12	4.39E+11	5.42E+10	1.24E+12	2.13E+12	1.07E+13	2.23E+12
7	1.26E+12	5.09E+11	7.52E+10	1.33E+12	2.36E+12	1.32E+13	4.78E+12
8	8.90E+11	2.71E+11	2.79E+10	9.43E+11	1.51E+12	6.97E+12	9.63E+11
9	1.48E+12	1.06E+12	8.74E+10	1.48E+12	3.33E+12	2.22E+13	7.63E+12
10	9.57E+11	7.48E+11	6.78E+10	9.88E+11	2.02E+12	1.30E+13	4.94E+12
11	1.40E+12	3.03E+11	7.95E+10	1.42E+12	2.99E+12	1.89E+13	6.27E+12
12	1.14E+12	8.55E+09	5.72E+10	1.16E+12	2.13E+12	1.09E+13	2.12E+12

H.2 Fecal Coliform Monthly Loads- Allocation Runs

Table I-9: Banister River (VAC-L65R-01) Fecal Coliform Load: Allocation Run (counts/ month)							
Month	Commercial/ Industrial	Cropland	Forest	High Density Residential	Medium Density Residential	Low Density Residential	Pasture
1	1.05E+11	1.03E+10	5.07E+10	1.23E+10	1.64E+10	4.79E+11	4.82E+11
2	7.62E+10	1.47E+10	3.32E+10	8.91E+09	1.15E+10	3.15E+11	2.37E+11
3	1.24E+11	4.46E+10	4.50E+10	1.45E+10	1.94E+10	5.67E+11	5.16E+11
4	8.74E+10	2.57E+10	3.99E+10	1.02E+10	1.29E+10	3.40E+11	2.62E+11
5	1.27E+11	3.07E+10	4.51E+10	1.50E+10	1.87E+10	4.99E+11	4.11E+11
6	9.36E+10	2.08E+10	3.38E+10	1.11E+10	1.32E+10	3.26E+11	1.93E+11
7	9.94E+10	2.41E+10	4.69E+10	1.19E+10	1.46E+10	4.03E+11	4.13E+11
8	7.03E+10	1.28E+10	1.74E+10	8.43E+09	9.36E+09	2.13E+11	8.32E+10
9	1.17E+11	5.00E+10	5.45E+10	1.34E+10	2.06E+10	6.78E+11	6.59E+11
10	7.56E+10	3.54E+10	4.23E+10	8.87E+09	1.25E+10	3.98E+11	4.27E+11
11	1.11E+11	1.44E+10	4.96E+10	1.28E+10	1.85E+10	5.76E+11	5.42E+11
12	8.99E+10	4.05E+08	3.57E+10	1.04E+10	1.31E+10	3.34E+11	1.83E+11

Table I-10: Banister River (VAC-L67R-01) Fecal Coliform Load: Allocation Run (counts/ month)							
Month	Commercial/ Industrial	Cropland	Forest	High Density Residential	Medium Density Residential	Low Density Residential	Pasture
1	6.08E+11	1.06E+11	6.94E+11	5.33E+11	9.74E+11	4.32E+12	2.71E+12
2	4.42E+11	1.51E+11	4.54E+11	3.86E+11	6.84E+11	2.84E+12	1.33E+12
3	7.18E+11	4.60E+11	6.16E+11	6.29E+11	1.15E+12	5.12E+12	2.90E+12
4	5.07E+11	2.65E+11	5.46E+11	4.44E+11	7.67E+11	3.07E+12	1.47E+12
5	7.37E+11	3.17E+11	6.17E+11	6.51E+11	1.11E+12	4.50E+12	2.31E+12
6	5.43E+11	2.14E+11	4.63E+11	4.82E+11	7.84E+11	2.94E+12	1.08E+12
7	5.77E+11	2.48E+11	6.42E+11	5.17E+11	8.69E+11	3.64E+12	2.32E+12
8	4.08E+11	1.32E+11	2.38E+11	3.67E+11	5.58E+11	1.92E+12	4.68E+11
9	6.76E+11	5.15E+11	7.46E+11	5.77E+11	1.23E+12	6.11E+12	3.70E+12
10	4.38E+11	3.65E+11	5.79E+11	3.84E+11	7.44E+11	3.59E+12	2.40E+12
11	6.42E+11	1.48E+11	6.79E+11	5.53E+11	1.10E+12	5.20E+12	3.04E+12
12	5.21E+11	4.17E+09	4.88E+11	4.53E+11	7.83E+11	3.01E+12	1.03E+12

Table I-11: Bearskin Creek (VAC-L65R-02) Fecal Coliform Load: Allocation Run (counts/ month)							
Month	Commercial/ Industrial	Cropland	Forest	High Density Residential	Medium Density Residential	Low Density Residential	Pasture
1	6.97E+10	5.80E+09	2.68E+10	0.00E+00	5.83E+09	3.17E+11	3.39E+11
2	5.07E+10	8.26E+09	1.75E+10	0.00E+00	4.08E+09	2.08E+11	1.67E+11
3	8.24E+10	2.51E+10	2.38E+10	0.00E+00	6.90E+09	3.76E+11	3.63E+11
4	5.81E+10	1.44E+10	2.11E+10	0.00E+00	4.57E+09	2.25E+11	1.84E+11
5	8.45E+10	1.73E+10	2.38E+10	0.00E+00	6.63E+09	3.30E+11	2.89E+11
6	6.23E+10	1.17E+10	1.79E+10	0.00E+00	4.66E+09	2.16E+11	1.36E+11
7	6.62E+10	1.35E+10	2.48E+10	0.00E+00	5.18E+09	2.67E+11	2.91E+11
8	4.68E+10	7.19E+09	9.20E+09	0.00E+00	3.30E+09	1.41E+11	5.86E+10
9	7.75E+10	2.81E+10	2.88E+10	0.00E+00	7.37E+09	4.49E+11	4.64E+11
10	5.03E+10	1.99E+10	2.24E+10	0.00E+00	4.46E+09	2.63E+11	3.00E+11
11	7.37E+10	8.07E+09	2.62E+10	0.00E+00	6.61E+09	3.82E+11	3.81E+11
12	5.98E+10	2.27E+08	1.89E+10	0.00E+00	4.66E+09	2.21E+11	1.29E+11

Table I-12: Cherrystone Creek (VAC-L66R-01) Fecal Coliform Load: Allocation Run (counts/ month)							
Month	Commercial/ Industrial	Cropland	Forest	High Density Residential	Medium Density Residential	Low Density Residential	Pasture
1	5.75E+10	4.18E+09	5.72E+10	1.19E+11	1.95E+11	6.06E+11	2.28E+11
2	4.18E+10	5.95E+09	3.74E+10	8.61E+10	1.37E+11	3.98E+11	1.12E+11
3	6.79E+10	1.81E+10	5.07E+10	1.40E+11	2.31E+11	7.17E+11	2.44E+11
4	4.79E+10	1.04E+10	4.50E+10	9.90E+10	1.54E+11	4.30E+11	1.24E+11
5	6.96E+10	1.24E+10	5.08E+10	1.45E+11	2.23E+11	6.30E+11	1.95E+11
6	5.13E+10	8.41E+09	3.81E+10	1.07E+11	1.57E+11	4.12E+11	9.15E+10
7	5.45E+10	9.75E+09	5.29E+10	1.15E+11	1.74E+11	5.10E+11	1.96E+11
8	3.85E+10	5.18E+09	1.96E+10	8.17E+10	1.12E+11	2.69E+11	3.94E+10
9	6.39E+10	2.02E+10	6.15E+10	1.29E+11	2.46E+11	8.57E+11	3.12E+11
10	4.14E+10	1.43E+10	4.77E+10	8.56E+10	1.49E+11	5.03E+11	2.02E+11
11	6.07E+10	5.82E+09	5.59E+10	1.23E+11	2.21E+11	7.28E+11	2.57E+11
12	4.93E+10	1.64E+08	4.02E+10	1.01E+11	1.57E+11	4.22E+11	8.69E+10

Table I-13: Polecat Creek (VAC-L71R-05)Fecal Coliform Load: Allocation Run (counts/ month)

Month	Commercial/ Industrial	Cropland	Forest	High Density Residential	Medium Density Residential	Low Density Residential	Pasture
1	6.50E+10	9.03E+09	3.01E+10	1.17E+10	6.84E+09	1.97E+11	3.09E+11
2	4.73E+10	1.29E+10	1.97E+10	8.49E+09	4.80E+09	1.29E+11	1.52E+11
3	7.68E+10	3.90E+10	2.67E+10	1.38E+10	8.11E+09	2.33E+11	3.31E+11
4	5.42E+10	2.25E+10	2.37E+10	9.76E+09	5.37E+09	1.40E+11	1.68E+11
5	7.88E+10	2.69E+10	2.67E+10	1.43E+10	7.79E+09	2.05E+11	2.64E+11
6	5.81E+10	1.82E+10	2.01E+10	1.06E+10	5.48E+09	1.34E+11	1.24E+11
7	6.17E+10	2.11E+10	2.78E+10	1.14E+10	6.09E+09	1.66E+11	2.65E+11
8	4.36E+10	1.12E+10	1.03E+10	8.07E+09	3.88E+09	8.75E+10	5.34E+10
9	7.23E+10	4.37E+10	3.23E+10	1.26E+10	8.65E+09	2.79E+11	4.23E+11
10	4.69E+10	3.10E+10	2.51E+10	8.42E+09	5.23E+09	1.64E+11	2.74E+11
11	6.87E+10	1.26E+10	2.94E+10	1.21E+10	7.75E+09	2.37E+11	3.48E+11
12	5.58E+10	3.54E+08	2.11E+10	9.95E+09	5.48E+09	1.37E+11	1.18E+11

Table I-14: Stinking River (VAC-L69R-01) Fecal Coliform Load: Allocation Run (counts/ month)

Month	Commercial/ Industrial	Cropland	Forest	High Density Residential	Medium Density Residential	Low Density Residential	Pasture
1	1.07E+11	2.44E+10	4.86E+10	0.00E+00	2.00E+10	4.80E+11	4.38E+11
2	7.78E+10	3.48E+10	3.18E+10	0.00E+00	1.40E+10	3.15E+11	2.16E+11
3	1.26E+11	1.06E+11	4.31E+10	0.00E+00	2.37E+10	5.69E+11	4.69E+11
4	8.93E+10	6.08E+10	3.83E+10	0.00E+00	1.57E+10	3.41E+11	2.38E+11
5	1.30E+11	7.27E+10	4.32E+10	0.00E+00	2.28E+10	4.99E+11	3.74E+11
6	9.56E+10	4.92E+10	3.24E+10	0.00E+00	1.61E+10	3.27E+11	1.76E+11
7	1.02E+11	5.70E+10	4.50E+10	0.00E+00	1.78E+10	4.04E+11	3.76E+11
8	7.18E+10	3.03E+10	1.67E+10	0.00E+00	1.14E+10	2.13E+11	7.58E+10
9	1.19E+11	1.18E+11	5.23E+10	0.00E+00	2.51E+10	6.79E+11	6.00E+11
10	7.72E+10	8.39E+10	4.06E+10	0.00E+00	1.52E+10	3.98E+11	3.89E+11
11	1.13E+11	3.40E+10	4.75E+10	0.00E+00	2.26E+10	5.77E+11	4.93E+11
12	9.18E+10	9.59E+08	3.42E+10	0.00E+00	1.60E+10	3.34E+11	1.67E+11

Table I-15:Sandy Creek (VAC-L70R-01) Fecal Coliform Load: Allocation Run (counts/ month)

Month	Commercial/ Industrial	Cropland	Forest	High Density Residential	Medium Density Residential	Low Density Residential	Pasture
1	1.88E+11	4.21E+10	1.53E+11	1.29E+10	1.95E+11	1.24E+12	9.42E+11
2	1.37E+11	5.99E+10	9.97E+10	9.35E+09	1.37E+11	8.14E+11	4.63E+11
3	2.22E+11	1.82E+11	1.35E+11	1.52E+10	2.31E+11	1.47E+12	1.01E+12
4	1.57E+11	1.05E+11	1.20E+11	1.07E+10	1.54E+11	8.80E+11	5.12E+11
5	2.28E+11	1.25E+11	1.36E+11	1.58E+10	2.23E+11	1.29E+12	8.03E+11
6	1.68E+11	8.48E+10	1.02E+11	1.17E+10	1.57E+11	8.43E+11	3.78E+11
7	1.79E+11	9.82E+10	1.41E+11	1.25E+10	1.74E+11	1.04E+12	8.08E+11
8	1.26E+11	5.22E+10	5.23E+10	8.87E+09	1.12E+11	5.51E+11	1.63E+11
9	2.09E+11	2.04E+11	1.64E+11	1.40E+10	2.46E+11	1.75E+12	1.29E+12
10	1.36E+11	1.45E+11	1.27E+11	9.29E+09	1.49E+11	1.03E+12	8.35E+11
11	1.99E+11	5.86E+10	1.49E+11	1.34E+10	2.21E+11	1.49E+12	1.06E+12
12	1.62E+11	1.65E+09	1.07E+11	1.10E+10	1.57E+11	8.63E+11	3.59E+11

Table I-16: Whitehorn Creek (VAC-L68R-01)Fecal Coliform Load: Allocation Run (counts/ month)

Month	Commercial/ Industrial	Cropland	Forest	High Density Residential	Medium Density Residential	Low Density Residential	Pasture
1	7.96E+10	1.31E+10	8.13E+10	8.22E+10	1.59E+11	9.41E+11	3.34E+11
2	5.79E+10	1.86E+10	5.31E+10	5.96E+10	1.11E+11	6.18E+11	1.65E+11
3	9.40E+10	5.65E+10	7.21E+10	9.71E+10	1.88E+11	1.11E+12	3.58E+11
4	6.64E+10	3.25E+10	6.40E+10	6.86E+10	1.25E+11	6.69E+11	1.82E+11
5	9.64E+10	3.89E+10	7.22E+10	1.00E+11	1.81E+11	9.79E+11	2.85E+11
6	7.11E+10	2.63E+10	5.42E+10	7.45E+10	1.28E+11	6.40E+11	1.34E+11
7	7.55E+10	3.05E+10	7.52E+10	7.97E+10	1.42E+11	7.92E+11	2.87E+11
8	5.34E+10	1.62E+10	2.79E+10	5.66E+10	9.09E+10	4.18E+11	5.78E+10
9	8.85E+10	6.33E+10	8.74E+10	8.90E+10	2.00E+11	1.33E+12	4.58E+11
10	5.74E+10	4.49E+10	6.78E+10	5.93E+10	1.21E+11	7.81E+11	2.97E+11
11	8.41E+10	1.82E+10	7.95E+10	8.53E+10	1.79E+11	1.13E+12	3.76E+11
12	6.83E+10	5.13E+08	5.72E+10	6.99E+10	1.28E+11	6.56E+11	1.27E+11