Bacteria Total Maximum Daily Load Development for Elk Creek

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Submitted: September 2009

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List of Acronyms

AVMA	American Veterinary Medical Association
BASINS	Better Assessment Science Integrating Point and Nonpoint Sources
BMPs	Best Management Practices
BSE	Biological Systems Engineering
BST	Bacterial Source Tracking
E&S	Erosion and Sediment Control Program
GIS	Geographic Information Systems
HRU	Hydrologic Response Unit
HSPF	Hydrologic Simulation Program – Fortran
LA	Load Allocation
MOS	Margin of Safety
MPID	Monitoring Point Identification Number
MPN	Most Probable Number
MRLC	Multi-Resolution Land Characterization
MS4	Phase II Municipal Separate Storm Sewer System
NASA	National Aeronautics and Space Administration
NCDC	National Climatic Data Center
NLCD	National Land Cover Data
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
NRCS	Natural Resources Conservation Service
NWS	National Weather Service
SCS	Soil Conservation Service
SERCC	Southeast Regional Climate Center
SMC	Unsaturated Soil Moisture Capacity
SWCD	Soil and Water Conservation District
TMDL	Total Maximum Daily Load
UAA	Use Attainability Analysis
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
USLE	Universal Soil Loss Equation
VADCR	Virginia Department of Conservation and Recreation
VADEQ	Virginia Department of Environmental Quality
VADGIF	Virginia Department of Game and Inland Fisheries
VASS	Virginia Agriculture Statistics Service
VCE	Virginia Cooperative Extension
VDACS	Virginia Department of Agricultural and Consumer Services
VDH	Virginia Department of Health
VPDES	Virginia Pollutant Discharge Elimination System

VWCB	Virginia Water Control Board
WLA	Waste Load Allocation
WQMP	Water Quality Management Plan

Executive Summary

Background

Elk Creek was first listed as an impaired stream in 2002 on Virginia's Section 303(d) Total Maximum Daily Load Priority List and Report (VADEQ, 2002) indicating that the recreational use goal was not being met. Elk Creek was further listed in 2004, 2006, and 2008 on Virginia's Section 303(d) Total Maximum Daily Load Priority List and Report (VADEQ 2004, 2006, and 2008) based on Virginia Department of Environmental Quality (VADEQ) monitoring data. The impaired portion of Elk Creek (VAS-N05R-01), extending 10.69 miles from the Turkey Fork confluence to confluence with New River, was listed as impaired on Virginia's 2004 Section 303(d) TMDL Priority List and Report due to water quality exceedances of the bacteria standard at station 9-EKC003.78. The Elk Creek impairment designation was extended to approximately 19.61 miles on Virginia's 2008 Section 303(d) TMDL Priority List and Report, from the Comers Rock Branch confluence downstream to the New River confluence. Impairment designation was based on 67% exceedance of the *E. coli* water quality standard at station 9-EKC000.11, 29% exceedance of the bacteria water quality standard at station 9-EKC003.78, 75% exceedance of the *E. coli* water quality standard at station 9-EKC012.13, and 92% exceedance of the *E. coli* water quality standard at station 9-EKC017.51.

The Elk Creek impairment watershed is located in Grayson County, Virginia. The Elk Creek impairment begins near Bennington Mill, Virginia and flows approximately 24 miles south east toward Carsonville, Virginia and empties into the New River. Major tributaries to Elk Creek include Turkey Fork, Knob Fork, Comers Rock Branch, and Wolfpen Branch. The Elk Creek watershed is approximately 53,700 acres, predominately forest, constituting approximately 59% of the total watershed area. The remaining land uses are divided between pasture (35%), residential (5%), and cropland (1%).

VADEQ personnel monitored pollutant concentrations throughout the Elk Creek watershed at stations 9-EKC000.11 and 9-EKC003.78 .14. Of the six water quality samples collected from January 2000 through December 2004 (the 2006 Section 303(d) 5-year listing period) at VADEQ station 9-EKC003.78, 50% of the samples exceeded the then-applicable instantaneous fecal coliform water quality standard. During the same period, five of eight samples exceeded the *E. coli* water quality standard. Consequently, Elk Creek was determined as not supporting of the Clean Water Act's Recreation Use Goal for the 2006 Section 305(b) water quality assessment report and was included in the 2006 Section 303(d) List of Impaired Waters (VADEQ, 2006).

Pollutant Sources

Currently, there are no active point source discharges with a VPDES permit to discharge bacteria within the Elk Creek watershed. Therefore, the fecal coliform load originates from nonpoint sources. Nonpoint sources of fecal coliform are primarily agricultural (i.e., land-applied animal waste, manure deposited directly on pastures by livestock, and a significant fecal coliform load due to cattle directly depositing manure in streams) with a significant load applied

to residential and forest land use categories. Non-agricultural anthropogenic nonpoint sources of fecal coliform loadings include straight pipes, failing septic systems, and pet waste. Wildlife contributes to fecal coliform loadings on all land uses, according to the acceptable habitat range for each species. The amounts of fecal coliform produced in different locations (e.g., confinement, pasture, forest) were estimated on a monthly basis to account for seasonal variability in wildlife habitat and livestock production and practices. Livestock management and production factors, such as the fraction of time cattle spend in confinement or in streams, the amount of manure storage, and spreading schedules, were considered on a monthly basis.

Modeling

The Hydrologic Simulation Program – Fortran (HSPF) was used to simulate the fate and transport of fecal coliform bacteria in the Elk Creek watershed. To identify localized sources of fecal coliform, the watersheds were divided into subwatersheds. These subdivisions were based primarily on homogeneity of land use. Observed stream flow values were not available for Elk Creek, therefore a “paired watershed” approach was used for hydrologic calibration and validation. The approach assumes that the paired watershed and Elk Creek watershed have similar hydrologic responses based on physical, geologic, and hydrologic characteristics. The Cripple Creek watershed was chosen as the paired watershed due to similar physiographic and hydrologic characteristics. Hydrology calibration and validation were performed based on the physical, hydrologic, and land use data for the Cripple Creek watershed. After calibration and validation completion, the parameterization for the Cripple Creek model was transferred to the Elk Creek model. Parameters describing watershed characteristics such as land use, slope, infiltration rate, and F-Tables were updated to reflect the physical properties in Elk Creek watershed.

The Cripple Creek model was calibrated using observed flow values from USGS station #03166000 on Cripple Creek near Ivanhoe, VA for the period January 1, 2000 to December 31, 2004. The calibration period covered a wide range of hydrologic conditions, including low- and high-flow conditions, as well as seasonal variations. The calibrated HSPF data set was validated on a separate period from January 1, 1995 to December 31, 1999. Calibration parameters were adjusted within the recommended ranges until the model performance was deemed acceptable.

Fecal coliform bacteria observations from the VADEQ ambient water quality monitoring station 9-EKC003.78 within the Elk Creek impairment were used to calibrate and validate the water quality component of HSPF. The period January 1, 1997 through December 31, 2001 was chosen for water quality calibration and January 1, 1992 through December 31, 1996 was chosen for water quality validation. Fecal coliform bacteria observations from the VADEQ ambient water quality monitoring station 9-EKC003.78 within the Elk Creek impairment were used to calibrate the water quality component of HSPF. Inputs to the model included fecal coliform loadings on land and in the stream along with simulated flow data. A comparison of simulated and observed fecal coliform loadings in the stream indicated that the model adequately simulated the fate and transport of fecal coliform in the watershed.

Margin of Safety

A margin of safety (MOS) was included to account for any uncertainty in the TMDL development process. There are several different ways that the MOS could be incorporated into the TMDL (USEPA, 1991). For the bacteria TMDL, the MOS was implicitly incorporated into the TMDL by conservatively estimating several factors affecting bacteria loadings, such as animal numbers, production rates, and contributions to streams.

TMDL Allocation Scenarios

No active point discharges in the Elk Creek watershed currently have VPDES permits. No municipalities with MS4 permits were identified within the Elk Creek watershed. The waste load allocation was calculated at <1% of the TMDL.

After calibrating to the existing water quality conditions, different scenarios were evaluated to identify implementable scenarios that meet both the calendar-month geometric mean *E. coli* criterion (126 cfu/100 mL) and the single sample maximum *E. coli* criterion (235 cfu/100 mL) with zero exceedances. Scenarios were evaluated to predict the effects of different combinations of source reductions on final in-stream water quality. Required reductions in fecal coliform loading from existing conditions for the selected TMDL allocation include a 100% reduction in straight pipes, 97% reduction in livestock direct deposition, 0% reduction in wildlife direct deposition, a 97% reduction in nonpoint source loadings to residential land use, a 97% reduction in nonpoint source loadings to pasture land use, a 97% reduction in nonpoint source loadings to cropland, and no reduction in nonpoint source loadings to forest land use.

Using equation [E.1], summaries of the Elk Creek bacteria TMDL for the selected allocation scenario are shown in Tables E.1 and E.2.

$$TMDL = WLA + LA + MOS \qquad [E.1]$$

where: WLA = wasteload allocation (point source contributions);
LA = load allocation (nonpoint source contributions); and
MOS = margin of safety (implicit).

Table E.1. Average annual *E. coli* bacteria loads (cfu/yr) modeled after TMDL allocation in Elk Creek impairment.

Pollutant	WLA[1] (cfu/yr)	LA[2] (cfu/yr)	MOS	TMDL[3] (cfu/yr)
E. coli	1.48E+11	1.47E+13	Implicit	1.48E+13

1 – The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.

2 – The LA is calculated as the TMDL minus the WLA.

3 – The TMDL is presented as the average annual load for the allocation period.

Table E.2. Daily *E. coli* bacteria loads (cfu/d) modeled after TMDL allocation in Elk Creek impairment.

Pollutant	WLA[1] (cfu/d)	LA[2] (cfu/d)	MOS	TMDL[3] (cfu/d)
E. coli	4.05E+08	5.04E+12	Implicit	5.04E+12

1 – The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe. The WLA is calculated as the average annual load divided by 365.

2 – The LA is calculated as the TMDL minus the WLA.

3 – The TMDL is presented for the 99th percentile daily flow condition at the numeric water quality criterion of 235 cfu/100ml. The TMDL is variable depending on flow conditions. The numeric water quality criterion will be used to assess progress toward TMDL goals.

TMDL Implementation and Reasonable Assurance

The goal of the TMDL program is to establish a three-step process that will enable the attainment of water quality standards. The first step in the process is to develop TMDLs that will result in meeting water quality standards. This report represents the culmination of that effort for the bacteria impairment on Elk Creek. The second step is to develop a TMDL implementation plan. The final step is to implement the TMDL implementation plan and monitor stream water quality to determine if water quality standards are being attained. Watershed stakeholders will have the opportunity to participate in the development of the TMDL implementation plan. Specific goals for BMP implementation will be established as part of the implementation plan development.

Following the development of the TMDL, the VADEQ will make every effort to continue to monitor the impaired stream in accordance with its ambient monitoring programs. The purpose, location, parameters, frequency, and duration of the monitoring will be determined by the VADEQ staff, in cooperation with VADCR staff, the Implementation Plan Steering Committee and local stakeholders. Whenever possible, the location of the follow-up monitoring station(s) will be the same as the listing station. VADEQ staff, in cooperation with VADCR staff, the Implementation Plan Steering Committee and local stakeholders, will continue to use data from the ambient monitoring stations to evaluate reductions in pollutants, “water quality milestones” as established in the implementation plan, 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. Implementation of this TMDL will contribute to on-going water quality improvement efforts aimed at restoring water quality in the watershed.

Staged implementation is a key component to restoring water quality in Elk Creek. An alternative scenario was evaluated to establish goals for the first implementation stage of the bacteria TMDL. The implementation of such a transitional scenario, or Stage 1 implementation, will allow for an evaluation of the effectiveness of management practices and accuracy of model assumptions through continued data collection. The bacteria Stage 1 implementation goal was to provide an instantaneous standard exceedance rate below 10%, a geometric mean standard

exceedance rate of 0%, and 0% reduction in wildlife loads. These exceedance rate criteria mirror the new proposed bacteria standard meeting a 10% exceedance rate of the single sample maximum criterion (235 cfu/100ml) and a 0% exceedance rate of the geometric mean criterion (126 cfu/100 ml).The Stage 1 allocation for the Elk Creek bacteria impairment requires a 100% reduction in straight pipes, 75% reduction in livestock direct deposition, 0% reduction in wildlife direct deposition, a 57% reduction in nonpoint source loadings to residential land use, a 57% reduction in nonpoint source loadings to pasture land use, a 57% reduction in nonpoint source loadings to cropland, and no reduction in nonpoint source loadings to forest land. This scenario resulted in a 9.91% instantaneous standard exceedance rate and a 0.0% geometric mean standard exceedance rate. After the proposed bacteria standard is adopted by the Virginia Water Control Board, the Stage I implementation scenario will become the TMDL allocation scenario, since it will meet the new revised standard.

Public Participation

During development of the Elk Creek Bacteria TMDL, public participation was encouraged through two public meetings and two Technical Advisory Committee (TAC) meetings. The first public meeting was held at the Elk Creek Rescue Squad on July 17, 2008, to discuss the need for a TMDL, and review the approach for TMDL development. The final public meeting was held at the Elk Creek Rescue Squad on July 21, 2009, to discuss the source allocations and reductions required to meet the TMDL. Copies of the draft TMDL report were available for public review and comment.

In addition to keeping the public apprised of progress in the development of theElk Creek Bacteria TMDL, a TMDL TAC was also established to help advise the TMDL developers. TAC meetings were held for this project on June 17, 2008 and July 20, 2009 at the Mount Rogers Planning District Commission in Marion, Virginia. The general public was solicited to participate on the TAC during the first public meeting in addition to agencies and groups already represented on the TAC. TheTAC membership for the Elk Creek Bacteria TMDL included representatives from the following agencies and organizations: Virginia Department of Environmental Quality, Virginia Department of Conservation and Recreation, Mount Rogers Planning District Commission, New River Soil and Water Conservation District, and Grayson County.

The meetings were used as a forum to facilitate understanding of, and involvement in, the TMDL process. Data and assumptions used in the TMDL development were reviewed along with stakeholder concerns about the implications of the TMDL. Feedback from these meetings was used in the TMDL development and improved confidence in the allocation.

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Acknowledgements

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Engineering Concepts, Inc. of Fincastle, Virginia supported this study as a contractor to Mount Rogers Planning District Commission through funding provided by the Virginia Department of Environmental Quality

Chapter 1. Introduction

1.1 Background

1.1.1 TMDL Definition and Regulatory Information

Section 303(d) of the Federal Clean Water Act and the U.S. Environmental Protection Agency's (USEPA) Water Quality Planning and Management Regulations (40 CFR Part 130) require states to identify water bodies that exceed state water quality standards and to develop Total Maximum Daily Loads (TMDLs) for such water bodies. A TMDL represents the total load of a pollutant that a water body can receive without exceeding state water quality standards. The TMDL process establishes the maximum allowable pollutant loading from both point and nonpoint sources for a water body, allocates the allowable load among the pollutant contributors, and provides a framework for taking actions to restore water quality.

1.1.2 Impairments Listing

Elk Creek was first listed as an impaired stream in 2002 on Virginia's Section 303(d) Total Maximum Daily Load Priority List and Report (VADEQ, 2002) indicating that the recreational use goal was not being met. Elk Creek was further listed in 2004, 2006, and 2008 on Virginia's Section 303(d) Total Maximum Daily Load Priority List and Report (VADEQ 2004, 2006, and 2008) based on Virginia Department of Environmental Quality (VADEQ) monitoring data. The impaired portion of Elk Creek (VAS-N05R-01), extending 10.69 miles from the Turkey Fork confluence to confluence with New River, was listed as impaired on Virginia's 2004 Section 303(d) TMDL Priority List and Report due to water quality exceedances of the bacteria standard at station 9-EKC003.78. The Elk Creek impairment designation was extended to approximately 19.61 miles on Virginia's 2008 Section 303(d) TMDL Priority List and Report, from the Comers Rock Branch confluence downstream to the New River confluence. Impairment designation was based on 67% exceedance of the *E. coli* water quality standard at station 9-EKC000.11, 29% exceedance of the bacteria water quality standard at station 9-EKC003.78, 75% exceedance of the *E. coli* water quality standard at station 9-EKC012.13, and 92% exceedance of the *E. coli* water quality standard at station 9-EKC017.51.

1.1.3 Watershed Location and Description

The Elk Creek impairment watershed is located in Grayson County, Virginia (Figure 1.1). The Elk Creek impairment begins near Bennington Mill, Virginia and flows approximately 24 miles south east toward Carsonville, Virginia and empties into the New River. Major tributaries to Elk Creek include Turkey Fork, Knob Fork, Comers Rock Branch, and Wolfpen Branch. The Elk Creek watershed is approximately 53,718 acres, predominately forest, constituting approximately 59.1% of the total watershed area. The remaining land uses are divided between pasture (35.5%), residential (4.9%), and cropland (0.5%).

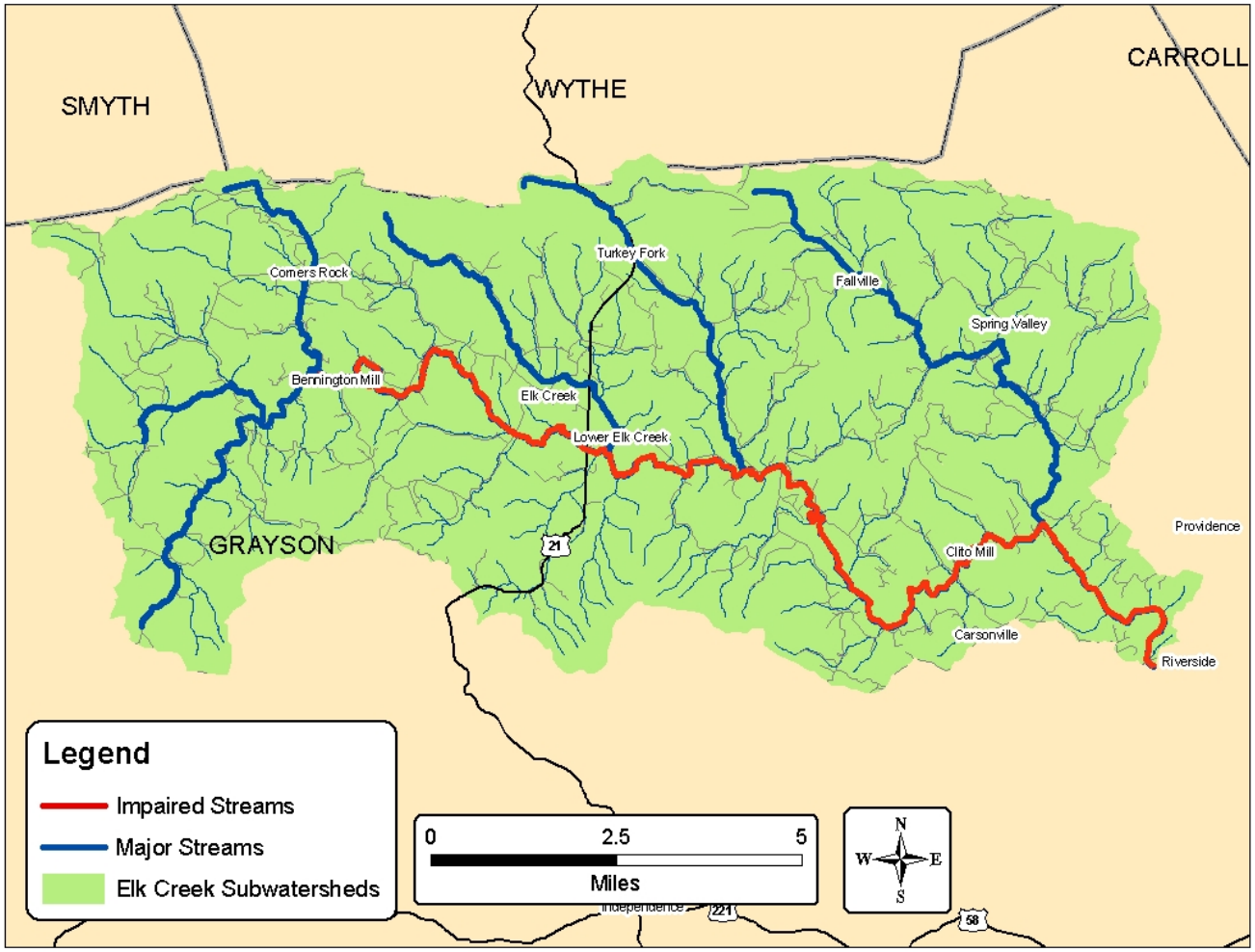

Figure 1.1. Location of Elk Creek (VAS-O05R) watershed.

1.1.4 Pollutant of Concern

Pollution from both point and nonpoint sources can lead to fecal coliform bacteria contamination of water bodies. Fecal coliform bacteria are found in the intestinal tract of warm-blooded animals; consequently, fecal waste of warm-blooded animals contains fecal coliform. Even though most fecal coliform are not pathogenic, some forms can be harmful to human health and their presence in water indicates recent contamination by fecal material. Because fecal material may contain pathogenic organisms, water bodies with fecal coliform counts may also contain pathogenic organisms. For recreational activities involving contact with water, such as boating and swimming, health risks increase with increasing fecal coliform counts. If the fecal coliform concentration in a water body exceeds state water quality standards, the water body is listed for an exceedance of the state fecal coliform standard for contact recreational uses. As discussed in Section 1.2.2, Virginia has adopted an Escherichia coli (*E. coli*) standard for water quality. The concentration of *E. coli* (a subset of the fecal coliform group) in water is considered to be a better indicator of pathogenic exposure than the concentration of the entire fecal coliform group in the water body.

1.2 Designated Uses and Applicable Water Quality Standards

1.2.1 Designation of Uses (9 VAC 25-260-10)

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

The goal of the Clean Water Act is that all streams should be suitable for recreational uses, including swimming and fishing. **Fecal coliform and *E. coli* bacteria** are used to indicate the presence of pathogens in streams supporting the **recreational use goal**. Bacteria in Elk Creek (VAS-N05R-01), exceed the fecal coliform criterion.

1.2.2 Bacteria Standard (9 VAC 25-260-170)

USEPA has recommended that all states adopt an *E. coli* or enterococci standard for fresh water and enterococci criteria for marine waters, because there is a stronger correlation between the concentration of these organisms (*E. coli* and enterococci) and the incidence of gastrointestinal illness than there is with fecal coliform. *E. coli* and enterococci are both bacteriological organisms that can be found in the intestinal tract of warm-blooded animals and are subsets of the fecal coliform and fecal streptococcus groups, respectively. In line with this recommendation, Virginia adopted and published revised bacteria criteria on June 17, 2002. The revised criteria became effective on January 15, 2003. As of that date, the *E. coli* standard described below applies to all freshwater streams in Virginia. Additionally, prior to June 30, 2008, the interim fecal coliform standard must be applied at any sampling station that has fewer than 12 samples of *E. coli*.

For a non-shellfish water body to be in compliance with Virginia's revised bacteria standards (as published in the Virginia Register Volume 18, Issue 20) the following criteria shall apply to protect primary contact recreational uses (VADEQ, 2000):

- **Interim Fecal Coliform Standard:** Fecal coliform bacteria shall not exceed a geometric mean of 200 fecal coliform bacteria per 100 mL of water for two or more samples over a calendar month nor shall more than 10% of the total samples taken during any calendar month exceed 400 fecal coliform bacteria per 100 mL of water.
- **Escherichia coli Standard:** *E. coli* bacteria concentrations for freshwater shall not exceed a geometric mean of 126 counts per 100 mL for two or more samples taken during any calendar month and shall not exceed an instantaneous single sample maximum of 235 cfu/100mL.

During an assessment period, conventional parameters such as bacteria require at least two exceedences of the standard, and an exceedance of greater than 10.5% of the total samples before a water is listed as impaired (VADEQ Assessment Guidance, 2006). If these conditions are met, the stream segment associated with that station is classified as impaired and a TMDL must be developed and implemented to bring the segment into compliance with the water quality standard. The original impairment designation for Elk Creek was based on exceedances of an earlier fecal coliform standard that included a numeric single sample maximum limit of 1,000 cfu/100 mL. The bacteria TMDL for these impaired segments was developed to meet the *E. coli* standard. As recommended by VADEQ, the modeling was conducted with fecal coliform inputs, and then a translator equation developed by the VADEQ was used to convert the output of the model to *E. coli*.

Chapter 2. Watershed Characterization

2.1 Water Resources

Elk Creek (VAS-N05R) watersheds were subdivided into sub-watersheds for fecal coliform modeling purposes, as discussed in Section 4.2. The impaired portion of Elk Creek runs for approximately 19.61 miles from the confluence with Comers Branch to the confluence with the New River. Elk creek is a perennial stream with a trapezoidal channel cross-section.

2.2 Ecoregion

The Elk Creek (VAS-N05R) subwatersheds (See Figure 4.1 for subwatershed delineation) lie in the Northern Ridge and Valley Ecoregion. The Northern Ridge and Valley Ecoregion is a northeast-southwest trending, relatively low-lying, but diverse ecoregion sandwiched between generally higher, more rugged mountainous regions with greater forest cover. As a result of extreme folding and faulting events, the region's roughly parallel ridges and valleys have a variety of widths, heights, and geologic materials, including limestone, dolomite, shale, siltstone, sandstone, chert, mudstone, and marble. Springs and caves are relatively numerous. Present-day forests cover about 50% of the region. The ecoregion has a diversity of aquatic habitats and species of fish.

2.2.1 Climate

The climate of the Elk Creek watersheds is characterized based on the meteorological observations from 08/3/1948 to 12/31/2008 assembled by the Southeast Regional Climate Center for the Galax Radio WBOB, Virginia (443267) station. Average annual precipitation is 43.33 inches with 54.0% of the precipitation occurring during the crop-growing season (May-October) (SERCC, 2009). Average annual snowfall is 15.3 inches with the highest snowfall occurring during January (SERCC, 2009). Average annual daily temperature is 63.4°F. The highest average daily temperature of 81.6°F occurs in July while the lowest average daily temperature of 23.7°F occurs in January (SERCC, 2009).

2.3 Land Use

Details of landuse used in this study are described in Section 4.3 with landuse per subwatershed listed in Table 4.2. For purposes of this study, it was assumed that residential development in the Elk Creek watershed will continue at the overall average rate of less than 1.0% annually.

2.4 Water Quality Data

2.4.1 Historic Data for Fecal Coliform

Of the six water quality samples collected from January 2000 through December 2004 (the 2006 Section 303(d) 5-year listing period) at VADEQ station 9-EKC003.78, 50% of the samples exceeded the then-applicable instantaneous fecal coliform water quality standard. During the same period, five of eight samples exceeded the *E. coli* water quality standard. Consequently, Elk Creek was determined as not supporting of the Clean Water Act's Recreation Use Goal for the 2006 Section 305(b) water quality assessment report and was included in the 2006 Section 303(d) List of Impaired Waters (VADEQ, 2006).

VADEQ personnel monitored pollutant concentrations throughout Elk Creek. Monitoring data with corresponding 6-day antecedent precipitation used in assessment of the impairment, as well as in this study, are included in Appendix A. Time series data of fecal coliform concentration from 1991 through the most recent data collected at the time this report was written are plotted in Figure 2.1. Data from bacteria monitoring station (9-EKC003.78) in Elk Creek watershed are shown in Figure 2.1. The Most Probable Number (MPN) and membrane filtration methods were used for analyzing water samples for fecal coliform concentration.

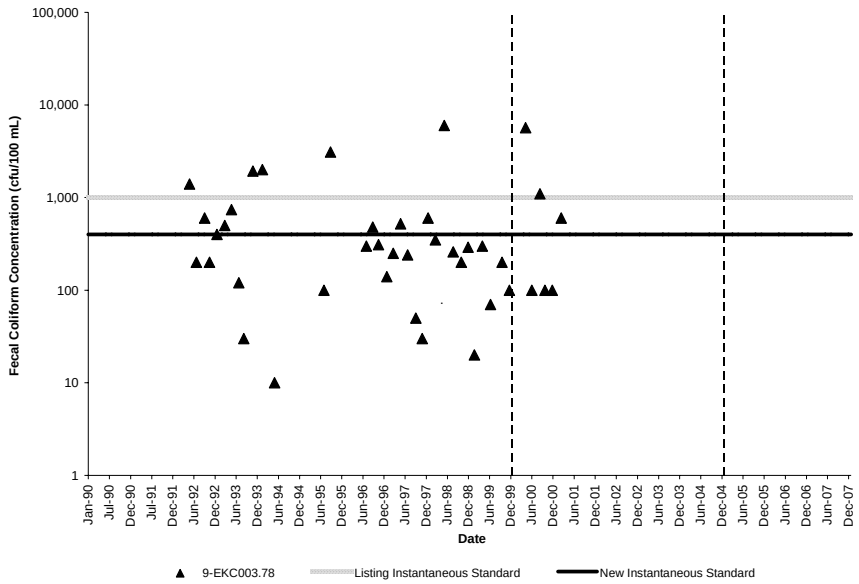

Figure 2.1. Fecal coliform concentrations (VADEQ station 9-EKC003.78) in the Elk Creek impairment.

Seasonal variability of fecal coliform concentrations in the stream network was evaluated by plotting the mean monthly fecal coliform concentration values. Mean monthly fecal coliform concentration values were determined as the average of two to five values for each month; the number of values varied according to the available number of samples for each month in the 1990 to 2006 period of record (Table 2.1). Mean monthly fecal coliform bacteria concentrations were plotted for Elk Creek (Figure 2.2). The highest mean concentration occurred in April and May with each season containing a month that the mean fecal coliform concentration was elevated, therefore a seasonal difference could not be determined at station 9-EKC003.78 (Figure 2.2). It should be noted that due to the upper cap (8,000 cfu/100 mL or 16,000 cfu/100 mL) and lower cap (100 cfu/100ml or 18 cfu/100ml) imposed on the fecal coliform count, the actual counts could be higher or lower in cases where fecal coliform levels are equal to these level limits, therefore changing the averages shown in Figure 2.2.

Table 2.1. Number of samples collected per month from 1/1/90 to 12/31/06 in the Elk Creek watershed.

Month	Samples Collected at 9-EKC003.78 (#)
January	3
February	3
March	3
April	2
May	5
June	2
July	5
August	2
September	5
October	3
November	4
December	3
TOTAL	**40**

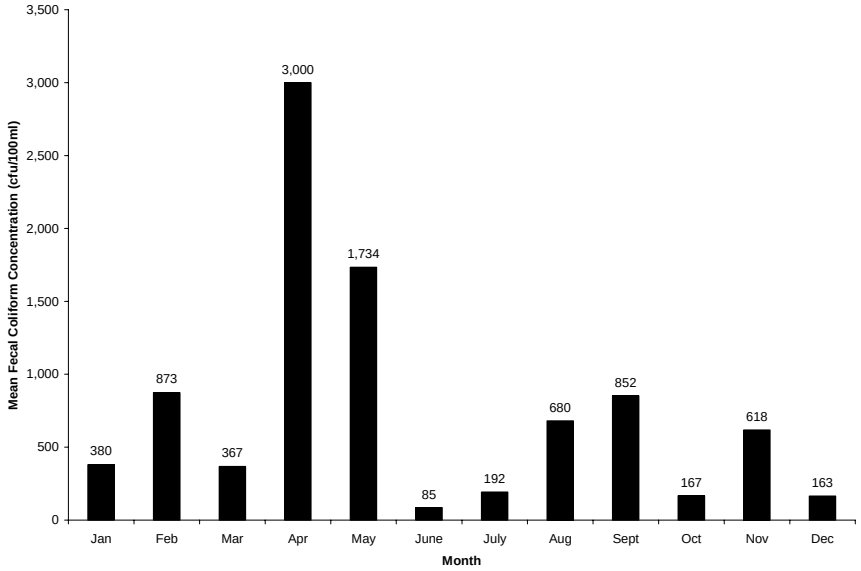

Figure 2.2. Impact of seasonality on fecal coliform concentrations (VADEQ station 9-EKC003.78) in the Elk Creek (VAS-N05R) impairment from 1992 through 2001.

2.4.2 Historic Data for E. coli

VADEQ staff examined water samples collected at station 9-EKC000.11, for the concentration of *E. coli* (Figure 2.24). This analysis was conducted concurrently with other monthly testing at the stations from July 2003 through May 2005. Eight of the 12 (66%) samples analyzed from station 9-EKC000.11 exceeded the instantaneous *E. coli* bacteria standard of 235 cfu/100 mL. Testing was also performed during the period from January 2008 through September 2009.

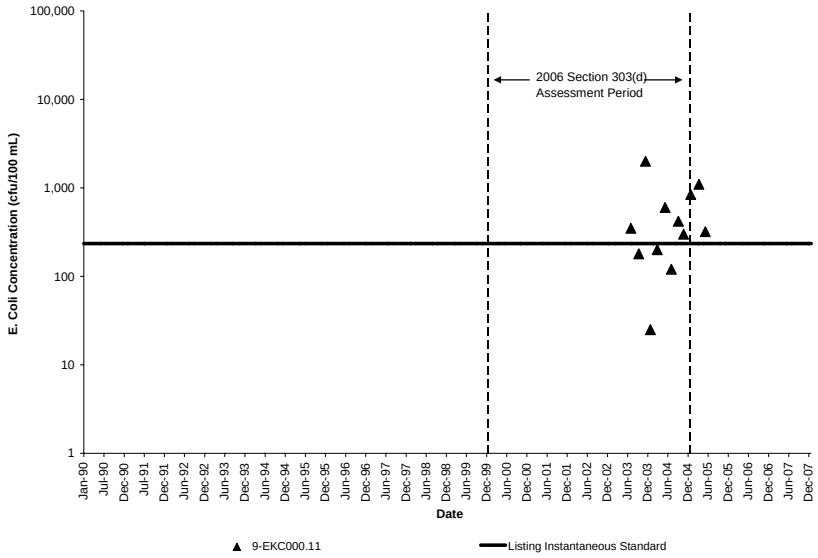

Figure 2.3. E. coli concentrations (VADEQ station 9-EKC000.11) in Elk Creek (VAS-N05R-EKC01A00) impairment.

VADEQ staff examined water samples collected at station 9-EKC010.47, for the concentration of *E. coli* (Figure 2.4.1). This analysis was conducted concurrently with other monthly testing at the stations from July 2003 through May 2005. Nine of the 12 (75%) samples analyzed from station 9-EKC000.11 exceeded the instantaneous *E. coli* bacteria standard of 235 cfu/100 mL. Testing was also performed during the period from January 2008 through September 2009.

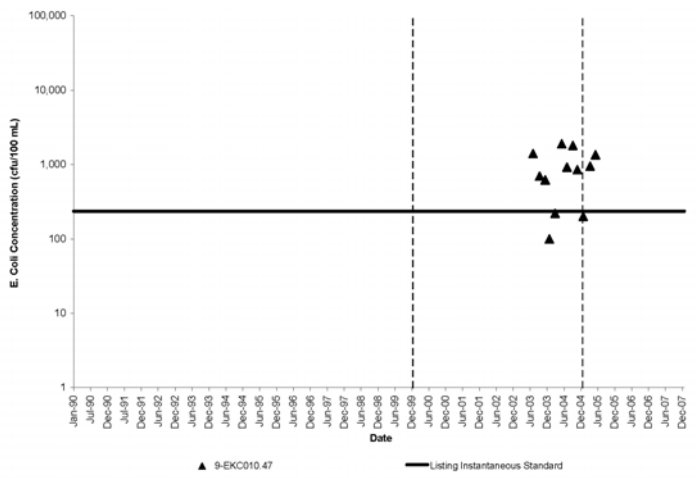

Figure 2.4.1 E. coli concentrations (VADEQ station 9-EKC010.47) in Elk Creek (VAS-N05R-EKC01A00) impairment.

VADEQ staff examined water samples collected at station 9-EKC012.13, for the concentration of *E. coli* (Figure 2.5). This analysis was conducted concurrently with other monthly testing at the stations from July 2003 through May 2005. Nine of the 12 (75%) samples analyzed from station 9-EKC000.11 exceeded the instantaneous *E. coli* bacteria standard of 235 cfu/100 mL. Testing was also performed during the period from January 2008 through September 2009.

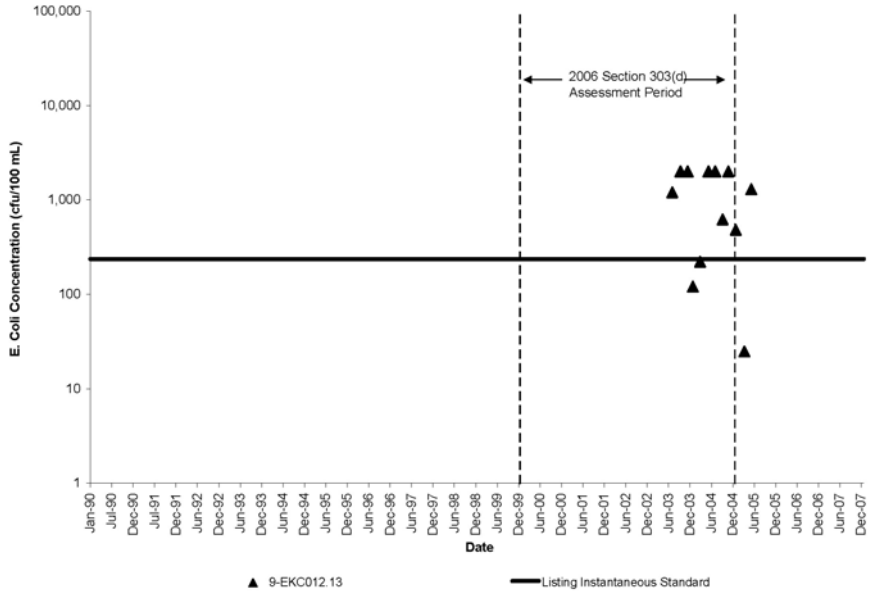

Figure 2.5. E. coli concentrations (VADEQ station 9-EKC012.13) in Elk Creek (VAS-N05R-EKC01A00) impairment.

VADEQ staff examined water samples collected at station 9-EKC017.51, for the concentration of *E. coli* (Figure 2.6). This analysis was conducted concurrently with other monthly testing at the stations from July 2003 through May 2005. Eleven of the 12 (92%) samples analyzed from station 9-EKC000.11 exceeded the instantaneous *E. coli* bacteria standard of 235 cfu/100 mL. Testing was also performed during the period from January 2008 through September 2009.

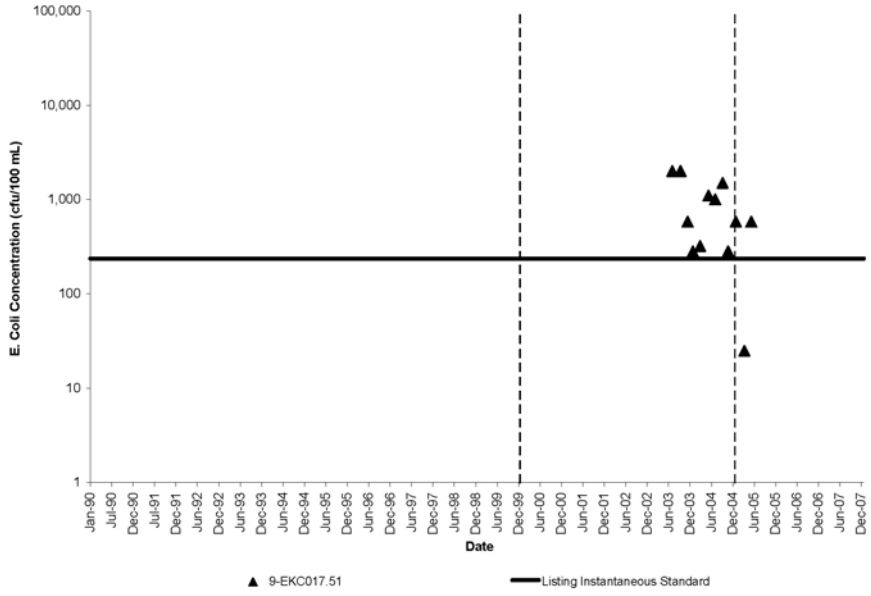

Figure 2.6. E. coli concentrations (VADEQ station 9-EKC017.51) in Elk Creek (VAS-N05R-EKC01A00) impairment.

2.4.3 Historic Data for Bacterial Source Tracking

The results from 12 monthly bacteria source tracking (BST) samples collected in 2008 at station 9-EKC000.11 were received at the time this report was prepared. The BST analysis was performed by MapTech, Inc. The results of the BST analysis provide a measure of the relative contribution of bacteria sources to the bacteria concentration found in the water samples. The bacteria sources were lumped into four categories: wildlife, human, livestock, and pet. Data

resulting from the BST study are referenced in Appendix B. A discussion of the BST results provided by VADEQ indicates there is 90% confidence that the indicated proportions for each sample are within 15% of the sampled population (Appendix B). These data represent a brief glimpse of bacteria concentration Elk Creek and may not be representative of long-term conditions in the stream.

The analysis in the BST report also included a test of statistical significance, providing an indication of presence or absence of contribution from a particular source. The presence/absence use of these data is most appropriate for use in this study due to statistical confidence, with presence defined as any proportional contribution greater than 15%. Table 2.2 summarizes the results of the presence/absence analysis of the BST data. The BST data were used to verify modeling methods and assumptions.

E. coli enumerations were also performed on the BST samples. These data are referenced in Appendix B. At station 9-EKC000.11, 16.7% (two of 12) of the samples exceeded the *E. coli* bacteria instantaneous standard. The exceedances occurred in June and July of 2008.

Table 2.2. Presence/absence analysis of bacteria sources at station 9-EKC000.11 in Elk Creek watershed.

Bacteria Source	Frequency of Presence in All Samples[1] (%)	Frequency of Presence in Samples Exceeding Water Quality Standards[2] (%)
Wildlife	58	100
Human	42	50
Livestock	25	0
Pet	17	0

1 – This is a measure of the number of times the source is present in all 12 samples.

2 – This is a measure of the number of times (i.e., two) the source was present in samples that exceeded the *E. coli* instantaneous standard.

Chapter 3. Bacteria Source Assessment

Potential bacteria sources in the Elk Creek watershed were assessed using multiple approaches, including information from VADEQ; Virginia Department of Conservation (VADCR); Virginia Department of Game and Inland Fisheries (VADGIF); Virginia Cooperative Extension (VCE); Virginia Department of Health (VDH); Grayson County Planning Department; Natural Resources Conservation Service (NRCS); Virginia Department of Agricultural and Consumer Services (VDACS); New River SWCD; public participation; watershed reconnaissance and monitoring; published information; and professional judgment. The gathered information was used to estimate source populations and their associated bacteria loads throughout the Elk Creek watershed, forming the basis for model development and analysis of allocation scenarios (Table 3.1). The following sections discuss available information and methods used to estimate bacteria loads for each modeling segment.

Table 3.1. Potential bacteria sources in the Elk Creek watershed.

Source Category	Source / Animal Type	Applied To
Human and Pets	Permitted Discharges	Stream Reach
	Sanitary Sewer	Land
	Straight Pipes	Stream Reach
	Failing Septic Systems	Land
	Biosolids Applications	Land
	Dogs / Cats	Land
Agricultural	Dairy Cattle	Land, Stream Reach
	Beef Cattle	Land, Stream Reach
	Horses	Land
	Turkey	Land
	Chicken	Land
	Other Livestock	Land
Wildlife	Deer	Land, Stream Reach
	Bear	Land, Stream Reach
	Raccoon	Land, Stream Reach
	Muskrats	Land, Stream Reach
	Beavers	Land, Stream Reach
	Turkeys	Land, Stream Reach
	Geese	Land, Stream Reach
	Ducks	Land, Stream Reach

3.1 Permitted Discharges

Currently, no individual Virginia Pollutant Discharge Elimination System municipal and industrial permitted facilities, as well as general permits issued for domestic sewage discharges of less than or equal to 1,000 gallons per day exist in the Elk Creek watershed.

Phase II Municipal Separate Storm Sewer System (MS4) permits were also reviewed and found no facilities with MS4 permits discharge within the Elk Creek watershed.

3.2 Humans

Wastewater from 1,479 households within the Elk Creek watershed is treated on site by traditional sewage handling and disposal systems. The Elk Creek watershed has an estimated population of 2,486 people (1,479 households at an average of 1.68 people per household (UCSB, 2000); actual people per household varies among sub-watersheds). Humans produce 1.95×10^{9} cfu/day-person (Geldreich et al., 1978), resulting in a total fecal coliform production of 4.85×10^{12} cfu/day (1.77×10^{15} cfu/year) in Elk Creek watershed.

Bacteria from humans can be transported to streams from failing septic systems, straight pipes discharging directly into streams, or biosolids applications to pasture and cropland.

3.2.1 Failing Septic Systems

Septic systems are designed to filter septic tank effluent through the soil allowing removal of bacteria and nutrients from the wastewater. Septic system failure is manifested by the rise of effluent to the soil surface. It was assumed treatment of effluent ceased once effluent containing fecal coliform reached the soil surface. Surface runoff can transport the effluent containing fecal coliform to receiving waters.

Total septic systems were classified into one of three age categories (pre-1967, 1967-1987, and post-1987) based on 1990, 2000, and 2004 U.S. Census Bureau demographics data (UCSB, 1990, 2000, and 2004). In accordance with estimates from Dr. Raymond B. Reneau, Jr. from Virginia Tech, a 15% failure rate for systems designed and installed prior to 1967, a 8% failure rate for systems designed and installed between 1967 and 1987, and a 3% failure rate on all systems designed and installed after 1987 was used in the development of the Elk Creek TMDL. The rates reported by Dr. Raymond B. Reneau, Jr. were a culmination of studies he performed throughout the state with numerous variables (e.g., soils) considered. These rates have been accepted by the Virginia Department of Environmental Quality, Virginia Department of Conservation and Recreation, and United States Environmental Protection Agency in TMDLs throughout Virginia. Estimates of these failure rates were also supported by the Holmans Creek Watershed Study which found that over 30% of all septic systems checked in the watershed were either failing or not functioning at all (SAIC, 2001).

An average number of people per household and number of houses and people in each subwatershed in 2008 were established using 1990, 2000, and 2004 U.S. Census Bureau demographics data (UCSB, 1990 and 2000). The applicable failure rate was multiplied by each total and summed to get the total failed septic systems per subwatershed. Daily total fecal coliform load to the land from a failing septic system in a particular sub-watershed was determined by multiplying the average household occupancy rate for that subwatershed by the per capita fecal coliform production rate of 1.95×10^{9} cfu/day (Geldreich et al., 1978). Hence, the total fecal coliform loading to the land from a single failing septic system in a subwatershed with an occupancy rate of 1.68 persons/household was 4.85×10^{12} cfu/day. Transport of some portion

of the fecal coliform to a stream by runoff may occur during storm events. The number of failing septic systems in the watershed is given in Table 3.2.

3.2.2 Straight Pipes

Houses that deliver a waste load directly to the stream, or straight pipes, were estimated by identifying those houses located within 150 feet of streams in the pre-1969 and 1970-1988 age categories. Any houses within 150 ft of streams are considered potential straight pipe dischargers. Using the age categories (pre-1969, 1970 – 1988, post 1988), 10% of old houses (pre-1969) within 150 ft of streams and 2% of mid-age houses (1970 – 1988) within 150 ft of streams are assumed to be straight pipe dischargers (CTWS, 2004). This method yielded 97 houses that potentially could be classified as straight pipes in the Elk Creek watershed (Table 3.2).

3.2.3 Biosolids

According to the VADEQ records, none of the facilities permitted for biosolids land application are currently disposing biosolids via land application in the Elk Creek watershed.

3.3 Pets

According to the American Veterinary Medical Association (AVMA), there are on average 0.53 dogs per household and 0.60 cats per household in the Unites States (AVMA, 1997). Based on these densities and number of households in each watershed, 784 dogs and 887 cats were projected to reside in the Elk Creek impairment. All pets were combined for modeling purposes into a standard ‘unit pet’ category. This ‘unit pet’ was assumed equivalent to one dog or several cats, and a rate of one ‘unit pet’ per household was used to calculate a total pet population of 1,479 for Elk Creek watershed. The maximum typical fecal coliform production for both dogs and cats is 5.0×10^9 cfu/day-animal (Keeling, 2003), and the typical ranges overlap significantly. The pet population was estimated to produce 4.50×10^8 cfu/day-animal based on these published values. The total bacteria production attributed to pets in the Elk Creek watershed is 6.66×10^{11} cfu/day (2.43×10^{14} cfu/yr). The pet population distribution among the subwatersheds is listed in Table 3.2. Pet waste is generated in the residential land use type. Bacteria loading to streams from pet waste can result from surface runoff transporting bacteria from residential areas.

Table 3.2. Estimated human population, number of sewered houses, number of unsewered houses by age category, number of failing septic systems, number of straight pipes, and pet population in the Elk Creek watershed.

Sub-shed	Human Population	Unsewered Houses in Each Age Category			Failing Septic System	Straight Pipes	Pet Population[a]
		Pre-1967	1967-1987	Post-1987			
ELC-01	114	67	12	6	11	2	85
ELC-02	164	61	13	16	10	2	90
ELC-03	26	16	3	1	2	2	19
ELC-04	87	52	9	4	8	7	65
ELC-05	31	19	3	1	3	2	23
ELC-06	100	59	10	4	9	5	74
ELC-07	142	75	15	7	11	8	97
ELC-08	153	77	17	10	11	12	104
ELC-09	138	57	17	9	10	4	82
ECL-10	286	59	71	25	15	2	155
ELC-11	248	94	32	20	16	10	146
ELC-12	212	78	28	18	13	8	125
ELC-13	299	38	88	29	11	16	156
ELC-14	100	2	37	10	3	2	48
ELC-15	269	37	78	26	11	12	141
ELC-16	117	42	16	11	7	3	69
Total	**2,486**	**833**	**449**	**197**	**151**	**97**	**1,479**

[a]Calculated from average of 1.0 pet per household.

3.4 Domesticated Animal Sources

In the Elk Creek watershed, bacteria from domesticated animal waste can be directly excreted to the stream, or it can be transported to the stream by surface runoff from animals depositing waste on pastures or from applying collected waste on crop and hay land. Domesticated animal populations in the Elk Creek watershed were estimated based on Virginia Agriculture Statistics Service (VASS) data and communication with staff from SWCD, NRCS, VADCR, VCE, watershed residents, and local producers.

3.4.1 Cattle

Based on information obtained from VADCR and SWCD, there are four dairy farms presently operating in the Elk Creek watershed. Based on information provided, it was determined that there were 350 milk cows, 175 dry cows, and 175 heifers distributed between the farms. The dairy cattle population was distributed among the sub-watersheds based on the location of the dairy farm (Table 3.3). Beef cattle in the Elk Creek watershed (4,000 pairs) included cow/calf and feeder operations (Table 3.3).

Table 3.3. Distribution of dairy cattle, dairy operations, and beef cattle among subwatersheds in Elk Creek watersheds.

Subwatershed	Dairy Cattle[a]	No. of Dairy Operations	Beef Cattle (pairs)
ELC-01	0	0	388
ELC-02	0	0	222
ELC-03	0	0	92
ELC-04	0	0	224
ELC-05	0	0	95
ELC-06	120	1	420
ELC-07	0	0	402
ELC-08	120	1	390
ELC-09	0	0	156
ECL-10	460	2	309
ELC-11	0	0	302
ELC-12	0	0	185
ELC-13	0	0	265
ELC-14	0	0	128
ELC-15	0	0	322
ELC-16	0	0	100
Total	**700**	**4**	**4,000**

[a]Consists of the milking herd, dry cows, and heifers.

Cattle spend varying amounts of time in confinement, loafing lots, streams, and pasture depending on the time of year and type of cattle (i.e., milk cow versus heifer). Accordingly, the proportion of bacteria deposited in any given land area varies throughout the year. Based on discussions with SWCDs, NRCS, VADCR, VCE, and local producers, the following assumptions and procedures were used to estimate the distribution of cattle (and thus their manure) among different land use types and in the stream:

- Cows are confined according to the schedule given in Table 3.4.
- When cattle are not confined, they spend their time on pasture and in loafing lots, where applicable.
- Pasture 1 (improved pasture/hay land) stocks twice as many cows per unit area as pasture 2 (unimproved pasture/grazed woodlands), which stocks twice as many cows per unit area as pasture 3 (overgrazed pasture).
- Cows on pastures that are contiguous to streams have stream access.
- Cows with stream access spend varying amounts of time in the stream during different seasons (Table 3.4). Cows spend more time in the stream during the three summer months to protect their hooves from hornflies, among other things.
- Thirty percent of cows in and around streams directly deposit fecal coliform into the stream. The remaining 70% of the manure is deposited on pastures.

Table 3.4. Time spent by cattle in confinement and in the stream in Elk Creek watershed.

Month	Time Spent in Confinement (%)		Time Spent in Stream (hours/day)*
	Milking	Dry Cows, Heifers, and Beef Cattle	
January	75	40	0.50
February	75	40	0.50
March	40	0	0.75
April	30	0	1.00
May	30	0	1.50
June	30	0	3.50
July	30	0	3.50
August	30	0	3.50
September	30	0	1.50
October	30	0	1.00
November	40	0	0.75
December	75	40	0.50

* Time spent in and around the stream by cows that have stream access.

The time cattle spend each month in various land uses or a given stream reach was estimated based on typical agricultural practice, and adjusted to reflect feedback from TAC members and agricultural producers. Using these data describing where cattle spend their time, the cattle and their resulting bacteria loads were distributed among the land uses for modeling purposes. The resulting numbers of cattle in each land use type as well as in the stream for all subwatersheds are given in Table 3.5 for dairy cattle and in Table 3.6 for beef cattle. Table 3.6 reflects animal unit (i.e., 1,000 lb) per beef cow-calf pair variation throughout year.

Table 3.5. Distribution of the dairy cattle[a] population in the Elk Creek watershed.

Month	Confined	Pasture 1	Pasture 2	Pasture 3	Stream[b]
January	262.50	66.62	16.68	4.17	0.03
February	262.50	66.62	16.68	4.17	0.03
March	140.00	159.86	40.03	10.01	0.10
April	105.00	186.47	46.70	11.67	0.15
May	105.00	186.41	46.69	11.67	0.23
June	105.00	186.18	46.63	11.66	0.54
July	105.00	186.18	46.63	11.66	0.54
August	105.00	186.18	46.63	11.66	0.54
September	105.00	186.41	46.69	11.67	0.23
October	105.00	186.47	46.70	11.67	0.15
November	140.00	159.86	40.03	10.01	0.10
December	262.50	66.62	16.68	4.17	0.03

[a]Includes milk cows, dry cows, and heifers.
[b]Number of dairy cattle defecating in stream.

Table 3.6. Distribution of the beef cattle population (pairs) in the Elk Creek watershed.

Month	Confined	Pasture 1	Pasture 2	Pasture 3	Stream*
January	1840.00	2101.32	526.25	131.56	0.86
February	2160.00	2466.77	617.77	154.44	1.01
March	0.00	4232.44	1059.96	264.99	2.61
April	0.00	4353.56	1090.30	272.57	3.58
May	0.00	4473.93	1120.44	280.11	5.51
June	0.00	4589.92	1149.49	287.37	13.21
July	0.00	4711.51	1179.94	294.99	13.56
August	0.00	4833.10	1210.39	302.60	13.91
September	0.00	4960.89	1242.40	310.60	6.11
October	0.00	3044.44	762.44	190.61	2.50
November	0.00	3197.17	800.69	200.17	1.97
December	1760.00	2009.96	503.37	125.84	0.83

*Number of beef cattle defecating in stream.

3.4.1.1 Direct Manure Deposition in Streams

Direct manure loading to streams is due to both dairy (Table 3.5) and beef cattle (Table 3.6) defecating in the stream. However, only cattle on pastures contiguous to streams which have not been fenced off have stream access. Manure loading increases during the warmer months when cattle spend more time in water, compared to the cooler months. Average annual manure loading directly deposited by cattle in the stream for the Elk Creek watershed is 139,124 lbs. Fecal coliform loading due to cows defecating in the stream, averaged over the year, is 1.93×10^{11} cfu/day (7.05×10^{13} cfu/year). Part of the fecal coliform deposited in the stream stays in the dissolved form while the remainder adsorbs to the sediment in the streambed. Under base flow conditions, it is likely that dissolved fecal coliform bacteria are the primary form transported with the flow. Sediment-bound bacteria are likely to be re-suspended and transported to the watershed outlet under high flow conditions. For this TMDL, the dissolved form of bacteria was modeled and re-suspension of sediment-bound bacteria was accounted for through calibration (see Chapter 4). Die-off of fecal coliform in the stream results from sunlight, predation, turbidity, and other environmental factors.

3.4.1.2 Direct Manure Deposition on Pastures

Dairy (Table 3.5) and beef (Table 3.6) cattle that graze on pastures, but do not deposit in streams, contribute the majority of fecal coliform loading on pastures. Manure loading on pasture was estimated by multiplying the total number of each type of cattle (milk cow, dry cow, heifer, and beef) on pasture by the amount of manure it produced per day. The total amount of manure produced by all types of cattle was divided by the pasture acreage to obtain manure loading (lb/ac-day) on pasture. Fecal coliform loading (cfu/ac-day) on pasture was calculated by multiplying the manure loading (lb/ac-day) by the fecal coliform content (cfu/lb) of the manure. Since the confinement and calving schedule of the cattle changes throughout the year, manure and fecal coliform loading on pasture also change with season.

In the Elk Creek watershed, pasture 1, pasture 2, and pasture 3 have average annual cattle manure loadings of 9,005; 4,541; and 2,194 lb/ac-year; respectively. The loadings vary because the stocking rate varies with pasture type, with improved pasture able to stock the most cattle. Fecal coliform loadings from cattle in Elk Creek, averaged over the year, are 5.60×10^{12}, 2.99×10^{12}, and 1.12×10^{12} cfu/ac-year for pastures 1, 2, and 3; respectively. Fecal coliform bacteria deposited on the pasture surface are subject to die-off due to desiccation and ultraviolet (UV) radiation. Runoff can transport part of the remaining fecal coliform to receiving waters.

3.4.1.3 Land Application of Liquid Dairy Manure

A typical milk cow weighs 1,400 pounds and produces 17 gallons of liquid manure daily (ASAE, 1998). Based on the monthly confinement schedule and the number of milk cows, annual liquid dairy manure production in the Elk Creek watershed is 929,911 gallons. Based on per capita fecal coliform production of milk cows, the fecal coliform concentration in fresh liquid dairy manure is 3.88×10^7 cfu/gal. Liquid dairy manure receives priority over other manure types (poultry litter and solid cattle manure) in application to land. Liquid dairy manure application rates are 6,600 and 3,900 gal/ac-year to cropland and pasture land use categories (BSE, 2003), respectively, with cropland receiving priority in application. Based on availability of land and liquid dairy manure, as well as the assumptions regarding application rates and priority of application, it was estimated that liquid dairy manure was applied to 66.0 acres of cropland and 126.8 acres of pasture 1 in the Elk Creek watershed.

The typical crop rotation in the watershed is a seven-year rotation with three years of corn-rye and four years of rotational hay (BSE, 2003). It was assumed that 50% of the corn acreage was under no-till cultivation. Liquid manure is applied to cropland during February through May (prior to planting) and in October-November (after the crops are harvested). For spring application to cropland, liquid manure is applied on the soil surface to rotational hay and no-till corn and is incorporated into the soil for corn in conventional tillage. In fall, liquid manure is incorporated into the soil for cropland under rye and surface-applied to cropland under rotational hay. It was assumed that only 10% of the subsurface-applied fecal coliform was available for removal in surface runoff based on local knowledge. The application schedule of liquid manure (BSE, 2003) is given in Table 3.7. Dry cows and heifers were assumed to produce only solid manure.

Table 3.7. Schedule of cattle waste application in Elk Creek watershed.

Month	Liquid Manure Applied (%)*	Solid Manure and Poultry Litter Applied (%)*
January	0	0
February	5	5
March	25	25
April	20	20
May	5	5
June	10	5
July	0	5
August	5	5
September	15	10
October	5	10
November	10	10
December	0	0

* As percent of annual production.

3.4.1.4 Land Application of Solid Manure

Solid manure produced by dry cows, heifers, and beef cattle during confinement is collected for land application. It was assumed that milk cows produce only liquid manure while in confinement. The number of cattle, their typical weights, amounts of solid manure produced, and fecal coliform concentration in fresh manure are given in Table 3.8.

Solid manure is last on the priority list for application to land (it falls behind liquid manure and poultry litter). The amount of solid manure produced in each sub-watershed was estimated based on the populations of dry cows, heifers, and beef cattle in the sub-watershed and their confinement schedules. Solid manure from dry cows, heifers, and beef cattle exhibits different fecal coliform concentrations (cfu/lb) (Table 3.8). Hence, a weighted average fecal coliform concentration in solid manure was calculated based on the relative manure contribution from dry cows, heifers, and beef cattle (Table 3.8). Solid manure is applied at the rate of12 tons/ac-year to both cropland and pasture, with priority given to cropland. As in the case of liquid manure, solid manure is only applied to cropland during February through May and the months of October and November.

Solid manure can be applied to pasture during the whole year except during December and January. The method of application of solid manure to cropland or pasture is assumed to be identical to the method of application of liquid dairy manure. The application schedule for solid manure is given in Table 3.7. Based on availability of land and solid manure, as well as the assumptions regarding application rate, it was estimated that solid manure was applied to 178.7 acres of cropland and 293.8 acres of pasture 1 in the Elk Creek watershed.

Table 3.8. Estimated population of dry cows, heifers, and beef cattle, typical weights, per capita solid manure production, fecal coliform concentration in fresh solid manure in individual cattle type, and weighted average fecal coliform concentration in fresh solid manure in Elk Creek watershed.

Type of Cattle	Population	Typical Weight (lb) [a]	Solid Manure Produced (lb/animal-day) [a]	Fecal Coliform Concentration in Fresh Manure ($x10^8$ cfu/lb) [a]	Weighted Average Fecal Coliform Concentration in Fresh Manure ($x10^8$ cfu/lb)
Dry Cow	175	1,400	115	2.17	5.16
Heifer	175	640	40.7	2.17	
Beef (pairs)	4,000	1,000	60	5.5	

[a]Source: BSE (2003)

3.4.2 Poultry

Based on confined animal feeding operations information obtained from VADCR, no poultry facilities are presently operating in the Elk Creek watershed. Based on feedback from the TAC, particulary the New River SWCD, bacteria load from approximately 3,000 poultry was estimated for the Elk Creek watershed. The poultry population was distributed among the sub-watersheds based on the proportion of beef cattle (Table 3.9).

Table 3.9. Distribution of poultry popualtion among subwatersheds in Elk Creek watersheds.

Subwatershed	Poultry Population (#)
ELC-01	291
ELC-02	167
ELC-03	69
ELC-04	168
ELC-05	71
ELC-06	315
ELC-07	302
ELC-08	292
ELC-09	117
ECL-10	231
ELC-11	226
ELC-12	139
ELC-13	199
ELC-14	96
ELC-15	242
ELC-16	75
TOTAL	**3,000**

3.4.2.1 Land Application of Poultry Litter

Poultry litter produced by chickens and turkeys during confinement is collected for land application. The main considerations for the poultry operations are the total number of birds

produced in a given cycle, the number of cycles per year, and the amount of time between cycles during which the poultry house is empty. Based on these factors, the amount of poultry litter produced in each watershed was estimated along with the bacteria content of the litter. Poultry litter is applied at an average rate of 6,000 lb/ac-year to both cropland and pasture, with priority given to cropland. As in the case of liquid and solid manure, poultry litter is only applied to cropland during February through May and the months of October and November.

Poultry litter can be applied to pasture during the whole year except during December and January. The application schedule for poultry litter is given in Table 3.7. Based on availability of land and poultry litter, as well as the assumptions regarding application rate, it was estimated that 6.2 acres of cropland and 2.3 acres of pasture 1 in the Elk Creek watershed received poultry litter application.

3.4.3 Horses

The estimated number of horses in the Elk Creek watershed is included in Table 3.10. The horse population in the watershed has risen in the last several years. Horse populations were estimated using data from the 2001 Virginia Equine Report produced by VASS (VASS, 2002). The number of horses within the watershed was estimated by distributing the equine population evenly throughout all pasture in each county and determining the number of horses in the watershed based on pasture area in the watershed. The same method was used to determine the equine population in each subwatershed. The estimates were adjusted based on feedback from the TAC.

The typical horse produces 4.2×10^{8} cfu/day (VADCR, 2003). Therefore, the daily fecal coliform production by horses in the Elk Creek watershed is 1.97×10^{11} cfu/day (7.19×10^{13} cfu/year).

Table 3.10. Horse, goat, and sheep population by subwatershed in the Elk Creek watershed.

Subwatershed	Horses	Goats	Ewes
ELC-01	46	73	143
ELC-02	26	41	83
ELC-03	11	18	33
ELC-04	26	41	83
ELC-05	11	18	33
ELC-06	49	78	154
ELC-07	47	73	149
ELC-08	46	73	143
ELC-09	18	28	61
ECL-10	36	55	116
ELC-11	35	55	110
ELC-12	22	32	66
ELC-13	31	5	8
ELC-14	15	3	4
ELC-15	38	5	10
ELC-16	12	2	4
Total	**469**	**600**	**1,200**

3.4.4 Other Livestock Sources

Based on county sheep population data obtained from VASS and input from SWCD, the sheep population was distributed to individual subwatersheds (Table 3.10). Based on information provided, it was determined that there were 1,200 ewes throughout the Elk Creek watershed. An estimated population of 600 goats in the Elk Creek watershed was based on feedback from the TAC (Table 3.10). Other minor livestock-related sources of bacteria were present during watershed visits; however, a significant population was not identified within the Elk Creek watershed. The potential bacteria load from these sources was accounted for during water quality calibration

3.5 Wildlife

Fecal coliform production rates for wildlife species considered in this study are listed in Table 3.13. The total wildlife fecal coliform production each year in the Elk Creek watershed is 6.06×10^{14}cfu/yr.

Wildlife fecal coliform contributions can be from excretion of waste on land and from excretion directly into streams. Information provided by VADGIF, USF&WS, and watershed residents was used to estimate wildlife populations. Wildlife species that were found in quantifiable numbers in the watershed included deer, raccoon, muskrat, beaver, wild turkey, goose, and wood duck. Preferred habitat, habitat area, and population density were determined for each species (Table 3.11).

Professional judgment was used in estimating the percent of each wildlife species defecating directly into streams based upon their habitat (Table 3.11). Fecal matter produced by

deer that is not directly deposited in streams is distributed among pastures and forest. Raccoons deposit their waste in streams and forests. Muskrats deposit their waste in streams and pastures.

Fecal loading from wildlife was estimated for each sub-watershed. The wildlife populations were distributed among sub-watersheds based on habitat descriptions included in Table 3.11, and further details of the wildlife habitat were used to distribute the populations among the sub-watersheds. For example, the deer population was evenly distributed across the watershed, whereas the 66 feet buffer around streams and impoundments determined the muskrat population. Therefore, a sub-watershed with more stream length and impoundments would have more muskrats than a sub-watershed with shorter stream length and fewer impoundments. Distribution of wildlife among sub-watersheds is given in Table 3.12.

Table 3.11. Wildlife habitat description, population density, and percent direct fecal deposition in streams in the Elk Creek watershed.

Wildlife Type	Habitat	Population Density (animal/ac-habitat)	Direct Fecal Deposition in Streams (%)
Deer	Primary: Forest and agricultural areas Secondary: rest of watershed	0.052	0.10
Raccoon	Primary: 600 feet buffer around streams and impoundments Secondary: 601 feet -7,920 feet buffer from streams and impoundments	0.070	0.10
Muskrat	Primary: 66 feet buffer around streams and impoundments in forest and cropland Secondary: 67-300 feet buffer from same	0.037[a]	0.25
Beaver	300 feet buffer around streams and impoundments in forest and pasture	0.015	0.50
Geese	300 feet buffer around main streams	0.003[b]	0.25
Wood Duck	300 feet buffer around main streams	0.004[b]	0.25
Wild Turkey	Entire watershed except urban areas	0.013[c]	0.00

[a] Muskrats per mile of stream through agricultural land.
[b] Animals per acres of all land uses.
[c] Animals per acres of forest.

Table 3.12. Distribution of wildlife among sub-watersheds in Elk Creek watershed.

Subwatershed	Deer (#)	Raccoon (#)	Muskrat (#)	Beaver (#)	Geese (#)	Wood Duck (#)	Wild Turkey (#)
ELC-01	209	129	367	13	13	16	29
ELC-02	173	110	215	12	11	13	30
ELC-03	47	43	103	5	3	4	6
ELC-04	157	121	249	13	10	12	26
ELC-05	55	45	110	5	4	4	8
ELC-06	179	117	412	12	12	14	19
ELC-07	195	160	458	17	13	16	24
ELC-08	213	164	571	17	14	17	30
ELC-09	122	114	279	13	8	9	21
ECL-10	245	186	466	19	16	19	44
ELC-11	216	188	478	20	14	17	36
ELC-12	183	122	213	13	12	14	35
ELC-13	246	184	386	19	16	19	46
ELC-14	80	67	184	7	5	6	12
ELC-15	222	157	431	16	14	17	36
ELC-16	101	81	86	9	7	8	19
Total	**2,643**	**1,988**	**5,008**	**210**	**172**	**205**	**421**

3.6 Summary: Contribution from All Sources

A synopsis of the fecal coliform loads characterized and accounted for in the Elk Creek watershed along with average fecal coliform production rates are shown in Table 3.13. The total fecal coliform production by all sources in the Elk Creek watershed is 8.89×10^{16} cfu/yr.

Table 3.13. Potential fecal coliform sources and daily fecal coliform production by source in Elk Creek watershed.

Potential Source	Population in Watershed	Fecal Coliform Produced ($\times 10^6$ cfu/AU-day)[a]	Fecal Coliform Produced ($\times 10^7$ cfu/ day)[b]
Dairy Cattle			
Milk and Dry Cows	575	25,000	1,313,399
Heifers	175	8,800	200,137
Beef Cattle (pairs)	4,000	33,000	17,846,671
Horses	469	420	19,711
Poultry	3,000	93	26,718
Sheep	1,200		
Humans	2,468	1,950	161,274
Pets (Dog & Cats)	1,479	450	66,601
Deer	2,643	350	92,568
Raccoon	1,988	50	9,947
Muskrat	5,008	25	12,529
Beaver	210	0.2	4
Wild Turkey	421	93	3,918
Geese	172	800	10,301
Wood Duck	205	2,400	36,833

[a]Source: Keeling (2003) - Production per animal unit per species.
[b]Fecal coliform production adjusted to account for local animal weight. This may not equal the product of the other two columns.

Based on the inventory of fecal coliform sources, a summary of the contributions made by the nonpoint sources to annual fecal coliform loading directly to the stream and to various land use categories is given in Table 3.14. Distribution of annual fecal coliform loading from nonpoint sources among the different land use categories is also given in Table 3.14.

From Table 3.14, it is clear in the Elk Creek watershed that nonpoint source loadings to the land surface are more than 327 times as large as direct loadings to the streams, with pastures receiving about 98.2% of the total fecal coliform load. It could be prematurely assumed that most of the fecal coliform loading in streams originates from upland sources, primarily from pastures. However, other factors such as precipitation (amount and pattern), manure application activities (time and method), type of waste (solid versus liquid manure), proximity to streams and environmental factors also impact the amount of fecal coliform from upland areas that reaches the stream. The HSPF model considers these factors when estimating fecal coliform loads to the receiving waters, as described in Chapter 4.

Table 3.14. Annual fecal coliform loadings to the stream and the various land use categories in the Elk Creek watershed.

Source	Fecal Coliform Loading ($x10^{10}$ cfu/year)	Percent of Total Loading (%)
Direct Loading to Streams		
Straight Pipes	11,771	0.14
Cattle in Stream	7,047	0.09
Wildlife in Stream	6,160	0.08
Loading to Land Surfaces		
Cropland	14,139	0.17
Pasture 1	6,113,387	74.60
Pasture 2	1,628,939	19.88
Pasture 3	304,172	3.71
Forest	37,882	0.46
Residential*	71,404	0.87
Total	**8,194,901**	**100.00**

*Includes loads received from failed septic systems and pets.

Chapter 4. Modeling Process for Bacteria TMDL Development

A key component in developing a TMDL is establishing the relationship between pollutant loadings (both point and nonpoint) and in-stream water quality conditions. Once this relationship has been developed, management options for reducing pollutant loadings to streams can be assessed. In developing a TMDL, it is critical to understand the processes that affect the fate and transport of the pollutants and cause the impairment of the water body of concern. Pollutant transport to water bodies is evaluated using a variety of tools, including monitoring, geographic information systems (GIS), and computer simulation models. In this chapter, modeling process, input data requirements, model calibration procedure and results, and model validation results for the bacteria TMDL are discussed.

4.1 Model Description

Conducting a TMDL study requires the use of a watershed-based model that integrates both point and nonpoint sources and simulates in-stream water quality processes. The Hydrologic Simulation Program – Fortran (HSPF) (Bicknell et al., 2000) was used to model fecal coliform transport and fate in the Elk Creek watershed. The ARCGIS 9.2 program was used to display and analyze landscape information.

The HSPF model simulates nonpoint source runoff and pollutant loadings, performs flow routing through streams, and simulates in-stream water quality processes (Bicknell et al., 2000). HSPF estimates runoff from both pervious and impervious parts of the watershed and stream flow in the channel network. The sub-module PWATER within the module PERLND simulates runoff, and hence, estimates the water budget on pervious areas (e.g., agricultural land). Runoff from largely impervious areas is modeled using the IWATER sub-module within the IMPLND module. The simulation of flow through the stream network is performed using the sub-modules HYDR and ADCALC within the module RCHRES. While HYDR routes the water through the stream network, ADCALC calculates variables used for simulating convective transport of the pollutant in the stream. Fate of fecal coliform on pervious and impervious land segments is simulated using the PQUAL (PERLND module) and IQUAL (IMPLND module) sub-modules, respectively. Fate of fecal coliform in stream water is simulated using the GQUAL sub-module within RCHRES module. Fecal coliform bacteria are simulated as a dissolved pollutant using the general constituent pollutant model (GQUAL) in HSPF.

The HSPF model requires a wide variety of input data to describe hydrology, water quality, and land use characteristics of the watershed. The different types and sources of input data used to develop the model for the Elk Creek watershed is discussed below in Sections 4.2 through 4.6. This information is translated into model parameters. Hydrology parameters required for the PWATER, IWATER, HYDR, and ADCALC sub-modules are listed in BASINS Version 3.0 User's Manual 3.0 (USEPA, 2001). Water quality parameters required as inputs for PQUAL, IQUAL, and GQUAL are given in the BASINS Version 3.0 User's Manual (USEPA, 2001). Values for the hydrology and water quality parameters were estimated based on local conditions when possible; otherwise the default parameters provided within HSPF were used.

4.2 Selection of Sub-watersheds

The stream network was delineated based on the blue line stream network from USGS topographic maps with each subwatershed having at least one stream segment. Subwatershed delineation of the Elk Creek TMDL impairment watershed was based on potential fecal loadings, flow and water quality data availability, and HSPF model constraints. Because loadings of fecal coliform are believed to be associated with land use activities, subwatersheds were chosen based on uniformity of land use. HSPF outputs flow and fecal coliform concentration at subwatershed outlets; therefore, subwatershed outlets were chosen to correspond to flow and water quality station locations. An hourly model time-step was used requiring the time of concentration in each subwatershed to be greater than one hour.

The Elk Creek watershed is approximately 53,718 acres and the model framework selected is suitable for this size. To account for the spatial distribution of fecal coliform sources, the watershed was divided into 16 subwatersheds as shown in Figure 4.1. Elk Creek watershed begins at subwatershed ELC-01, at the headwaters of Middle Branch Elk Creek. South Branch Elk Creek (ELC-02) and Comer's Rock Branch (ELC-04) flow into Elk Creek at ELC-03 which flows into ELC-05 where the impairment begins and continues to flow through ELC-06 and ELC-07 where it confluences with Stone Creek (ELC-08). Elk Creek flows downstream through ELC-09 and ELC-11 where it confluences with Turkey Fork (ELC-10). It continues through ELC-12 where it confluences with Knob Fork (ELC-13, ELC-14, and ELC-15) and then downstream to ELC-16 where the impairment ends and Elk Creek continues to flow downstream to confluence with the New River.

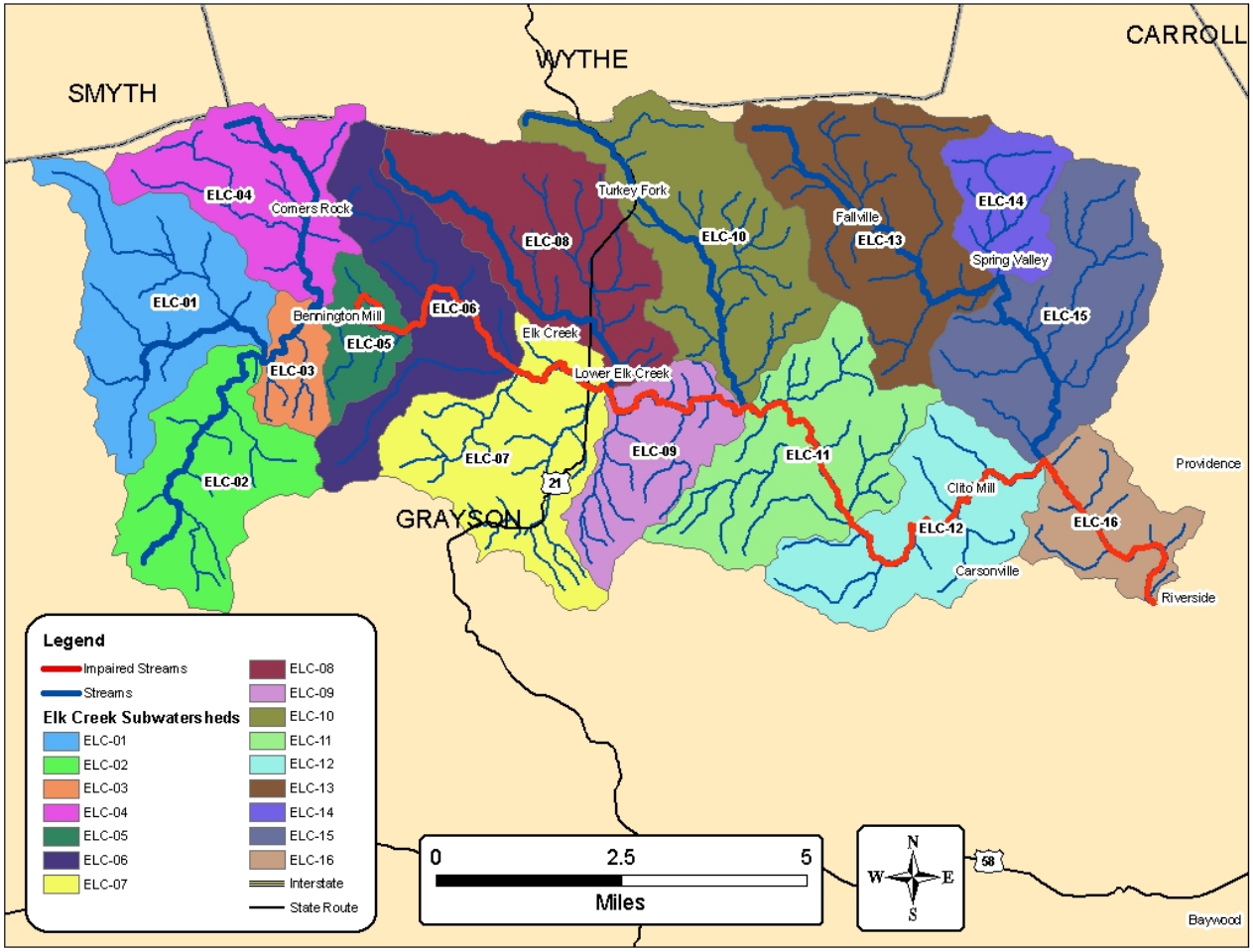

Figure 4.1. Elk Creek impairment subwatersheds.

4.3 Land Use

The National Land Cover Data (NLCD) produced by U.S. Geological Survey (USGS) in cooperation with the USEPA was used for this study. NLCD was developed from 30-meter Landsat 7 thematic mapper (TM) data between 1990 and 1994 and updated with data between 1999 and 2003 acquired by the Multi-resolution Land Characterization (MRLC) Consortium, a partnership between USGS, USEPA, U.S. Forest Service, National Oceanic and Atmospheric Administration (NOAA), Bureau of Land Management (BLM), NRCS, National Park Service (NPS), National Aeronautics and Space Administration (NASA), and United States Fish and Wildlife Service (USFWS). NLCD is classified into 21 land use types. The NLCD land use types within the watershed were consolidated into eight categories based on similarities in hydrologic and waste application/production features (Table 4.1). The land use categories were assigned pervious/impervious percentages, which allowed a land use with both pervious and impervious fractions to be modeled using both the PERLND and IMPLND modules. Some hydrology and water quality model parameters used in the PERLND and IMPLND modules are a function of land use.

As discussed in Section 4.2, subwatersheds were defined to spatially analyze waste or fecal coliform distribution within the watershed (Figure 4.1). Land use distribution in the subwatersheds as well as in the entire Elk Creek watershed is presented in Table 4.2.

Figure 4.1. Consolidation of NLCD land use categories for Elk Creek watershed.

TMDL Land Use Categories	Pervious / Impervious* (%)	NLCD Land Use Classification (Class No.)
Cropland	Pervious (100)	Cultivated Crops (82)
Pasture 1	Pervious (100)	Pasture/Hay (81)
Pasture 2	Pervious (100)	Pasture/Hay (81)
Pasture 3	Pervious (100)	Pasture/Hay (81)
Residential	Pervious (75), Impervious (25)	Developed, Open Space (21) Developed, Low Intensity (22) Developed, Medium Intensity (23) Developed, High Intensity (24)
Water	Impervious (100)	Open Water (11)
Wetland	Pervious (100)	Woody Wetlands (91) Emergent Herbaceous Wetlands (92)
Forest	Pervious (100)	Barren Land, Rock, Sand, Clay (31) Deciduous Forest (41) Evergreen Forest (42) Mixed Forest (43)

*Percent pervious / impervious information was used in modeling (described in later sections).

Table 4.2. Land use distribution in Elk Creek watershed.

Subwatershed	Cropland (ac)	Forest (ac)	Residential (ac)	Pasture (ac)	Transitional (ac)	Wetland (ac)	Total (ac)
ELC-1	18.4	2,164.9	165.0	1,850.8	14.1	0.0	4,213.3
ELC-2	0.0	2,238.6	120.3	1,059.9	48.9	0.0	3,467.8
ELC-3	5.8	469.5	45.1	435.3	1.6	1.7	959.0
ELC-4	17.5	1,985.0	130.0	1,066.4	13.1	0.0	3,211.9
ELC-5	6.3	615.0	62.4	449.2	2.1	0.0	1,135.0
ELC-6	50.4	1,418.1	148.0	1,999.6	4.1	0.0	3,620.2
ELC-7	36.2	1,791.2	309.2	1,919.0	28.8	0.0	4,084.4
ELC-8	56.0	2,224.6	250.5	1,855.8	13.7	0.0	4,400.6
ELC-9	16.1	1,586.8	70.7	745.4	9.0	1.3	2,429.4
ELC-10	17.7	3,328.4	223.4	1,468.6	20.2	0.0	5,058.4
ELC-11	20.3	2,716.2	153.7	1,433.8	19.0	3.6	4,346.6
ELC-12	0.0	2,637.2	157.8	879.4	36.3	0.0	3,710.6
ELC-13	0.0	3,475.1	186.4	1,263.5	28.0	0.0	4,953.0
ELC-14	1.8	935.2	55.4	607.4	4.2	0.0	1,604.0
ELC-15	4.4	2,710.1	186.5	1,537.7	39.8	1.1	4,479.7
ELC-16	0.0	1,458.7	87.4	475.3	23.0	0.0	2,044.4
Total (ac)	**250.9**	**31,754.6**	**2,351.9**	**19,047.2**	**306.0**	**7.7**	**53,718.3**
Total (%)	**0.47**	**59.11**	**4.38**	**35.46**	**0.57**	**0.01**	**100.00**

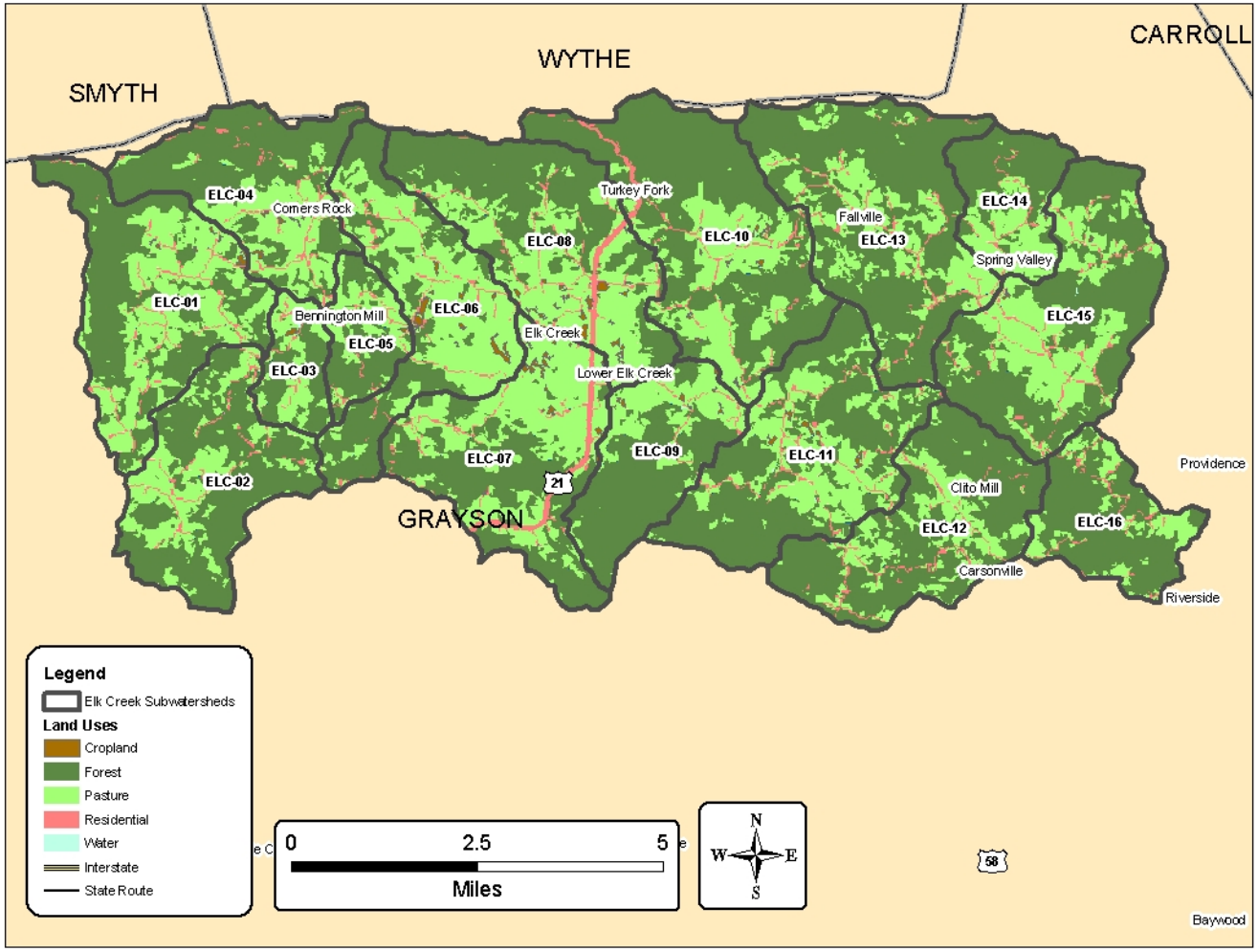

Figure 4.2. Elk Creek watershed land use distribution.

4.4 Stream Channel Characteristics

For each stream reach, a function table (F-Table) is required to describe the relationship between water depth, surface area, volume, and discharge (Bicknell et al., 2000). These parameters were estimated by surveying representative channel cross-sections in each subwatershed. Trapezoidal channel geometry with pitch breaks at the beginning of the flood plain was developed for each reach.

4.5 Climatological Data

The climate data needed for model simulations conducted as a part of this study were obtained from the National Climatic Data Center (NCDC) (NCDC, 2008), part of the National Weather Service (NWS). Simulations performed for Elk Creek watershed used hourly weather data from the Troutdale 3 SSE (448547) and Abingdon 3 S (440021) weather stations. Daily precipitation data from stations Troutdale s SSE (448547), Abingdon 3 S (440021), and Saltville 1 N (447506) were transformed to address discrepancies (i.e., missing data) between observed runoff and hourly precipitation records.

Using hourly precipitation data, frequency of precipitation events and precipitation amounts per hour were calculated. For daily precipitation amounts equal to or less than 0.3 inches, the daily amount was assigned to the hour with the highest likelihood of rainfall. For daily rainfall amounts greater than 0.3 inches, the daily amount was distributed over the day using the calculated hourly precipitation amount frequency distribution.

4.6 Accounting for Pollutant Sources

4.6.1 Overview

There are no permitted point dischargers or MS4 permitted facilities located in the Elk Creek watershed. Fecal coliform loads that are directly deposited into the stream by straight pipes, or by cattle and wildlife in the stream, were treated as direct nonpoint sources in the model. Fecal coliform that is land-applied or deposited on land was treated as nonpoint source loading; all or part of that load may get transported to the stream as a result of surface runoff during rainfall events. Direct nonpoint source loading was applied to the stream in each sub-watershed as appropriate.

Nonpoint source loading was applied as fecal coliform counts to the pervious fraction of each land use category in a sub-watershed on a daily basis. Both direct nonpoint and land-based nonpoint source loadings were varied by month to account for seasonal differences such as cattle and wildlife access to streams. Nonpoint source loading was applied as fecal coliform counts to the impervious fraction of each land use category in a subwatershed at a constant rate during the year. These constant application rates are a function of land use and are discussed in detail in Section 4.6.4. Fecal coliform die-off was simulated during periods when manure is stored, while on the land between runoff generating precipitation events, and while in streams.

4.6.2 Modeling Fecal Coliform Die-off

Fecal coliform die-off was modeled using a first order die-off equation of the form:

$$C_t = C_0 10^{-kt} \qquad [4.1]$$

where: C_t = concentration or load at time t;

C_0 = starting concentration or load (cfu/ 100ml);

K = decay rate (day-1); and

t = time in days.

A review of literature provided estimates of decay rates that could be applied to waste storage and handling in the Elk Creek watershed (Table 4.3).

Table 4.3. First order decay rates for different animal waste storage as affected by storage/application conditions and their sources in the Elk Creek watershed.

Waste Type	Storage / Application	Decay Rate (1/day)	Reference
Dairy Manure	Pile (not covered)	0.066	Jones (1971)*
	Pile (covered)	0.028	
Beef Manure	Anaerobic Lagoon	0.375	Coles (1973)*

*Cited in Crane and Moore (1986).

Based on the values cited in the literature, the following decay rates were used in simulating fecal coliform die-off in stored waste.

- Liquid dairy manure: no decay rate for liquid dairy manure storage could be found in the literature, therefore the decay rate for beef manure in anaerobic lagoons (0.375 / day) was used.
- Solid cattle manure: based on the range of decay rates (0.028-0.066 / day) reported for solid dairy manure, a decay rate of 0.05 / day was used assuming that a majority of manure piles are not covered.

Based on these decay rates, die-off of fecal coliform in different storage capacities at the end of the respective storage period were calculated using Equation [4.1]. Depending on the duration of storage, type of storage, type of manure, and die-off factor, the fraction of fecal coliform surviving in the manure at the end of storage was calculated. While calculating survival fraction at the end of the storage period, the daily addition of manure and coliform die-off of each fresh manure addition was considered to arrive at an effective survival fraction over the entire storage period. By multiplying the survival fraction with total fecal coliform produced per year (in as-excreted manure), the amount of fecal coliform available for application to land per year was estimated. Monthly fecal coliform application to land was estimated by multiplying the amount of fecal coliform available for application to land per year by the fraction of manure applied to land during that month. The decay rate for fecal coliform on the land surface was represented in HSPF by specifying a maximum surface buildup (i.e., MON-SQOLIM) based on the daily loading rate (i.e., MON-ACCUM). An in-stream decay rate for each reach segment (i.e., FSTDEC) was specified in HSPF.

4.6.3 Modeling Direct Nonpoint Sources

Fecal coliform loads from direct nonpoint sources included straight pipes, cattle in streams, and wildlife in streams. Also, contribution of fecal coliform from interflow was modeled as having a constant concentration of 4.0 cfu/100mL. Based on Technical Advisory Committee (TAC) feedback, no instances of groundwater contamination were acknowledged and as a result it was assumed that the groundwater contained no bacteria. Loads from direct nonpoint sources in each watershed are described in detail in Chapter 3.

4.6.4 Modeling Land-based Nonpoint Sources

For modeling purposes, nonpoint fecal coliform loads were those that were deposited or applied to land and, hence, required surface runoff events for transport to streams. Fecal coliform loading by land use for all sources in each sub-watershed is presented in Chapter 3. The existing condition fecal coliform loads are based on best estimates of existing wildlife, livestock, human, and pet populations along with fecal coliform production rates. Fecal coliform in stored waste was adjusted for die-off prior to the time of land application when calculating loadings to cropland and pasture. For a given period of storage, the total amount of fecal coliform present in the stored manure was adjusted for die-off on a daily basis. The sources of fecal coliform to different land use categories and how the model handled them are briefly discussed below.

- Cropland: Where applicable, liquid dairy manure, solid manure, and poultry litter are applied to cropland as described in Chapter 3. Fecal coliform loadings to cropland were adjusted to account for die-off during storage and partial incorporation during land-application. Wildlife contributions were also added to the cropland areas. For modeling, monthly fecal coliform loading assigned to cropland was distributed over as many acres within the subwatershed as were needed to utilize the generated manure. Thus, loading rate varied by month and sub-watershed.

- Pasture: Deposition of manure on pasture resulted from deposition from livestock and wildlife, as well as dairy manure, solid manure, and poultry litter applications as described in Chapter 3. For modeling, the monthly fecal coliform loading assigned to pasture was distributed over the entire pasture acreage within a sub-watershed. Thus, loading rate varied by month and sub-watershed.

- Residential: Fecal coliform loading on the pervious fraction of this land use category is described in Chapter 3. Residential land use loading came from failing septic systems and waste from pets. In the model simulations, fecal coliform loads produced by failing septic systems and pets in a sub-watershed were combined and assumed to be uniformly applied. Loading to the impervious fraction of this land use category was assumed constant throughout the year varying per subwatershed.

- Forest: Wildlife not defecating in streams or on cropland and pastures provided fecal coliform loading to the forested land use. Fecal coliform from wildlife was applied uniformly over the forest areas, except for the percentage considered as direct load to forested streams.

4.6.5 Modeling Existing BMPs

Data describing existing best management practices (BMPs) were provided by staff from the VADCR to VADEQ. Additional data were collected during windshield surveys in the watershed. These data were applied in multiple fashions when developing the model to represent the effects of BMPs on loads and load transport. BMPs were either accounted for directly in the development of loads associated with direct deposition and/or deposition on specific land uses, accounted for during calibration of the water quality model, or incorporated into the implicit margin of safety (MOS).

BMPs incorporated directly into the model, such as collection, storage, and spreading of confined animal waste were modeled as previously described. Die-off during storage was accounted for prior to spreading, as well as after spreading. Three grades of pasture were modeled to represent pasture management practices observed in the watershed. Reductions in stream access based on exclusion fencing were accounted for directly when developing the cattle distribution schedules listed in Chapter 3. Some BMPs were accounted for during calibration, such as grassed buffer strips between pasture or cropland and stream edges.

Identified BMPs that were not directly accounted for during load development or model calibration were incorporated into the implicit MOS. The MOS accounts for uncertainty in the model and helps ensure that the final TMDL allocation will enable the stream to meet water quality standards when implemented.

4.7 Model Calibration and Validation

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

4.7.1 Hydrology

Observed stream flow values were not available for Elk Creek, therefore a “paired watershed” approach was used for hydrologic calibration and validation. The approach assumes that the paired watershed and Elk Creek watershed have similar hydrologic responses based on physical, geologic, and hydrologic characteristics. The Cripple Creek watershed was chosen as the paired watershed due to similar physiographic and hydrologic characteristics. Hydrology calibration and validation were performed based on the physical, hydrologic, and land use data for the Cripple Creek watershed. After calibration and validation completion, the parameterization for the Cripple Creek model was transferred to the Elk Creek model. Parameters describing watershed characteristics such as land use, slope, infiltration rate, and F-Tables were updated to reflect the physical properties in Elk Creek watershed.

The Cripple Creek model was calibrated using observed flow values from USGS station #03166000 on Cripple Creek near Ivanhoe, VA for the period January 1, 2000 to December 31,

2004. The model was validated for the period January 1, 1995 to December 31, 1999. The daily average flow data were used in the hydrologic calibration and validation. Output from the HSPF model for both calibration and validation was daily average flow in cubic feet per second (cfs). Calibration parameters were adjusted within the recommended ranges until the model performance was deemed acceptable.

The HSPEXP decision support system developed by USGS and tools developed by Engineering Concepts, Inc. were used to calibrate and validate the hydrologic portion of HSPF. Calibration and validation criteria as well as model performance are presented in Tables 4.4 and 4.5. All criteria were within the recommended ranges. As shown in Figures 4.3 and 4.4, the simulated flow for both the calibration and validation matched the observed flow well. The agreement with observed flows is further illustrated in Figures 4.5 and 4.6 for a representative storm. The agreement of the simulated and observed time series can be further seen through the comparison of their cumulative frequency curves (Figures 4.7 and 4.8).

Table 4.4. Summary statistics for the calibration period (1/1/00 to 12/31/04) at USGS station #03166000 in Cripple Creek.

	Criterion (%)	Observed	Modeled	Error (%)
Total Flow Volume(in)	10	76.67	76.87	0.26
Total of Highest 10% Flow Volume (in)	15	25.28	27.37	8.29
Total of Lowest 50% Flow Volume (in)	10	17.01	15.88	-6.66
Total Winter Flow Volume (in)	30	21.94	21.69	-1.14
Total Summer Flow Volume (in)	30	16.11	15.87	-1.45
Total Storm Volume (in)	30	56.64	60.78	7.30
Groundwater Recession Coefficient	1	0.97	0.98	1.00
Coefficient of Determination, r^2	0.81			

Table 4.5. Summary statistics for the validation period (1/1/95 to 12/31/99) at USGS station #03166000 in Cripple Creek.

	Criterion (%)	Observed	Modeled	Error (%)
Total Flow Volume(in)	10	69.54	68.98	-0.79
Total of Highest 10% Flow Volume (in)	15	23.10	23.09	-0.05
Total of Lowest 50% Flow Volume (in)	10	14.80	13.35	-9.81
Total Winter Flow Volume (in)	30	29.49	30.63	3.87
Total Summer Flow Volume (in)	30	8.34	7.15	-14.24
Total Storm Volume (in)	30	50.01	54.37	8.72
Groundwater Recession Coefficient	1	0.97	0.98	1.00
Coefficient of Determination, r^2	0.84			

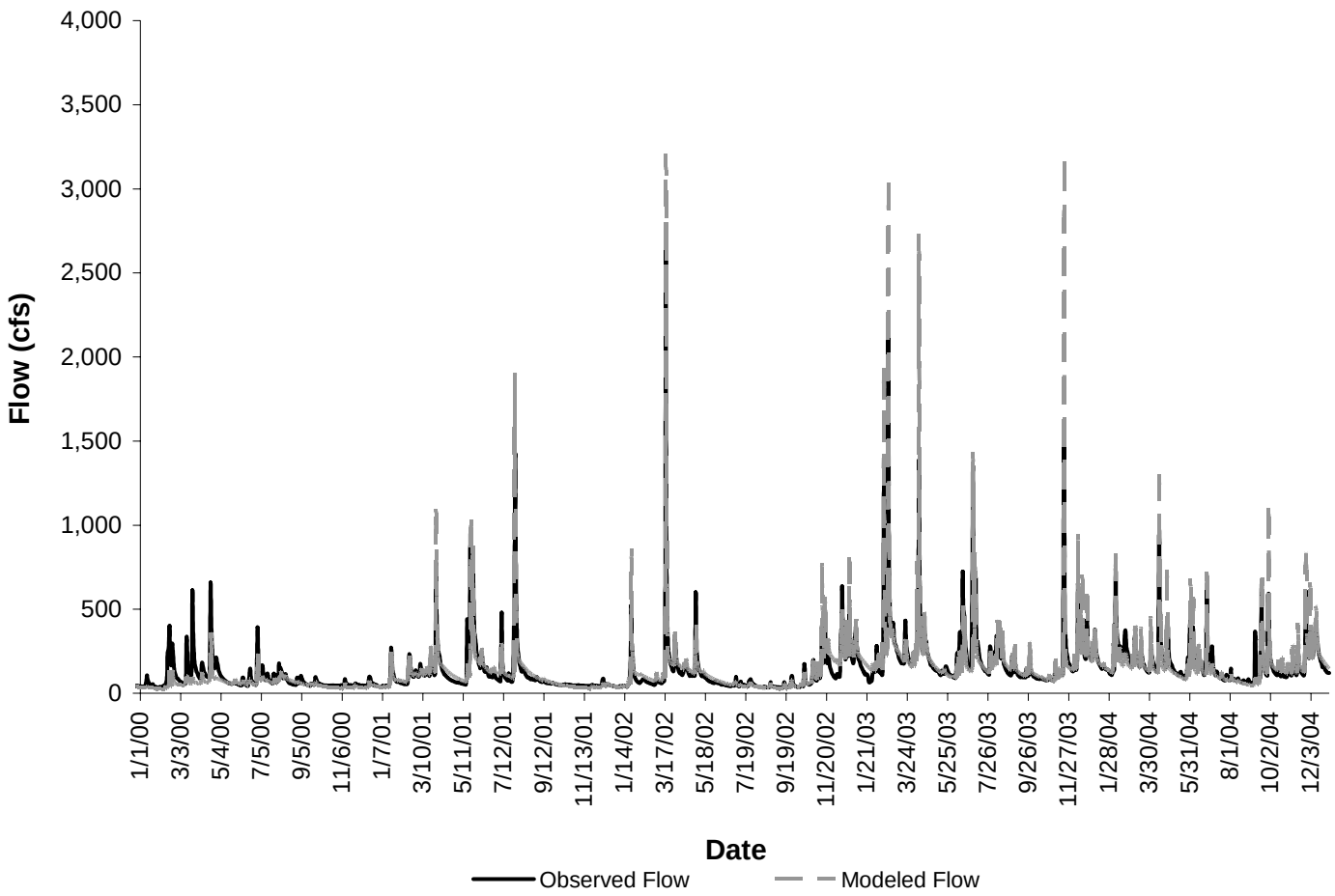

Figure 4.3. Observed and modeled flows for the calibration period 1/1/00 to 12/31/04 at USGS station #03166000 in Cripple Creek.

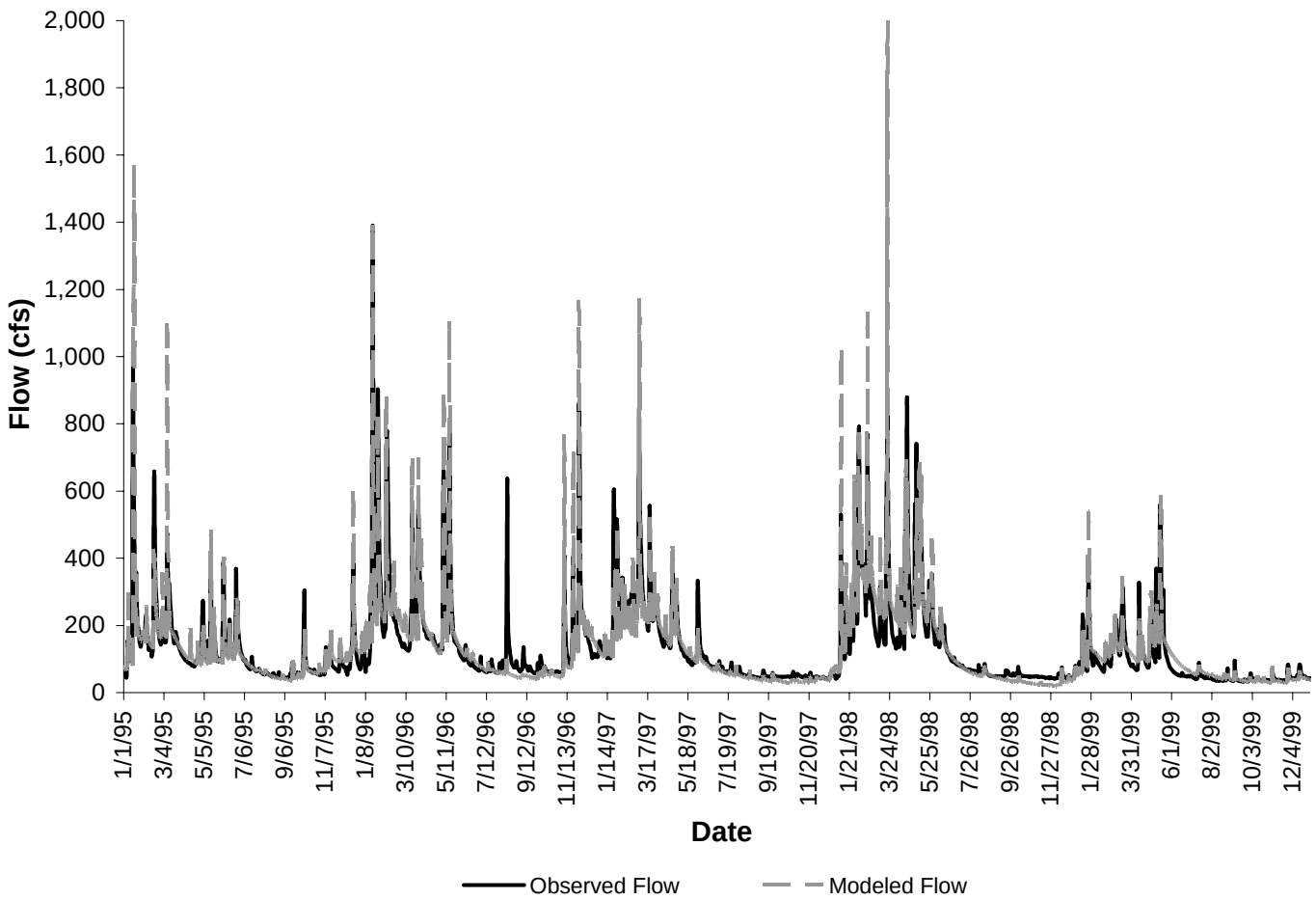

Figure 4.4. Observed and modeled flows for the validation period 1/1/95 to 12/31/99 at USGS station #03166000 in Cripple Creek.

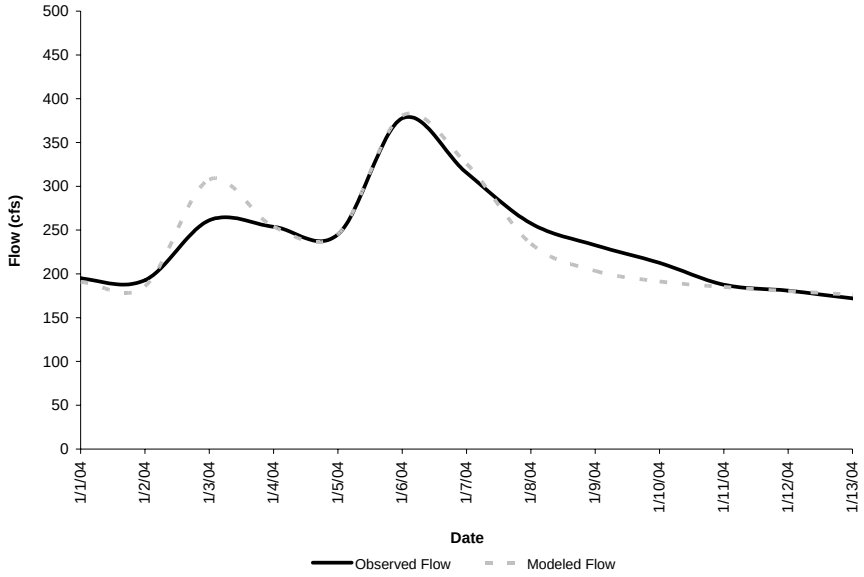

Figure 4.5. Observed and modeled flows for representative storm (1/1/04-1/131/04) during the calibration period at USGS station #03166000 in Cripple Creek.

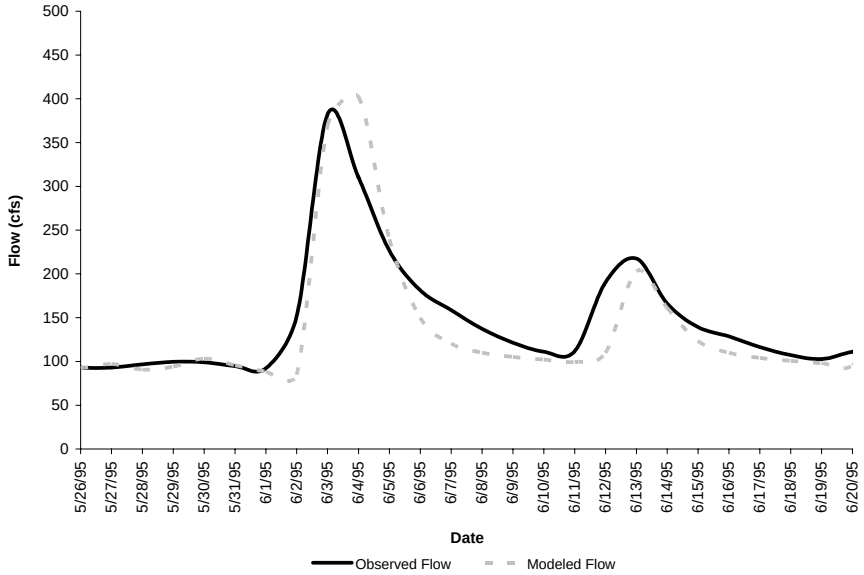

Figure 4.6. Observed and modeled flows for a representative storm (5/26/95-6/20/95) during the validation period at USGS station #03166000 in Cripple Creek.

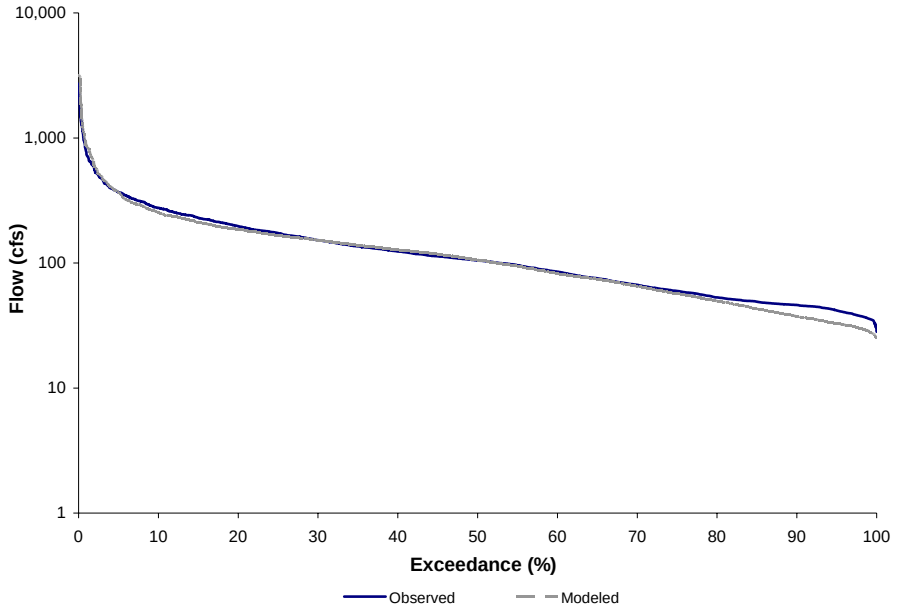

Figure 4.7. Cumulative frequency curves for the calibration period 1/1/00 to 12/31/04 at USGS station #03166000 in Cripple Creek.

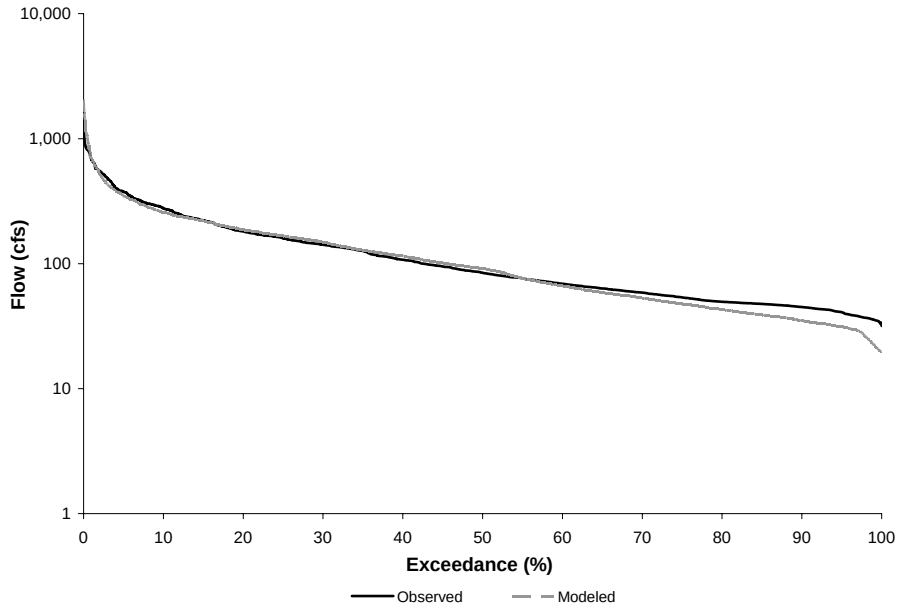

Figure 4.8. Cumulative frequency curves for the validation period 1/1/95 to 12/31/99 at USGS station #03166000 in Cripple Creek.

Flow partitioning for Cripple Creek hydrologic model calibration and validation is shown in Table 4.6.

Table 4.6. Flow partitioning for the calibration and validation periods in Cripple Creek.

Average Annual Flow	Calibration	Validation
Total Runoff (in)	27.0	24.2
Surface Runoff (in)	3.9 (14.3%)	2.5 (10.4%)
Interflow (in)	4.0 (14.7%)	3.1 (12.8%)
Baseflow (in)	19.2(71.0%)	18.6 (76.8%)

A list of final calibration parameters for the hydrology calibration can be found in Tables 4.7 and 4.8.

Table 4.7. Calibrated hydrology HSPF parameters (PERLND) for Elk Creek watershed.

Parameter	Definition	Units	Range of Values*				Start	Final	Function of…
			Typical		Possible				
			Min	Max	Min	Max			
PERLND									
PWAT-PARM2									
FOREST	Fraction forest cover	none	0.0	0.5	0.0	0.95	0.5	0.5	Forest cover
LZSN	Lower zone nominal soil moisture storage	in	3.0	8.0	2.0	15.0	3.5	6.5	Soil properties
INFILT	Index to infiltration capacity	in/hr	0.01	0.25	0.001	0.5	0.10	0.005-0.087	Soil and cover condition
LSUR	Length of overland flow	ft	200	500	100	700	300	300	Topography
SLSUR	Slope of overland flowplane	none	0.01	0.15	0.001	0.3	0.005-0.167	0.005-0.167	Determined by GIS
KVARY	Groundwater recession variable	1/in	0	3	0	5	0	0	Calibrate
AGWRC	Base groundwater recession	none	0.92	0.99	0.85	0.999	0.975	0.991	Calibrate
PWAT-PARM3									
PETMAX	Temp below which evapotranspiration (ET) is reduced	deg. F	35	45	32	48	40	40	Climate, vegetation
PETMIN	Temp below which ET is set to zero	deg. F	30	35	30	40	35	35	Climate, vegetation
INFEXP	Exponent in infiltration equation	none	2	2	1	3	2	2	Soil properties
INFILD	Ratio of max/mean infiltration capacities	none	2	2	1	3	2	2	Soil properties
DEEPFR	Fraction of groundwater inflow to deep recharge	none	0.0	0.2	0.0	0.5	0.0	0.0	Geology
BASETP	Fraction of remain ET from active baseflow	none	0.0	0.05	0.0	0.2	0.1	0.0	Riparian vegetation
AGWETP	Fraction of remain ET from active groundwater	none	0.0	0.05	0.0	0.2	0.0	0.0 – 0.7	Marsh/wetlands ET
PWAT-PARM4									
CEPSC	Interception storage capacity	in	0.03	0.2	0.01	0.4	0.1-0.3	0.01 – 0.224	Vegetation
UZSN	Upper zone nominal soil moisture storage	in	0.10	1	0.05	2	1.50	1.5 – 2.0	Soil properties
NSUR	Manning's n (roughness)	none	0.15	0.35	0.1	0.5	0.20 - 0.35	0.20 – 0.35	Land use, surface conditions
INTFW	Interflow/surface runoff partition parameter	none	1	3	1	10	2.0	0.85	Soils, topography, land use
IRC	Interflow recession parameter	none	0.5	0.7	0.3	0.85	0.8	0.3 – 0.519	Soils, topography, land use
LZETP	Lower zone ET parameter	none	0.2	0.7	0.1	0.9	0.3-0.9	0.3 - 0.896	Vegetation

* USEPA, 2000.

Table 4.8. Calibrated hydrology HSPF parameters (IMPLND and RCHRES) for Elk Creek watershed.

Parameter	Definition	Units	Range of Values*				Start	Final	Function of…
			Typical		Possible				
			Min	Max	Min	Max			
IMPLND									
IWAT-PARM2									
LSUR	Length of overland flow	ft	200	500	100	700	100	100	Topography
SLSUR	Slope of overland flow	none	0.01	0.15	0.001	0.3	0.20	0.005-0.167	Topography
NSUR	Manning's n (roughness)	none	0.15	0.35	0.1	0.5	0.1	0.1	Land use, surface condition
RETSC	Retention/interception storage capacity	in	0.03	0.2	0.01	0.4	0.065	0.065	Land use, surface condition
IWAT-PARM3									
PETMAX	Temp below which ET is reduced	deg. F	35	45	32	48	40	40	Climate, vegetation
PETMIN	Temp below which ET is set to zero	deg. F	30	35	30	40	35	35	Climate, vegetation
RCHRES									
HYDR-PARM2									
KS	Weighting factor for hydraulic routing	none	0.3	0.7	0.0	0.9	0.5	0.5	Stream channel, topography

* USEPA, 2000.

4.7.2 Water Quality

The simulation of water quality concentrations (e.g., bacteria concentrations) is built on the hydrology simulation. The simulation runs at an hourly time step with average daily fecal coliform bacteria concentrations output at the stream reaches. Based on critical period analysis and availability of data, modeling periods were chosen for water quality calibration and validation for the impairment.

The PQUAL and IQUAL modules of HSPF were used to represent the build-up, die-off, and wash-off of fecal coliform bacteria from land surfaces. The modules are characterized by the following parameters: 1) Daily accumulation rate of bacteria on the soil surface (ACQOP); 2) Maximum bacteria build-up rate on the soil (SQOLIM); 3) Rate of surface runoff that removes 90% of the accumulated bacteria from the soil surface (WSQOP); and 4) Bacteria concentration in interflow, PQUAL only (IOQC). The GQUAL module in HSPF was used to represent the transport, settling, and die-off of dissolved bacteria in-stream. Settling and die-off were estimated using the first-order decay rate (FSTDEC). The listed model parameters were adjusted within reasonable limits until an acceptable match between measured and modeled bacteria concentrations was established.

A number of factors, not inclusive to description below, complicate the water quality calibration. The difficulty in measuring bacteria concentrations is attributed to variability in bacteria density in feces, variability in location and timing of fecal deposition, variability in bacteria amount delivered to the stream, and environmental impacts on re-growth and die-off.

The bacteria concentrations are highly dependent on flow conditions and variability associated with modeling stream flows compounds the variability in modeling the bacteria concentrations. The usually limited number of grab samples collected at each VADEQ station and the practice of censoring both high (over 8,000 cfu/100 ml or 16,000 cfu/100 ml) and low (under 100 cfu/100 ml or 18 cfu/100 ml) concentrations hinder the water quality calibration process.

The period January 1, 1997 through December 31, 2001 was chosen for water quality calibration and January 1, 1992 through December 31, 1996 was chosen for water quality validation. Fecal coliform bacteria observations from the VADEQ ambient water quality monitoring station 9-EKC003.78 within the Elk Creek impairment were used to calibrate the water quality component of HSPF. The final water quality calibration parameters are shown in Table 4.9. Observations from VADEQ station 9-EKC003.78 were graphically compared to corresponding modeled concentrations at subwatershed ELC-12 (Figures 4.9 and 4.10). It should be noted that each observed bacteria concentration datum represents a “snapshot” resulting from the examination of one grab sample, while the modeled data represent a continuous time series of bacteria concentration. Uncertainty exists in the stream condition the grab sample represents. For example, was the sample taken as the bacteria concentration was increasing or decreasing in the stream? The short-period fluctuations in the modeled bacteria concentration represent the variability within daily concentrations associated with the wildlife, livestock, and straight pipe direct deposition distribution across each day. Careful inspection of graphical comparisons between continuous simulation results and limited observed points yielded acceptable results given the modeling constraints listed above. Seasonal variations are exhibited by the modeled concentrations, and most observed concentrations are simulated accurately for the calibration period.

To provide a quantitative measure of the agreement between observed and modeled data, the fecal coliform geometric mean concentrations and 400 cfu/100mL fecal coliform instantaneous water quality standard exceedance rates were calculated. Tables 4.10 and 4.11 illustrate the comparison of observed and modeled geometric mean concentration and exceedance rates for the calibration and validation periods, respectively. The highest difference (i.e., -1.1%) between observed and modeled geometric mean concentrations was recorded during the calibration period at subwatershed 12. It should be noted that a limited number of observed values were available for comparison when determining exceedance rates in Tables 4.10 and 4.11. A difference of one exceedance during the calibration and validation periods results in an exceedance rate difference of 4% and 6%, respectively. The modeled exceedance rates matched the observed exceedance rates exactly during the calibration and validation periods. The modeled versus observed geometric mean concentrations and exceedance rates comparison yielded acceptable results for the calibration and validation periods.

Based on the qualitative and quantitative analyses performed during hydrology and water quality calibration and validation, it was established that the developed model adequately represented the processes and interactions associated with the production and transport of bacteria within the Elk Creek watershed.

Table 4.9. Calibrated water quality HSPF parameters for Elk Creek watershed.

Parameter	Definition	Units	Range of Values*				Start	Final	Function of…
			Typical		Possible				
			Min	Max	Min	Max			
PERLND									
QUAL-INPUT									
SQO	Initial storage of constituent	#/ac	0	1E20	0	1E30	1E08	1E08	Land use
ACQOP	Rate of accumulation of constituent	#/day	0	1E20	0	1E30	00E00-08E08	00E00-08E08	Land use
SQOLIM	Maximum accumulations of constituent	#/ac	0.01	1E30	0.01	1E40	00E00-07E09	00E00-07E09	Land use
WSQOP	Wash-off rate	in/hr	0.05	3.00	0.01	5.0	1.0	2.0	Land use
IOQC	Constituent concentration in interflow	#/ft^3	0	1E6	0	1E10	1E03	1E03	Land use
AOQC	Constituent concentration in active groundwater	#/ft^3	0	1E6	0	1E10	0E00	0E00	Land use
IMPLND									
QUAL-INPUT									
SQO	Initial storage of constituent	#/ac	0	1E20	0	1E30	1E09	1E09	Land use
ACQOP	Rate of accumulation of constituent	#/day	0	1E20	0	1E30	18E06-57E06	18E06-57E06	Land use
SQOLIM	Maximum accumulations of constituent	#/ac	0.01	1E30	0.01	1E40	19E06-04E08	19E06-04E08	Land use
WSQOP	Wash-off rate	in/hr	0.05	3.00	0.01	5.0	0.1	0.1	Land use
RCHRES									
GQ-GENDECAY									
FSTDEC	First order decay rate of the constituent	1/day	0.01	10.0	0.01	30.0	2.5	5.0-7.0	Stream channel, environment
THFST	Temperature correction coefficient for FSTDEC	none	1	2	1	2	1.07	1.07	Water temperature

* USEPA, 2000.

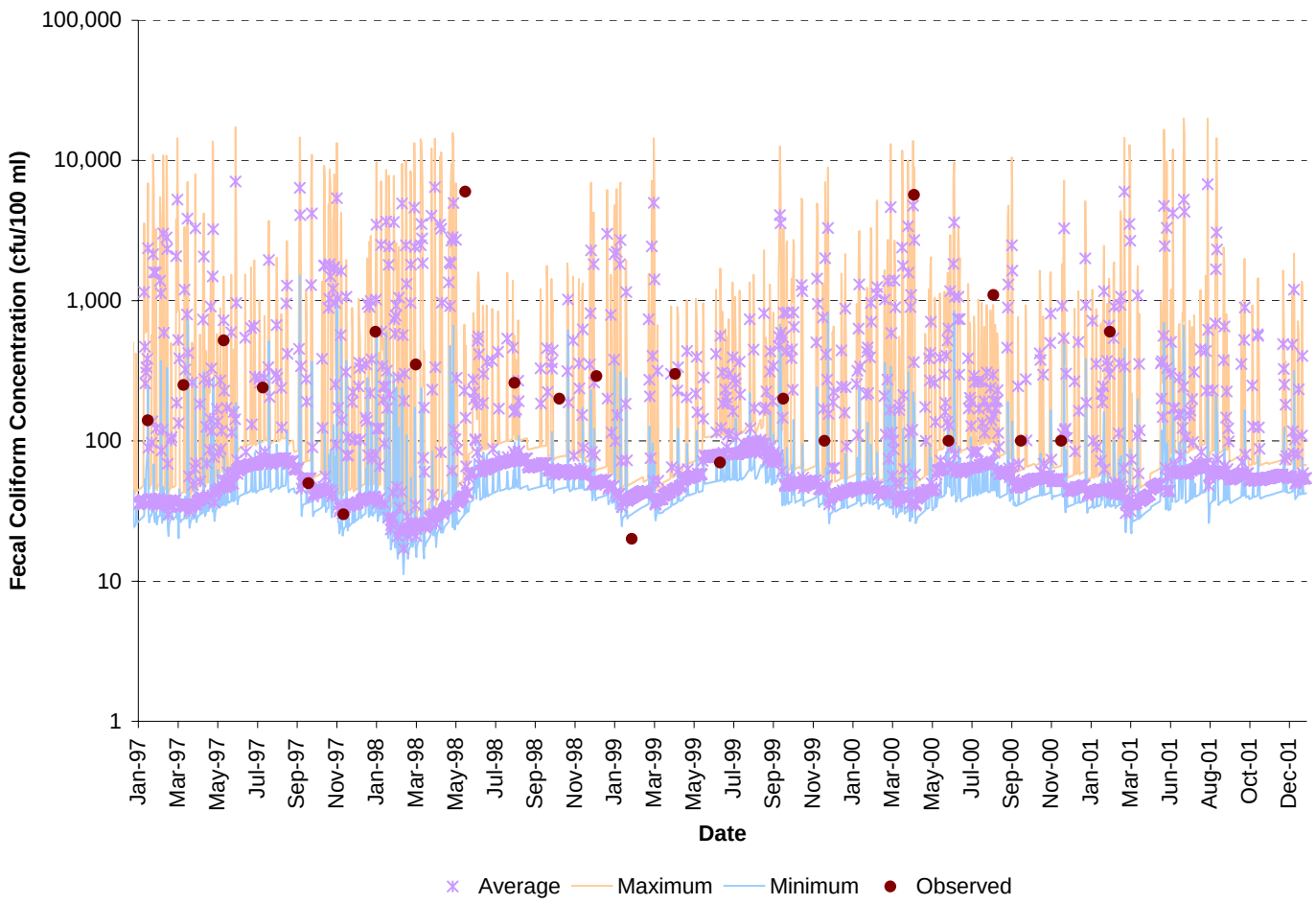

Figure 4.9. Water quality calibration results with observed and modeled average, maximum, and minimum daily fecal coliform concentrations for subwatershed ELC-12 in Elk Creek watershed.

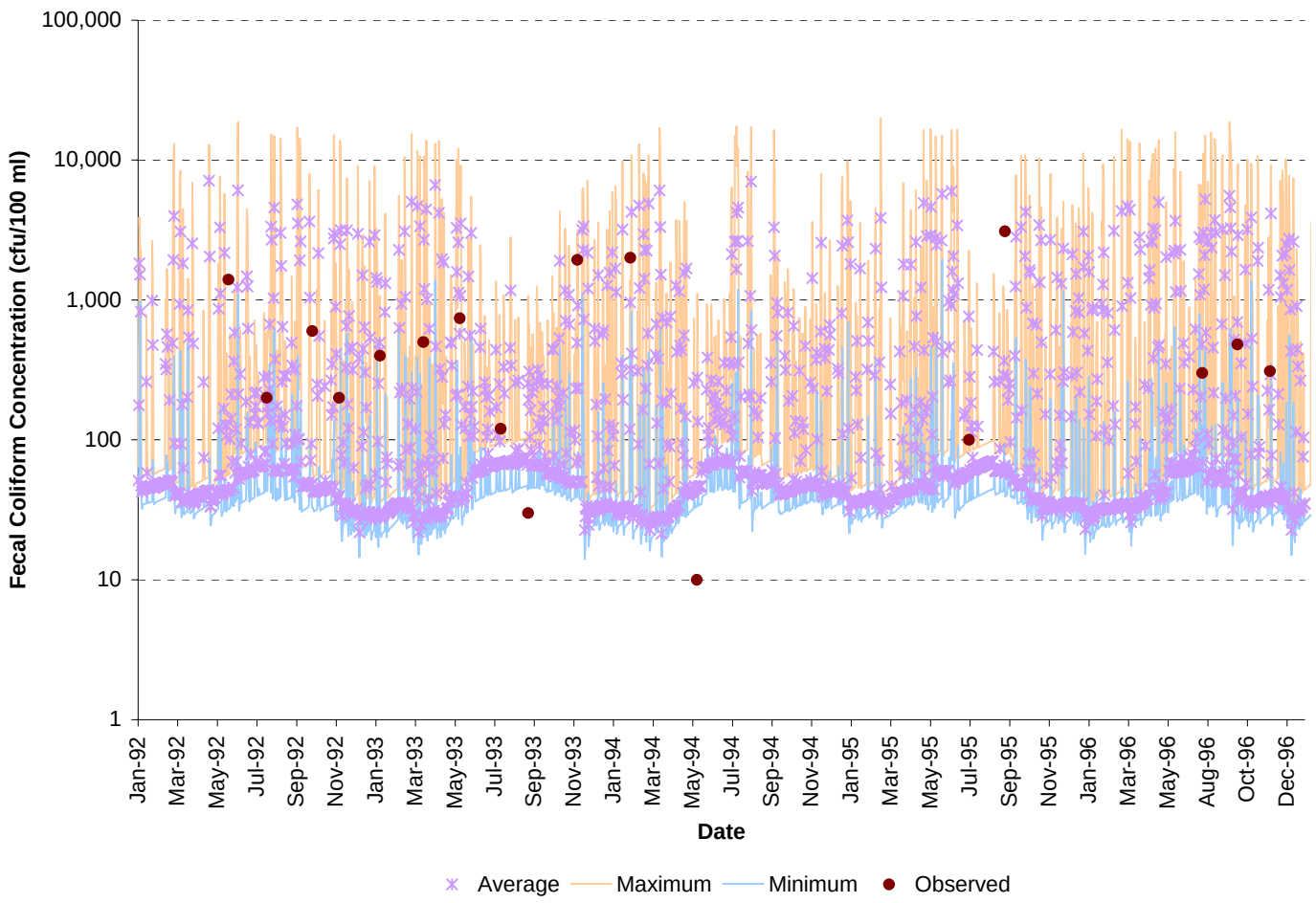

Figure 4.10. Water quality validation results with observed and modeled average, maximum, and minimum daily fecal coliform concentrations for subwatershed ELC-12 in Elk Creek watershed.

Table 4.10. Observed and modeled geometric mean concentrations and instantaneous water quality standard exceedance rates for the calibration period in Elk Creek watershed.

Parameter	Sub ELC-12
Geometric Mean of Observed Values, (cfu/100mL)	236
Geometric Mean of Corresponding Modeled Values (cfu/100mL)	234
Observed Fecal Coliform Instantaneous Standard, 400 cfu/100mL, Exceedance Rate (%)	26.1
Modeled Fecal Coliform Instantaneous Standard, 400 cfu/100mL, Exceedance Rate (%)	26.1

Table 4.11. Observed and modeled geometric mean concentrations and instantaneous water quality standard exceedance rates for the validation period in Elk Creek watershed.

Parameter	Sub ELC-12
Geometric Mean of Observed Values, (cfu/100mL)	337
Geometric Mean of Corresponding Modeled Values (cfu/100mL)	340
Observed Fecal Coliform Instantaneous Standard, 400 cfu/100mL, Exceedance Rate (%)	47.1
Modeled Fecal Coliform Instantaneous Standard, 400 cfu/100mL, Exceedance Rate (%)	47.1

Chapter 5. TMDL Allocations

5.1 Background

The objective of a TMDL is to allocate allowable loads among different pollutant sources so that the appropriate control actions can be taken to achieve water quality standards (USEPA, 1991). The goal for the Elk Creek TMDL was to determine what reductions in bacteria loadings from point and nonpoint sources are required to meet state water quality standards. The state water quality standards for *E. coli* used in the development of the TMDL were 126 cfu/100mL (calendar-month geometric mean) and 235 cfu/100mL (single sample maximum). The TMDL considers all sources contributing *E. coli* to Elk Creek. The sources can be separated into nonpoint and point (or direct) sources. The incorporation of the different sources into the TMDL is defined in the following equation:

$$TMDL = WLA + LA + MOS \qquad [5.1]$$

where: WLA = wasteload allocation (point source contributions);

LA = load allocation (nonpoint source contributions); and

MOS = margin of safety.

While developing allocation scenarios to implement the bacteria TMDL, an implicit MOS was used by formulating conservative estimates of all factors that would affect the bacteria loadings in the watershed (e.g., animal numbers, production rates, and contributions to streams). These factors were estimated in such a way as to represent the worst-case scenario; i.e., these factors would describe the highest in-stream bacteria conditions that could exist in the watershed. Creating a TMDL with these conservative estimates ensures that the worst-case scenario has been considered and that no water quality standard exceedances will occur if the TMDL plan is followed.

Bacteria loadings were updated to reflect 2008 conditions for the existing conditions and allocation runs. The simulation period selected for the load allocation study was January 2000 to December 2004. This period incorporates average rainfall, low rainfall, and high rainfall years allowing the representation of both low and high flow conditions.

The calendar-month geometric mean values used in this report are geometric means of the daily concentrations. Because HSPF was operated with a one-hour time step in this study, 24 hourly concentrations were generated each day. To estimate the calendar-month geometric mean from the hourly HSPF output, the arithmetic mean of the hourly values was computed on a daily basis, and then the geometric mean was calculated from these average daily values.

The guidance for developing an *E. coli* TMDL put forth by the VADEQ is to develop input for the model using fecal coliform loadings as the bacteria source in the watershed. Then, the model output of average fecal coliform concentrations is converted to daily average *E. coli* concentrations through the use of the following translator equation derived by the VADEQ:

$$\log_2(EC) = -0.0172 + 0.91905*\log_2(FC) \quad [5.2]$$

where: EC = *E. coli* concentration (cfu/100mL); and
FC = fecal coliform concentration (cfu/100mL)

Daily *E. coli* loads were obtained by using the *E. coli* concentrations calculated from the translator equation and multiplying them by the average daily flow. Average annual loads were obtained by summing the daily loads and dividing by the number of years in the allocation period.

5.2 Existing Conditions

Bacteria loadings for 2008 conditions were inserted into the model and simulated for the period January 2000 to December 2004. Model output was translated to average daily *E. coli* concentrations and the monthly geometric mean was calculated. Average daily *E. coli* concentrations at the impairment outlets were compared to the single sample maximum standard of 235 cfu/100 mL. Subwatershed outlets were used for comparison of modeled concentrations to water quality standards for the Elk Creek impairment. Appendix C contains tables with monthly land-based and direct bacteria loadings for existing conditions.

Figure 5.1 shows the monthly geometric mean for each subwatershed in relation to the monthly geometric mean (126 cfu/100mL) standard. Average daily *E. coli* concentrations at the impairment outlet were compared to the single sample maximum standard of 235 cfu/100 mL (Figure 5.2). The subwatershed outlet used for comparison of modeled concentrations to water quality standards for the Elk Creek impairment was subwatershed ELC-16.

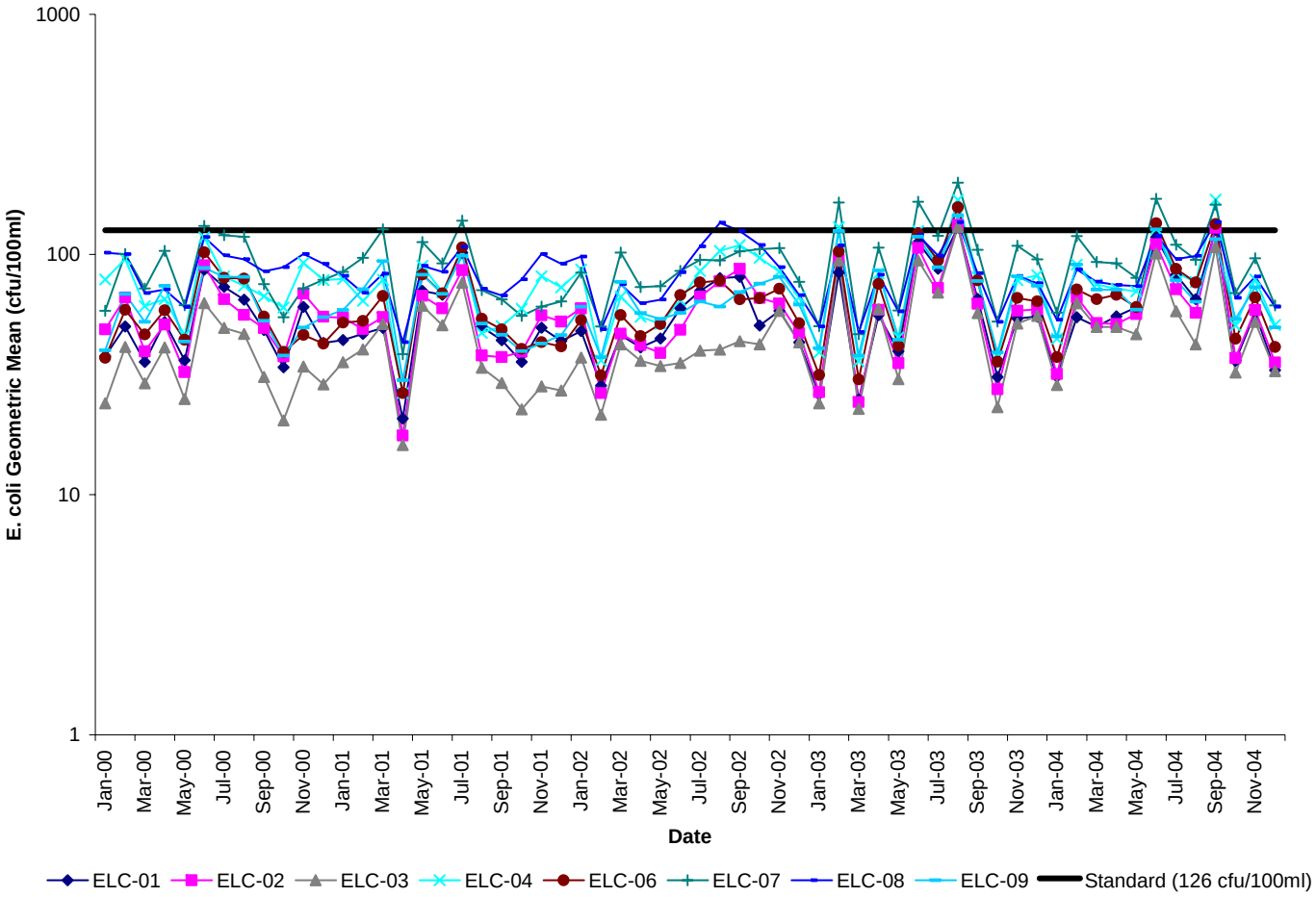

Figure 5.1. Monthly *E. coli* geometric mean concentrations for existing conditions in subwatersheds ELC-01 to ELC-09 in the Elk Creek watershed.

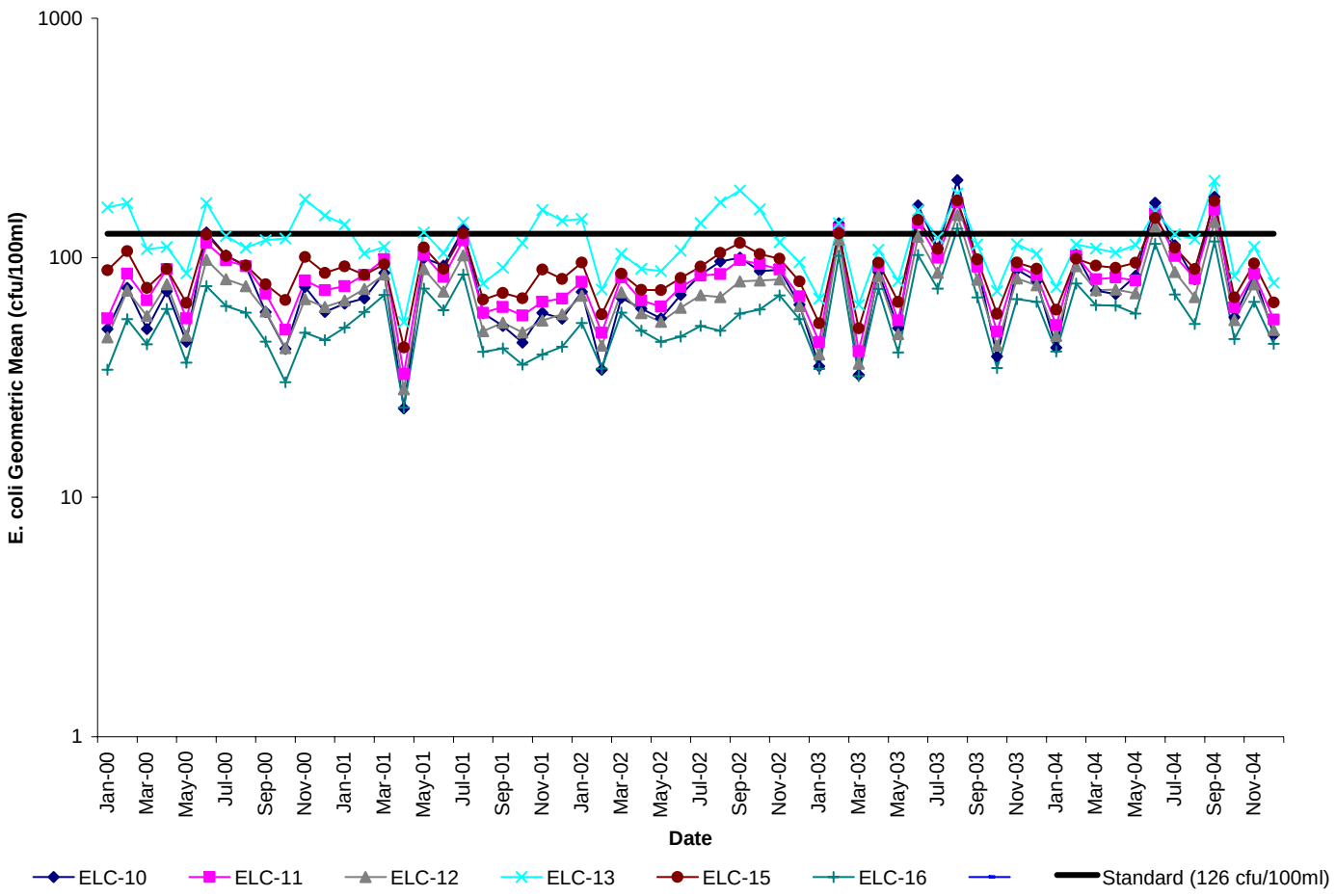

Figure 5.2. Monthly *E. coli* geometric mean concentrations for existing conditions in subwatersheds ELC-10 to ELC-16 in the Elk Creek watershed.

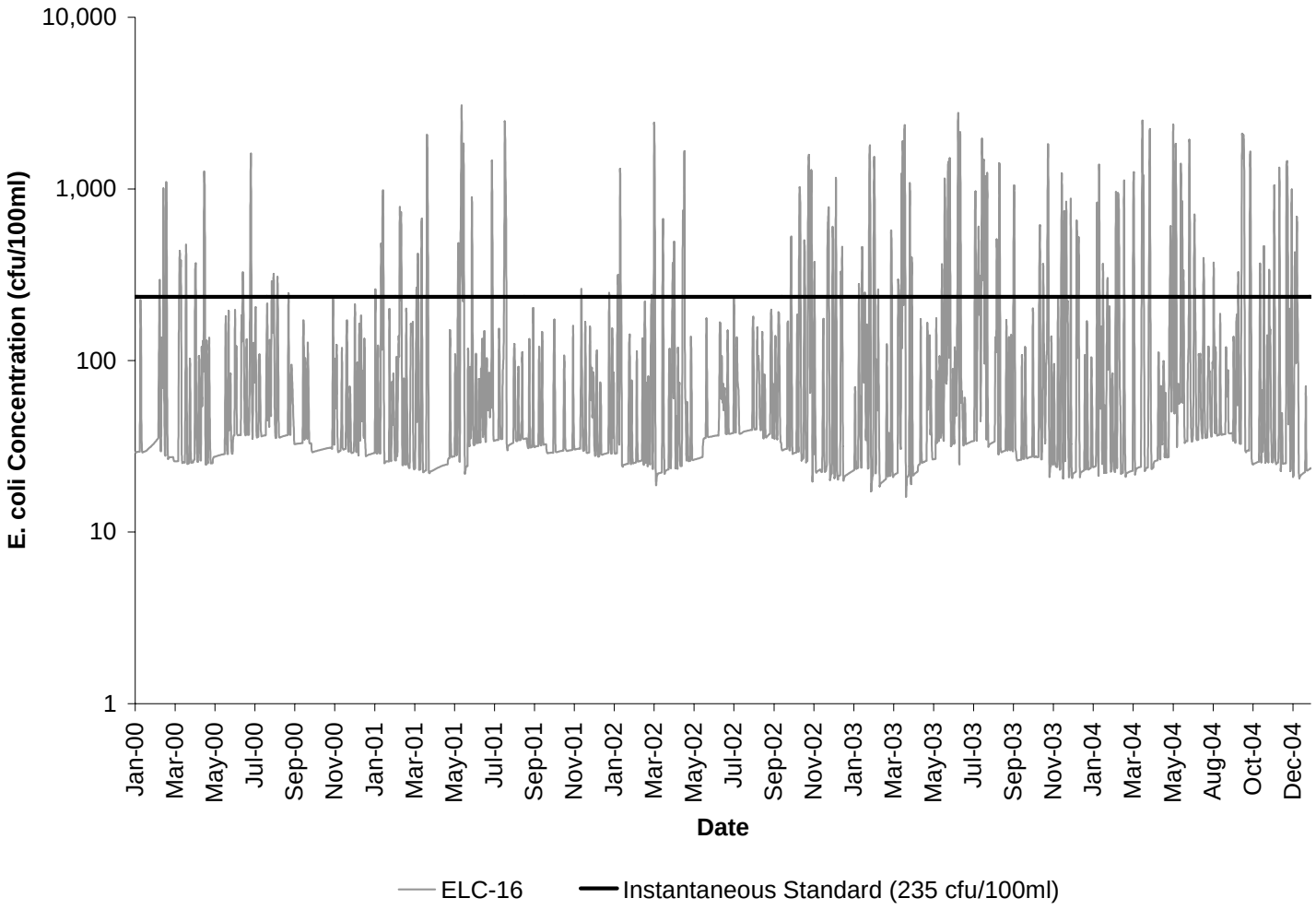

Figure 5.3. Daily average *E. coli* concentrations for subwatershed ELC-16 in Elk Creek watershed.

5.3 Impact Analysis

Analyses were conducted to assess the impact of unknown variability in source allocations on changes in direct and land-based loads. Model output from existing conditions was set as the comparative base to adjustments in direct and land-based loads of +100%, +10%, -10%, and -100% of the base value. Model simulations were made for the period January 2000 to December 2004, corresponding with the period used in the allocation scenarios. Percent difference in monthly geometric mean *E. coli* concentration and maximum daily average *E. coli* concentration per month for each direct and land-based load change to base value was calculated and plotted. Analysis results were used to assess the affects of future growth on the rate of water quality standards exceedance.

Percent difference in monthly geometric mean *E. coli* concentration for each direct and land-based load change to base value was calculated and plotted in Figures 5.3 and 5.4, respectively. Figures 5.5 and 5.6, respectively, show the percent difference in the maximum daily average *E. coli* concentration per month for each direct load and land load change to base value. It is apparent by comparing Figure 5.3 with Figure 5.4 that increasing directly deposited loads impact the in-stream geometric mean *E. coli* concentrations more significantly than increasing land-based loads. Comparing Figure 5.5 to Figure 5.6 indicates that the maximum daily average *E. coli* concentrations are affected greatly by increasing land-based loads and affected by increasing directly deposited loads during lower flow periods.

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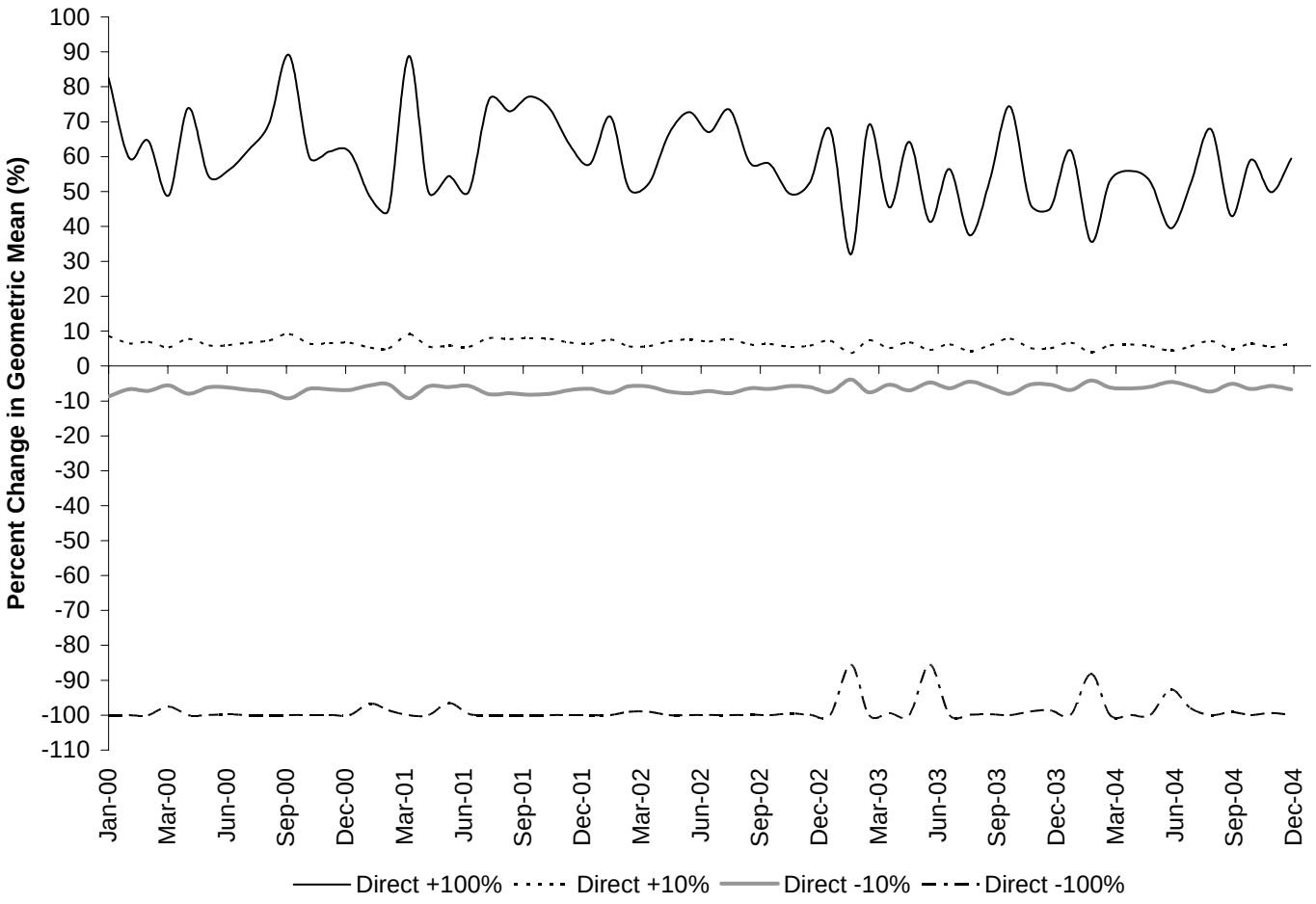

Figure 5.4. Results of impact analysis on monthly geometric mean *E. coli* concentration at outlet (subwatershed ELC-16) of Elk Creek watershed, as affected by direct load changes.

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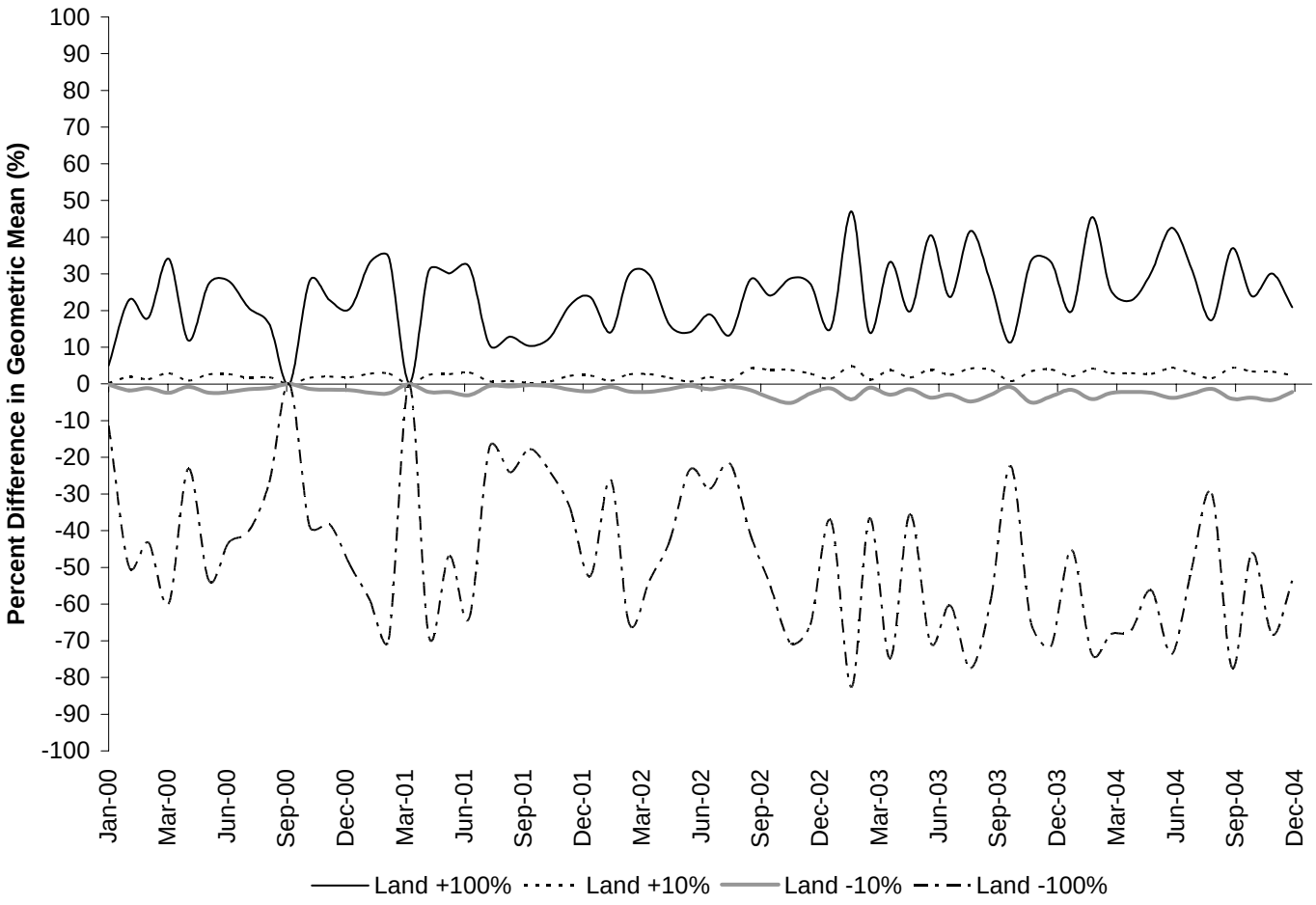

Figure 5.5. Results of impact analysis on monthly geometric mean *E. coli* concentration at outlet (subwatershed ELC-16) of Elk Creek watershed, as affected by land-based load changes.

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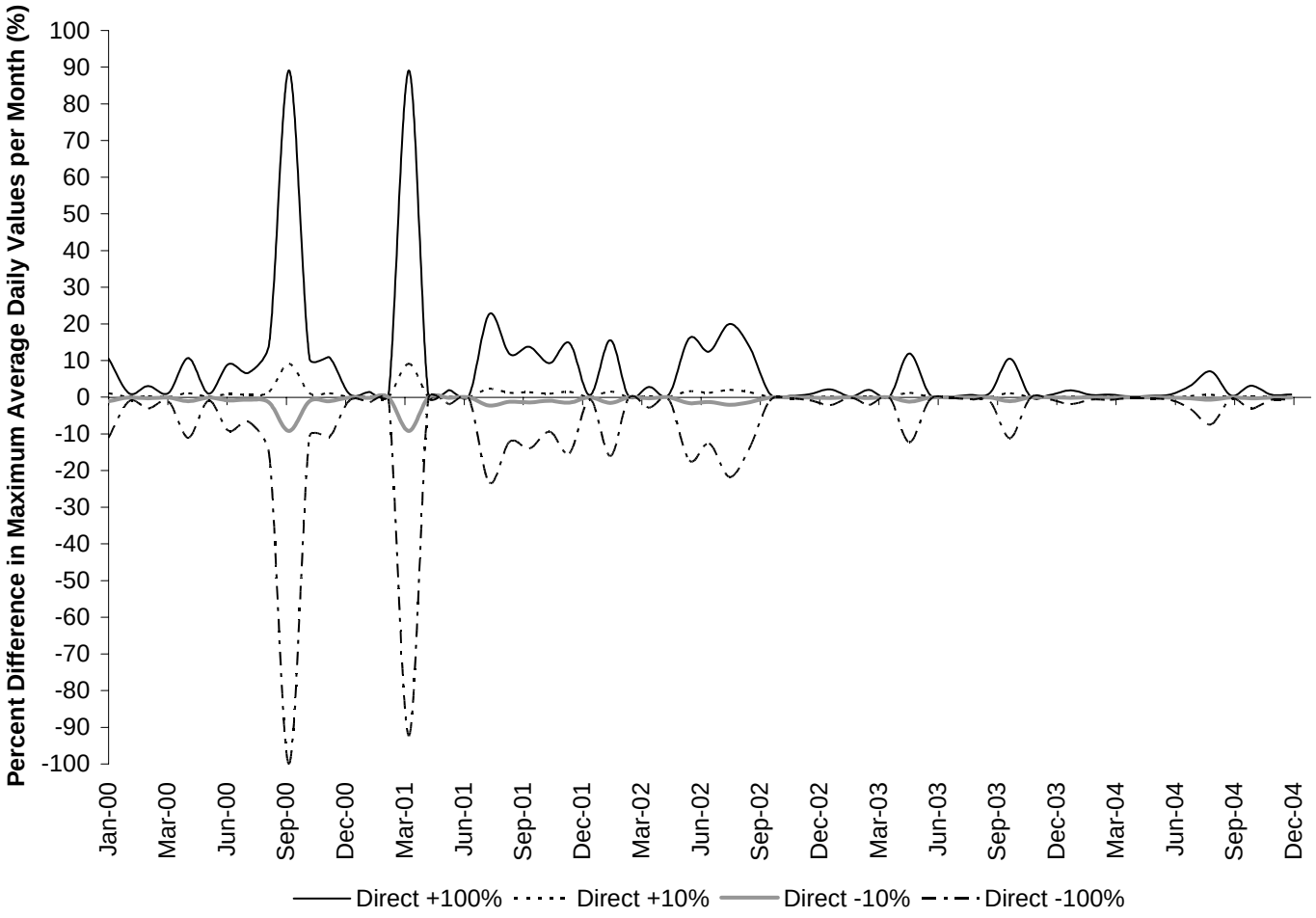

Figure 5.6. Results of impact analysis on maximum daily average *E. coli* concentration per month at outlet (subwatershed ELC-16) of Elk Creek watershed, as affected by direct load changes.

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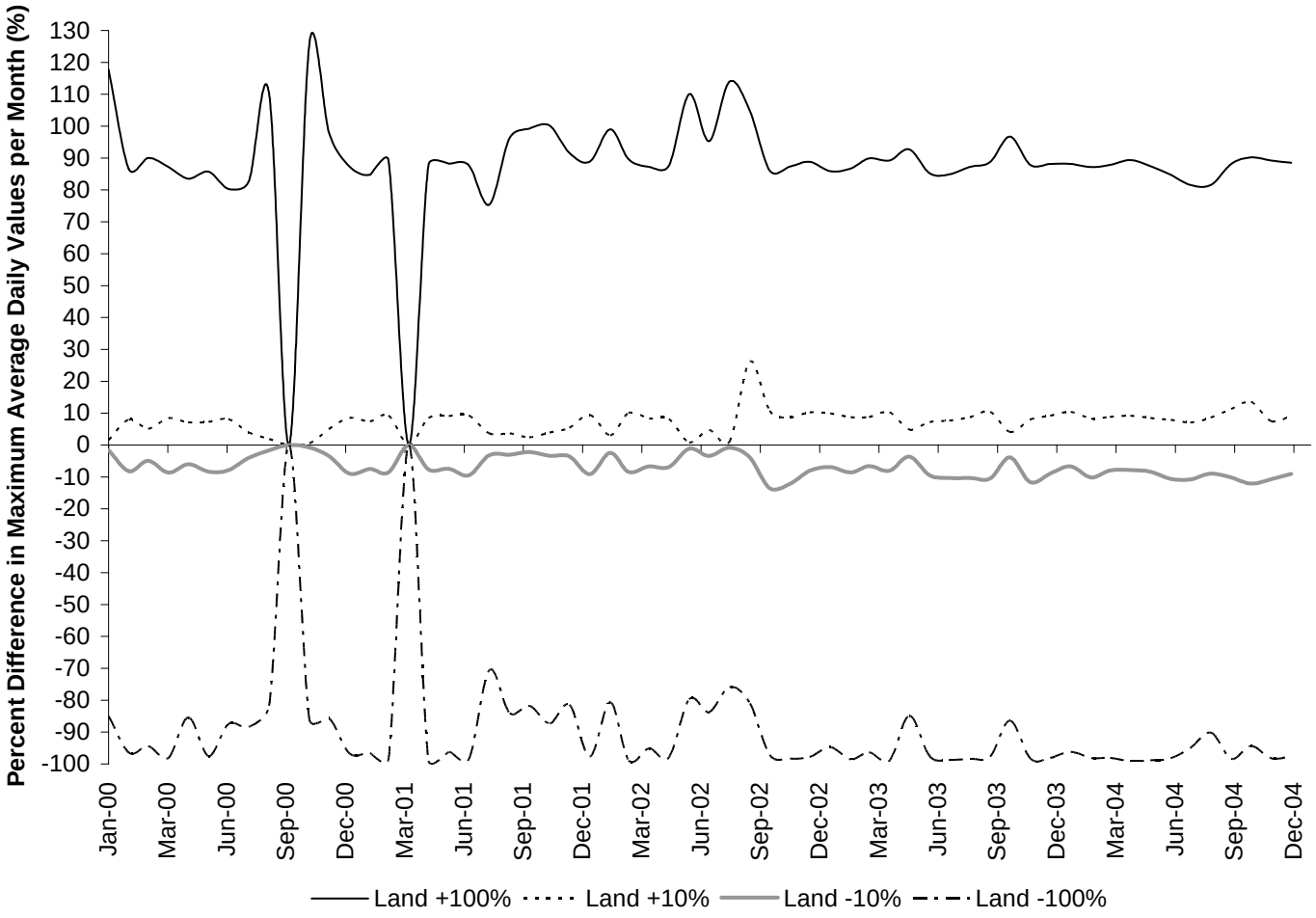

Figure 5.7. Results of impact analysis on maximum daily average *E. coli* concentration per month at outlet (subwatershed ELC-16) of Elk Creek watershed, as affected by land-based load changes.

5.4 TMDL Allocation Scenarios

Direct and land-based loads representing existing conditions were reduced in a variety of allocation scenarios (addressing anthropogenic sources first) until the *E. coli* TMDL goals of a calendar-month geometric mean of 126 cfu/100mL and the single sample maximum limit of 235 cfu/100mL were met. The representative modeling period selected for allocation scenarios was January 2000 through December 2004. This period incorporates average rainfall, low rainfall, and high rainfall years allowing the representation of both low and high flow conditions. The general approach to allocation scenario development was to develop a scenario that allowed the Elk Creek impairment to meet bacteria water quality standards.

No active point discharges in the Elk Creek watershed currently have VPDES permits. No municipalities with MS4 permits were identified within the Elk Creek watershed. The ultimate waste load allocation (WLA) was calculated at <1% of the TMDL. Scenarios to address the load allocations to nonpoint sources were divided between direct and land-based loadings affected by both high and low stream flow conditions. Bacterial source tracking results from samples taken during 2008 confirmed the presence of human, pet, livestock, and wildlife contamination. As a result, scenarios were formulated to address reductions from all sources and delivery mechanisms (See Section 6.5.4 for discussion of wildlife bacteria). In general, direct loads modeled as consistent loadings independent of the flow regime heavily influenced low flow concentrations, whereas land-applied loads reached the stream through runoff producing events during high flow conditions. Representative allocation reduction scenarios developed for the Elk Creek impairment and corresponding results are summarized in Table 5.1.

In Table 5.1, the first scenario represents existing conditions. Scenario number 1 reduces straight pipes and livestock directly deposited loads by 100%, keeping the remaining source reductions at 0%. Scenarios numbered 2 through 4 represent a stepwise reduction of the following anthropogenic sources: residential land-based, cropland land-based, and pasture land-based. In these scenarios, wildlife loads (directly deposited and forest land-based) were not reduced and straight pipes and livestock directly deposited loads were reduced by 100%. Load from straight pipes was reduced by 100% in all reduction scenarios since they are illegal. Utilizing results of Scenarios 1 through 4, subsequent scenarios were used to determine required reductions in anthropogenic sources. Scenario 5 tested the land-based load reductions at 96%. Table 5.1 shows that exceedances are present when the anthropogenic sources are tested at a 96% reduction rate. Scenario 6 tested the land-based load reductions at 97% and met the 0% exceedance rate criterion for both standards, but an attempt to reduce the livestock direct deposition was performed to match the land-based anthropogenic source reductions. Scenario 7 tested the land-based and livestock directly deposited loads at a 97% reduction rate. Scenario 7 met the 0% exceedance rate criterion for both standards and was selected as the final TMDL allocation. It was determined that no reductions were required in wildlife loads (directly deposited and forest land-based) to meet the bacteria water quality standards in the Elk Creek watershed. Concentrations for the calendar-month and daily average *E. coli* values are shown in Figure 5.7 for the final TMDL allocation (Scenario 7), along with the geometric mean and instantaneous standards. Table 5.2 presents the existing and allocated direct and land-

applied fecal coliform and *E. coli* loads that result in in-stream *E. coli* concentrations to meet the applicable *E. coli* water quality standards after application of the VADEQ translator for fecal coliform to *E. coli* concentration. Table 5.3 presents the final allocated in-stream *E. coli* loads for the Elk Creek impairment. Table 5.4 presents the TMDL for the 99th percentile daily flow condition at the numeric water quality criterion of 235 cfu/100ml.

Increases in loads over the next five years must be considered to ensure the stated allocation will meet the water quality standards. Future growth in discharges from permitted point sources in the Elk Creek watershed was accounted for by developing the WLA at <1% of the TMDL. These WLAs did not result in exceedance of the water quality standard. This growth-expanded allocation was calculated and presented based on the current limits of existing permits in the watershed, but it will be allocated to both new and existing permits as determined by the VADEQ Virginia Pollutant Discharge Elimination System program. All current permit limits remain in effect and can only be altered through the VADEQ permitting process. From information provided by the Technical Advisory Committee, it is our understanding that no major zoning changes are planned by counties in the watersheds that would result in accelerated development of the watershed. For purposes of this study, it was assumed that residential development in the study watersheds will continue at the current rates. New housing development is expected to produce no direct deposition, and a minimal land-based load increase based on the 3% failure rate associated with new septic systems and the number of pets added by this development. Data from the VASS indicated that beef cattle populations have decreased by approximately 10% per year since peaking in 2005 and there is no evidence that any new dairy or poultry operations are planned. Wildlife populations are expected to remain relatively constant over the next five years. Based on these observations and the TMDL allocations, it is anticipated that the increase in directly deposited and land-based loads in the study watersheds will be negligible over the next five years. The effects of changes in loads on the in-stream bacteria concentration is examined in the impact analysis in Section 5.3. These changes are adequately accounted for in the implicit MOS. This implies that the final TMDL allocation is valid for the next five years, accounting for the anticipated growth during that time period.

The selected *E. coli* TMDL allocation for the Elk Creek impairment that meets both the calendar-month geometric mean and single sample maximum water quality goals addresses the following issues:

- The TMDL was developed to meet the calendar-month geometric mean and single sample water quality standards.
- Because *E. coli* loading data were not available to quantify point or nonpoint source bacterial loads, available fecal coliform loading data were used as input to HSPF. HSPF was used to simulate in-stream fecal coliform concentrations. The VADEQ fecal coliform to *E. coli* concentration translator was then used to convert the simulated fecal coliform concentrations to *E. coli* concentrations on which the bacteria TMDL was based.
- The TMDL was developed taking into account all fecal bacteria sources (anthropogenic and natural) from both point and nonpoint sources.

- An implicit MOS was incorporated by utilizing professional judgment and conservative estimates of model parameters.
- Both high- and low-flow stream conditions were considered while developing the TMDL.
- Both the flow regime and bacteria loading to Elk Creek are seasonal. The TMDL accounts for these seasonal effects.
- The exceedance rates listed in the allocation scenario table indicate the highest exceedance rate observed at a subwatershed outlet within the impaired segment (i.e., subwatershed ELC-05). Some scenarios resulted in bacteria water quality standard exceedances in subwatersheds upstream of the outlet but not within the impaired reach subwatersheds.
- The TMDL was developed to account for future growth in the Elk Creek watershed.

Table 5.1. TMDL allocation scenarios for Elk Creek impairment.

Scenario Number	Percent Reduction in Fecal Coliform Loading from Existing Conditions							% Violations of E. coli Standard	
	Straight Pipes	Residential	Livestock DD	Cropland	Pasture	Wildlife DD	Forest	Geometric Mean	Instantaneous
Existing Conditions	0	0	0	0	0	0	0	3.3	11.9
1	100	0	100	0	0	0	0	0.0	11.7
2	100	50	100	50	50	0	0	0.0	9.1
3	100	75	100	75	75	0	0	0.0	6.1
4	100	90	100	90	90	0	0	0.0	3.2
5	100	96	100	96	96	0	0	0.0	0.2
6	100	97	100	97	97	0	0	0.0	0.0
7	100	97	97	97	97	0	0	0.0	0.0

Table 5.2. Annual nonpoint source fecal coliform loads for existing conditions and final allocation along with corresponding reductions in Elk Creek impairment.

Source	Fecal Coliform		*E. coli*[1]		Scenario Reduction
	Existing Condition Load (cfu/yr)	TMDL Allocation Load (cfu/yr)	Existing Condition Load (cfu/yr)	TMDL Allocation Load (cfu/yr)	(%)
Direct					
Straight Pipes	1.18E+14	0.00E+00	8.46E+12	0.00E+00	100
Livestock	7.05E+13	2.12E+12	5.27E+12	2.11E+11	97
Wildlife	6.16E+13	6.16E+13	4.66E+12	4.66E+12	0
Total	*2.50E+14*	*6.37E+13*	*1.84E+13*	*4.87E+12*	75
Land-based					
Residential	7.14E+14	2.14E+13	4.43E+13	1.76E+12	97
Cropland	1.41E+14	4.23E+12	9.97E+12	3.97E+11	97
Pasture	8.05E+16	2.42E+15	3.40E+15	1.36E+14	97
Forest	3.79E+14	3.79E+14	2.47E+13	2.47E+13	0
Total	*8.17E+16*	*2.82E+15*	*3.48E+15*	*1.63E+14*	97

[1] Loads derived from fecal coliform loads using equation 5.1

Table 5.3. Average annual *E. coli* bacteria loads (cfu/yr) modeled after TMDL allocation in Elk Creek impairment.

Pollutant	WLA[1] (cfu/yr)	LA[2] (cfu/yr)	MOS	TMDL[3] (cfu/yr)
E. coli	1.48E+11	1.47E+13	Implicit	1.48E+13

1 – The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.

2 – The LA is calculated as the TMDL minus the WLA.

3 – The TMDL is presented as the average annual load for the allocation period.

Table 5.4. Daily *E. coli* bacteria loads (cfu/d) modeled after TMDL allocation in Elk Creek impairment.

Pollutant	WLA[1] (cfu/d)	LA[2] (cfu/d)	MOS	TMDL[3] (cfu/d)
E. coli	4.05E+08	5.04E+12	Implicit	5.04E+12

1 – The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe. The WLA is calculated as the average annual load divided by 365.

2 – The LA is calculated as the TMDL minus the WLA.

3 – The TMDL is presented for the 99th percentile daily flow condition at the numeric water quality criterion of 235 cfu/100ml. The TMDL is variable depending on flow conditions. The numeric water quality criterion will be used to assess progress toward TMDL goals.

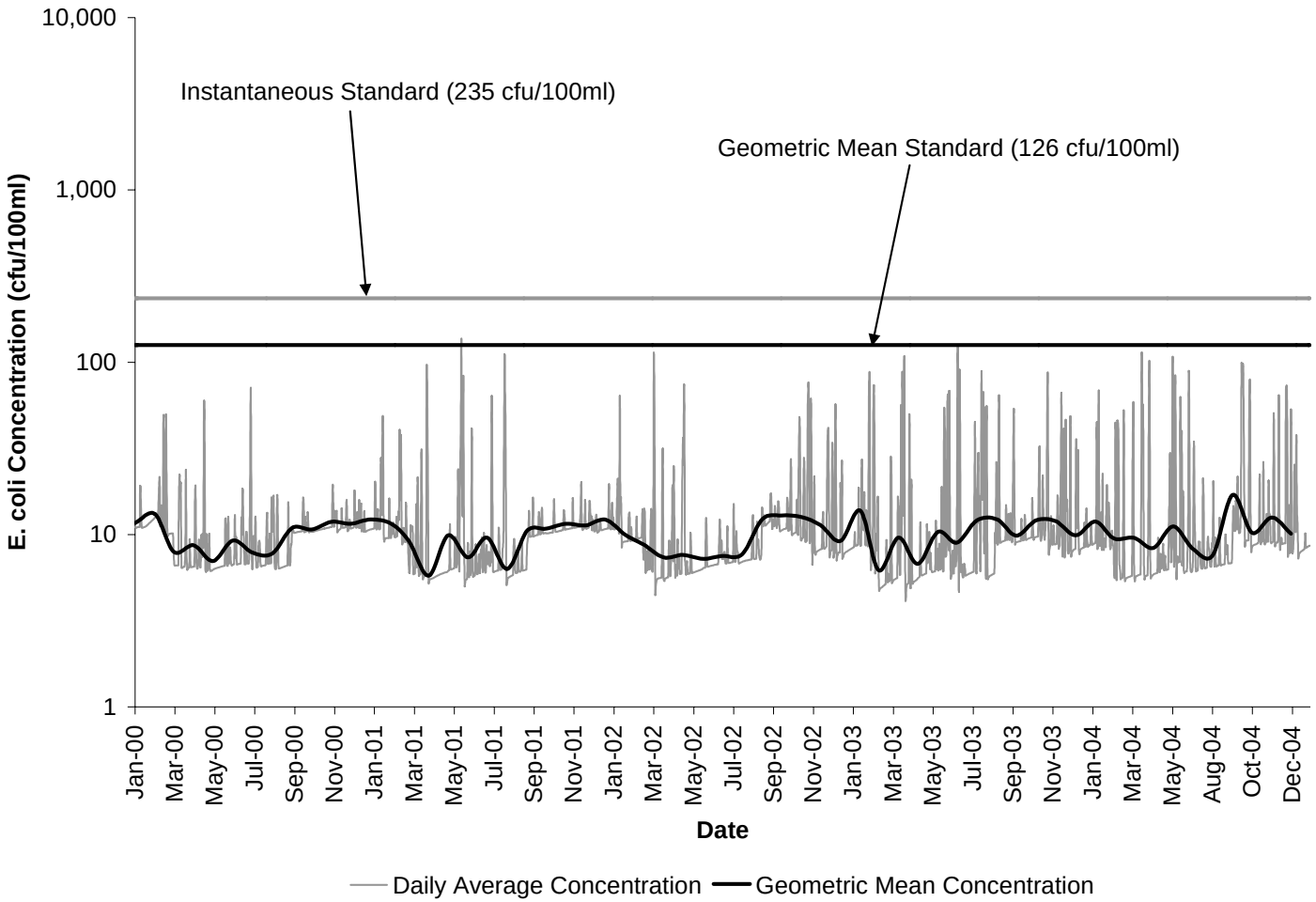

Figure 5.7. Geometric mean standard, instantaneous single sample standard, and average daily and geometric mean E. coli concentrations from successful TMDL allocation (Allocation Scenario 7 from Table 5.1) in Elk Creek impairment.

Chapter 6. TMDL Implementation and Reasonable Assurance

Once a TMDL has been approved by USEPA, measures must be taken to reduce pollution levels from both point and non point sources in the stream (see section 6.4.2). 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 USEPA for approval. The measures for nonpoint source reductions, which can include the use of better treatment technology and the installation of best management practices (BMPs), are implemented in an iterative process that is described along with specific BMPs in the 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 VADEQ and VADCR 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 the 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 implementation scenarios is to reduce the bacteria loading reductions from controllable sources (excluding wildlife) such that exceedances of the single sample maximum criterion (235 cfu/100ml) are less than 10 percent, with no reduction from wildlife sources. The less than 10 percent exceedance rate is a conservative estimate of the extent of implementation needed to have each impaired segment de-listed, currently; a less than 10.5% exceedance rate is required. In addition, the 10 percent exceedance rate criteria mirrors the new proposed bacteria standard meeting a 10% exceedance rate of the single sample maximum criterion (235 cfu/100ml) and a 0% exceedance rate of the geometric mean criterion (126 cfu/100 ml). After the proposed bacteria standard is adopted by the VWCB, the Stage I implementation scenario will become the TMDL allocation scenario, since it will meet the new revised standard.

HSPF was run with a one-hour time step for the period January 2000 to December 2004, as with the TMDL allocation scenarios. The implicit MOS used in allocation scenarios was utilized in determining the Stage 1 implementation scenarios. Several scenarios were run until the Stage 1 goal was met.

The Stage 1 allocation for the Elk Creek impairment requires a 100% reduction in straight pipes, 75% reduction in livestock direct deposition, 0% reduction in wildlife direct deposition, a 57% reduction in nonpoint source loadings to residential land use, a 57% reduction in nonpoint source loadings to pasture land use, a 57% reduction in nonpoint source loadings to cropland, and no reduction in nonpoint source loadings to forest land. This scenario resulted in a 9.91% instantaneous standard exceedance rate. Fecal coliform loadings for the existing allocation and Stage 1 allocation scenario for nonpoint sources by land use and direct nonpoint sources are presented in Table 6.1 for the Elk Creek impairment. *E. coli* concentrations resulting from application of the fecal coliform to *E. coli* translator equation to the fecal coliform loads from the Stage 1 scenario are presented graphically in Figure 6.1.

Table 6.1. Annual nonpoint source fecal coliform loads for existing conditions and Stage 1 TMDL implementation scenario along with corresponding reductions in Elk Creek impairment.

Source	Existing Condition Load (cfu/yr)	Stage 1 Allocation Load (cfu/yr)	Scenario Reduction (%)
Direct			
Straight Pipes	1.18E+14	0.00E+00	100
Livestock	7.05E+13	1.76E+13	75
Wildlife	6.16E+13	6.16E+13	0
Total	*2.50E+14*	*7.92E+13*	68
Land-based			
Residential	7.14E+14	3.07E+14	57
Cropland	1.41E+14	6.06E+13	57
Pasture	8.05E+16	3.46E+16	57
Forest	3.79E+14	3.79E+14	0
Total	*8.17E+16*	*3.54E+16*	57

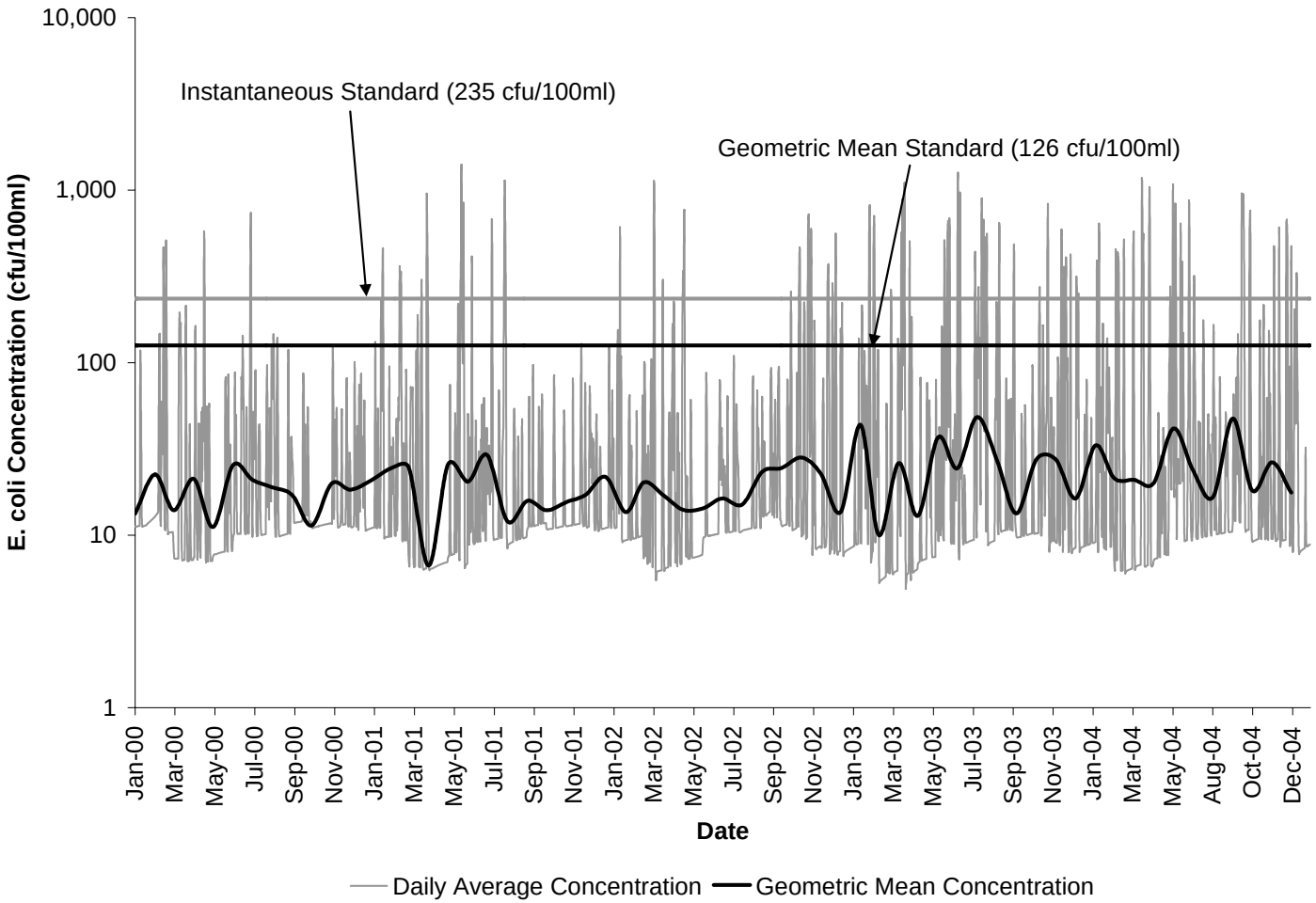

Figure 6.1. Geometric mean standard, instantaneous single sample standard, and average daily and geometric mean E. coli concentrations for the Stage 1 TMDL implementation scenario in Elk Creek (VAS-O05R) impairment.

6.3 Link to Ongoing Restoration Efforts

Implementation of this TMDL will contribute to on-going water quality improvement efforts aimed at restoring water quality in the watershed. Several BMPs known to be effective in controlling bacteria have also been identified for implementation to control sediment and nutrients in the southern rivers region.

6.4 Reasonable Assurance for Implementation

6.4.1 Follow-up Monitoring

Following the development of the TMDL, the VADEQ will make every effort to continue to monitor the impaired stream in accordance with its ambient and biological monitoring programs. VADEQ's Ambient Watershed Monitoring Plan for conventional pollutants calls for watershed monitoring to take place on a rotating basis, bi-monthly for two consecutive years of a six-year cycle. In accordance with DEQ Guidance Memo No. 03-2004 (http://www.deq.virginia.gov/waterguidance/pdf/032004.pdf), during periods of reduced resources, monitoring can temporarily discontinue until the TMDL staff determines that implementation measures to address the source(s) of impairments are being installed. Monitoring can resume at the start of the following fiscal year, next scheduled monitoring station rotation, or where deemed necessary by the regional office or TMDL staff, as a new special study. Since there may be a lag time of one-to-several years before any improvement in the benthic community will be evident, follow-up biological monitoring may not have to occur in the fiscal year immediately following the implementation of control measures.

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

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

In some cases, watersheds will require monitoring above and beyond what is included in VADEQ's standard monitoring plan. Ancillary monitoring by citizens' or watershed groups, local government, or universities is an option that may be used in such cases. An effort should be

made to ensure that ancillary monitoring follows established quality assurance/quality control (QA/QC) guidelines in order to maximize compatibility with VADEQ monitoring data. In instances where citizens' monitoring data is not available and additional monitoring is needed to assess the effectiveness of targeting efforts, TMDL staff may request of the monitoring managers in each regional office an increase in the number of stations or monitor existing stations at a higher frequency in the watershed. The additional monitoring beyond the original bimonthly single station monitoring will be contingent on staff resources and available laboratory budget. More information on citizen monitoring in Virginia and QA/QC guidelines is available at http://www.deq.virginia.gov/cmonitor/.

In order 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), VADEQ must meet the minimum data requirements from the original listing station or a station representative of the originally listed segment. The minimum data requirement for conventional pollutants (bacteria, dissolved oxygen, etc) is bimonthly monitoring for two consecutive years. For biological monitoring, the minimum requirement is two consecutive samples (one in the spring and one in the fall) in a one year period.

6.4.2 Regulatory Framework

While section 303(d) of the Clean Water Act and current USEPA 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. USEPA also requires that all new or revised National Pollutant Discharge Elimination System (NPDES) permits must be consistent with the assumptions and requirements of any applicable TMDL WLA pursuant to 40 CFR §122.44 (d)(1)(vii)(B). All such permits should be submitted to USEPA 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. USEPA 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 utilizes 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 IP development, especially those implemented through the water quality based effluent limitations. However, those requirements that are considered BMPs may be enhanced by inclusion in the TMDL IP, and their connection to the targeted

impairment. New permitted point source discharges will be allowed under the waste load allocation provided they implement applicable VPDES requirements (including any BMP, offset, trading, or payment-in-lieu conditions established to meet any future reduction requirements). Permits issued for facilities with wasteload allocations developed as part of a TMDL must be consistent with the assumptions and requirements of these wasteload allocations (WLA), as per USEPA regulations. In cases where a proposed permit modification is affected by a TMDL WLA, permit and TMDL staff must coordinate to ensure that new or expanding discharges meet this requirement. In 2005, VADEQ issued guidance memorandum 05-2011 describing the available options and the process that should be followed under those circumstances, including public participation, USEPA approval, State Water Control Board actions, and coordination between permit and TMDL staff. The guidance memorandum is available on VADEQ's web site at http://www.deq.virginia.gov/waterguidance/.

For the implementation of the TMDL's LA component, a TMDL implementation plan addressing at a minimum the WQMIRA requirements will be developed. An exception are the municipal separate storm sewer systems (MS4s) that are both covered by NPDES permits and expected to be included in TMDL implementation plans. It is the intent of the Commonwealth that the TMDL will be implemented using existing regulations and programs. VADEQ and VADCR coordinate separate State programs that regulate the management of pollutants carried by storm water runoff. VADEQ regulates storm water discharges associated with "industrial activities", while VADCR regulates storm water discharges from construction sites and MS4s. USEPA approved VADCR's VPDES stormwater program on December 30, 2004. VADCR's regulations became effective on January 29, 2005. VADEQ is no longer the regulatory agency responsible for administration and enforcement of the MS4 and construction stormwater permitting programs. More information is available on VADCR's web site through the following link: http://www.dcr.virginia.gov/sw/vsmp. Additional 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/soil_&_water/stormwat.shtml. As there are no MS4s permitted in the watershed at the time of this TMDL, they are not included in this study.

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

In response to a Memorandum of Understanding (MOU) between USEPA and VADEQ, VADEQ also submitted a draft Continuous Planning Process to USEPA in which VADEQ 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.

VADEQ staff will present both USEPA-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.

VADEQ staff will also request that the SWCB adopt TMDL WLAs as part of the Water Quality Management Planning Regulation (9VAC 25-720), except in those cases when permit limitations are equivalent to numeric criteria contained in the Virginia Water Quality Standards, such as 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 VADEQ's web site under http://www.deq.state.va.us/tmdl/pdf/ppp.pdf

6.4.3 Implementation Funding Sources

The implementation on pollutant reductions from non-regulated nonpoint sources relies heavily on incentive-based programs. Therefore, the identification of funding sources for non-regulated implementation activities is a key to success. Cooperating agencies, organizations and stakeholders must identify potential funding sources available for implementation during the development of the implementation plan in accordance with the "Virginia Guidance Manual for Total Maximum Daily Load Implementation Plans". The TMDL Implementation Plan Guidance Manual contains information on a variety of funding sources, as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

Some of the major potential sources of funding for non-regulated implementation actions may include the U.S. Department of Agriculture's Conservation Reserve Enhancement and Environmental Quality Incentive Programs, USEPA Section 319 funds Virginia's Nonpoint Source Management Program, the Virginia State Revolving Loan Program (also available for permitted activities), Virginia Agricultural Best Management Practices Cost-Share Programs, and the Virginia Water Quality Improvement Fund (available for nonpoint source pollution). With additional appropriations for the Water Quality Improvement Fund during the last two legislative sessions, the Fund has become an important funding stream for agricultural BMPs. Additionally, funding is being made available to address urban and residential water quality problems. Information on WQIF projects and allocations can be found at http://www.deq.virginia.gov/bay/wqif.html and at http://www.dcr.virginia.gov/soil_&_water/wqia.shtml.

6.4.4 Addressing Wildlife Contributions

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. Virginia and USEPA are not proposing the elimination of natural wildlife to allow for the attainment of water quality standards. However, managing overpopulations of wildlife remains an option available to local stakeholders. Should during the implementation plan development phase of a TMDL process, and in consultation with a local government or land owner, the Department of Game and Inland Fisheries (VDGIF) determine that a population of resident geese, deer or other wildlife is a at "nuisance" levels, measures to reduce such populations may be deemed acceptable if undertaken under the supervision, or issued permit, of the VDGIF or the U.S. Fish and Wildlife Service as appropriate.

Additional information on VDGIF's wildlife programs can be found at http://www.dgif.virginia.gov/hunting/va_game_wildlife/.

Based on the above, USEPA and Virginia have developed a process to address the wildlife issue. First step in this process 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 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 above. VADEQ 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, a use attainability analysis (UAA) may be initiated to reflect the presence of naturally high bacteria levels due to uncontrollable sources. In some cases, the effort may never have to go to the UAA phase because the water quality standard exceedances attributed to wildlife in the model may have been very small and infrequent and within the margin of error.

6.4.5 Attainability of Designated Use

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

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

1. Naturally occurring pollutant concentration prevents the attainment of the use;
2. Natural, ephemeral, intermittent or low flow conditions prevent the attainment of the use unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating state water conservation;
3. Human-caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place;
4. Dams, diversions or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the waterbody to its original condition or to operate the modification in such a way that would result in the attainment of the use;

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

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

This and other information is collected through a special study called a UAA. All site-specific criteria or designated use changes must be adopted by the SWCB as amendments to the water quality standards regulations. During the regulatory process, watershed stakeholders and other interested citizens, as well as the USEPA, will be able to provide comment during this process. Additional information can be obtained at http://www.deq.virginia.gov/wqs/pdf/WQS05A_1.pdf.

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

Chapter 7. Public Participation

The development of the Elk Creek TMDL would not have been possible without public participation. The stakeholder insight provided is gratefully acknowledged.

The first public meeting was held at the Elk Creek Rescue Squad on July 17, 2008 to discuss the need for a TMDL, discuss the draft watershed source assessment, and review the approach for TMDL development. Twenty-seven people attended the meeting. Copies of the presentation materials, watershed history results, source assessment per subwatershed, and various TMDL information handouts were available for public distribution. Public notice of the meetings was printed in the Virginia Register and advertised on the VADEQ and Mount Rogers Planning District Commission websites. Notification regarding the meetings was sent to area appointed and elected officials and Technical Advisory Committee (TAC) members. Members of the TAC were encouraged to distribute fliers advertising the meetings as appropriate. The general public was notified of the meetings through advertisements in the community calendar section of local newspapers, through post card mailings randomly distributed throughout the watershed, and through advertisements on the local cable television channels. There was a 30-day public comment period for the public meeting (July 17, 2008 to August 17, 2008), and three written comments were received.

The second and final public meeting was held at the Elk Creek Rescue Squad on July 21, 2009 to discuss the source allocations and reductions required to meet the TMDL. Copies of the draft TMDL report were available for public review and comment. Public notice of the meetings was printed in the Virginia Register and advertised on the VADEQ and Mount Rogers Planning District Commission websites. Notification regarding the meeting was sent to area appointed and elected officials, TAC members, and prior public meeting attendees. Members of the TAC were encouraged to distribute fliers advertising the meetings as appropriate. The general public was notified of the meeting through advertisements in the community calendar section of local newspapers and through advertisements on the local cable television channels. In addition, postcard mailings were randomly distributed throughout the watershed. There was a 30-day public comment period for the meeting that extended from July 21, 2009 to August 21, 2009. Twenty-five people attended and one written comment was received.

In addition to keeping the public apprised of progress in the development of the Elk Creek TMDL, a TMDL TAC was also established to help advise the TMDL developers. TAC meetings were held prior to public meetings. TAC meetings were held for this project on June 17, 2008 and July 20, 2009 at the Mount Rogers Planning District Commission in Marion, VA. Public notice was provided for these meetings in the Virginia Register. The TAC meetings were also advertised on the VADEQ and Mount Rogers Planning District Commission websites. Notification regarding the meeting was sent to area appointed and elected officials and TAC members. The TAC membership for the Elk Creek TMDL included representatives from the following agencies and organizations:

- Virginia Department of Environmental Quality
- Virginia Department of Conservation and Recreation

- Mount Rogers Planning District Commission
- New River Soil and Water Conservation District
- Grayson County Government

Four and 14 people attended the June and July meetings, respectively. TAC meetings were used as a forum to review data and assumptions used in the modeling, and to provide local government agencies an opportunity to raise concerns about the implications of the TMDL for their jurisdictions. The generous assistance of the staff of these agencies is gratefully acknowledged.

Glossary

Allocation
That portion of a receiving water's loading capacity that is attributed to one of its existing or future pollution sources (nonpoint or point) or to natural background sources.

Allocation Scenario
A proposed series of point and nonpoint source allocations (loadings from different sources), which are being considered to meet a water quality planning goal.

Background levels
Levels representing the chemical, physical, and biological conditions that would result from natural geomorphologic processes such as weathering and dissolution. A computer-run tool that contains an assessment and planning component that allows users to organize and display geographic information for selected watersheds. It also contains a modeling component to examine impacts of pollutant loadings from point and nonpoint sources and to characterize the overall condition of specific watersheds.

Bacterial Source Tracking (BST)
A collection of scientific methods used to track sources of fecal coliform.

Best Management Practices (BMP)
Methods, measures, or practices that are determined to be reasonable and cost- effective means for a land owner to meet certain, generally nonpoint source, pollution control needs. BMPs include structural and nonstructural controls and operation and maintenance procedures.

Calibration
The process of adjusting model parameters within physically defensible ranges until the resulting predictions give a best possible good fit to observed data.

Die-off (of fecal coliform)
Reduction in the fecal coliform population due to predation by other bacteria as well as by adverse environmental conditions (e.g., UV radiation, pH).

Direct Nonpoint Sources
Sources of pollution that are defined statutorily (by law) as nonpoint sources that are represented in the model as point source loadings due to limitations of the model. Examples include: Direct loads from straight pipes to streams.

E-911 digital data
Emergency response database prepared by the county that contains graphical data on road centerlines and buildings. The database contains approximate outlines of buildings, including dwellings and poultry houses.

Failing septic system
Septic systems in which drain fields have failed such that effluent (wastewater) that is supposed to percolate into the soil, now rises to the surface and ponds on the surface where it can flow over the soil surface to streams or contribute pollutants to the surface where they can be lost during storm runoff events.

Fecal coliform
A type of bacteria found in the feces of various warm-blooded animals that is used as indicator of the possible presence of pathogenic (disease causing) organisms.

Geometric mean
The geometric mean is simply the nth root of the product of n values. Using the geometric mean lessens the significance of a few extreme values (extremely high or low values). In practical terms, this means that if you have just a few bad samples, their weight is lessened.

Mathematically the geometric mean, $\bar{x}_g$, is expressed as: $\bar{x}_g = \sqrt[n]{x_1 \cdot x_2 \cdot x_3 \ldots \cdot x_n}$ where n is the number of samples, and x_i is the value of sample i.

Hydrology
The study of the distribution, properties, and effects of water on the earth's surface, in the soil and underlying rocks, and in the atmosphere.

HSPF (Hydrological Simulation Program-Fortran)
A computer-based model that calculates runoff, sediment yield, and fate and transport of various pollutants to the stream. The model was developed under the direction of the U.S. Environmental Protection Agency (EPA).

Instantaneous criterion
The instantaneous criterion or instantaneous water quality standard is the value of the water quality standard that should not be exceeded at any time. For example, the Virginia instantaneous water quality standard for fecal coliform is 1,000 cfu/100 mL. If this value is exceeded at any time, the water body is in exceedance of the state water quality standard.

Load Allocation (LA)
The portion of a receiving water's loading capacity that is attributed either to one of its existing or future nonpoint sources of pollution or to natural background.

Margin of Safety (MOS)
A required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the receiving waterbody. The MOS is normally incorporated into the conservative assumptions used to develop TMDLs (generally within the calculations or models). The MOS may also be assigned explicitly, as was done in this study, to ensure that the water quality standard is not violated.

Model
Mathematical representation of hydrologic and water quality processes. Effects of land use, slope, soil characteristics, and management practices are included.

Nonpoint Source
Pollution that is not released through pipes but rather originates from multiple sources over a relatively large area. Nonpoint sources can be divided into source activities related to either land or water use including failing septic tanks, improper animal-keeping practices, forest practices, and urban and rural runoff.

Pathogen
Disease-causing agent, especially microorganisms such as certain bacteria, protozoa, and viruses.

Point Source
Pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels from either municipal wastewater treatment plants or industrial waste treatment facilities. Point sources can also include pollutant loads contributed by tributaries to the main receiving water stream or river.

Pollution
Generally, the presence of matter or energy whose nature, location, or quantity produces undesired environmental effects. Under the Clean Water Act for example, the term is defined as the man-made or man-induced alteration of the physical, biological, chemical, and radiological integrity of water.

Reach
Segment of a stream or river.

Runoff
That part of rainfall or snowmelt that runs off the land into streams or other surface water. It can carry pollutants from the air and land into receiving waters.

Septic system
An on-site system designed to treat and dispose of domestic sewage. A typical septic system consists of a tank that receives liquid and solid wastes from a residence or business and a drainfield or subsurface absorption system consisting of a series of tile or percolation lines for disposal of the liquid effluent. Solids (sludge) that remain after decomposition by bacteria in the tank must be pumped out periodically.

Simulation
The use of mathematical models to approximate the observed behavior of a natural water system in response to a specific known set of input and forcing conditions. Models that have been validated, or verified, are then used to predict the response of a natural water system to changes in the input or forcing conditions.

Straight Pipe
Delivers wastewater directly from a building, e.g., house or milking parlor, to a stream, pond, lake, or river.

Total Maximum Daily Load (TMDL)
The sum of the individual wasteload allocations (WLA's) for point sources, load allocations (LA's) for nonpoint sources and natural background, plus a margin of safety (MOS). TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures that relate to a state's water quality standard.

Urban Runoff
Surface runoff originating from an urban drainage area including streets, parking lots, and rooftops.1

Validation (of a model)
Process of determining how well the mathematical model's computer representation describes the actual behavior of the physical process under investigation.

Wasteload Allocation (WLA)
The portion of a receiving water's loading capacity that is allocated to one of its existing or future point sources of pollution. WLAs constitute a type of water quality-based effluent limitation.

Water Quality Standard
Law or regulation that consists of the beneficial designated use or uses of a water body, the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular water body, and an anti-degradation statement.

Watershed
A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

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Appendix A – Historic Water Quality Data

Table A.0.1. Observed fecal coliform concentration and antecedent rainfall from 1992 to 1998 for VADEQ station 9-EKC003.78 in Elk Creek watershed.

Station	Date	Observed Fecal Coliform Concentration (cfu/100mL)	Total Rainfall for Sampling Day and Preceding 5 Days (in)
9-EKC003.78	05/21/1992	1,400	2.87
9-EKC003.78	07/20/1992	200	1.62
9-EKC003.78	09/29/1992	600	0.81
9-EKC003.78	11/10/1992	200	0.62
9-EKC003.78	01/13/1993	400	0.78
9-EKC003.78	03/22/1993	500	0.42
9-EKC003.78	05/18/1993	740	0.23
9-EKC003.78	07/21/1993	120	0.51
9-EKC003.78	09/02/1993	30	0.23
9-EKC003.78	11/18/1993	1,930	0.39
9-EKC003.78	02/09/1994	2,000	1.83
9-EKC003.78	05/24/1994	10	0.00
9-EKC003.78	07/24/1995	100	0.24
9-EKC003.78	09/18/1995	3,100	2.04
9-EKC003.78	07/23/1996	300	0.57
9-EKC003.78	09/16/1996	480	0.71
9-EKC003.78	11/06/1996	310	0.21
9-EKC003.78	01/15/1997	140	0.54
9-EKC003.78	03/12/1997	250	0.39
9-EKC003.78	05/14/1997	520	0.43
9-EKC003.78	07/14/1997	240	0.12
9-EKC003.78	09/23/1997	50	0.18
9-EKC003.78	11/17/1997	30	0.38
9-EKC003.78	01/06/1998	600	0.04
9-EKC003.78	03/10/1998	350	1.11
9-EKC003.78	05/26/1998	6,000	2.26
9-EKC003.78	08/11/1998	260	3.50
9-EKC003.78	10/20/1998	200	0.15
9-EKC003.78	12/17/1998	290	1.07

Table A.0.2. Observed fecal coliform concentration and antecedent rainfall from 1998 to 2001 for VADEQ station 9-EKC003.78 in Elk Creek watershed.

Station	Date	Observed Fecal Coliform Concentration (cfu/100mL)	Total Rainfall for Sampling Day and Preceding 5 Days (in)
9-EKC003.78	02/10/1999	20	0.28
9-EKC003.78	04/19/1999	300	0.60
9-EKC003.78	06/28/1999	70	1.10
9-EKC003.78	10/05/1999	200	0.45
9-EKC003.78	12/08/1999	100	0.24
9-EKC003.78	04/26/2000	5,700	0.89
9-EKC003.78	06/19/2000	100	1.29
9-EKC003.78	08/28/2000	1,100	1.58
9-EKC003.78	10/10/2000	100	0.05
9-EKC003.78	12/12/2000	100	1.02
9-EKC003.78	02/26/2001	600	0.84

Appendix B – Bacteria Source Tracking Report

The bacterial source tracking (BST) data were generated in a separate study for VADEQ performed by MapTech, Inc. and New River Highlands RC&D. The reader should refer to data and analyses for station 9-EKC000.11.

Bacterial Source Tracking Analyses to Support Virginia's TMDLs: *Non-Shellfish Stations*

Incorporated by Reference

Please refer to full document posted at:

http://www.deq.virginia.gov/tmdl/pdf/bstreports/directoryListing/032009bst.pdf

or contact VADEQ-SWRO

Appendix C – Fecal Coliform Loading in Subwatersheds

Table C.0.1. Monthly nonpoint fecal coliform loadings in sub-watershed ELC-01

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	1	33,701	9,505	1,324	256	351
Feb.	90	34,125	9,489	1,413	234	320
Mar.	446	55,393	14,801	2,648	201	351
Apr.	357	54,678	14,615	2,635	194	340
May.	90	57,354	15,401	2,798	201	351
Jun.	1	56,621	15,183	2,777	192	340
Jul.	1	59,711	15,992	2,945	199	351
Aug.	1	60,918	16,294	3,021	199	351
Sep.	1	60,292	16,076	3,000	248	340
Oct.	137	43,278	11,849	1,910	256	351
Nov.	137	43,355	11,834	1,940	248	340
Dec.	1	32,795	9,278	1,267	256	351
Total	1,265	592,222	160,316	27,679	2,684	4,138

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table C.0.2. Monthly nonpoint fecal coliform loadings in sub-watershed ELC-02

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)				
	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	19,314	5,449	758	240	430
Feb.	19,601	5,439	809	219	392
Mar.	31,962	8,479	1,515	197	430
Apr.	31,504	8,372	1,508	191	416
May.	32,894	8,823	1,601	197	430
Jun.	32,474	8,698	1,589	184	416
Jul.	34,243	9,161	1,686	190	430
Aug.	34,934	9,333	1,729	190	430
Sep.	34,622	9,208	1,717	233	416
Oct.	24,888	6,790	1,093	240	430
Nov.	24,931	6,781	1,110	233	416
Dec.	18,795	5,319	725	240	430
Total	340,161	91,853	15,840	2,555	5,069

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table C.0.3. Monthly nonpoint fecal coliform loadings in sub-watershed ELC-03.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	0	7,988	2,253	314	61	87
Feb.	28	8,082	2,249	335	55	80
Mar.	140	13,100	3,509	628	48	87
Apr.	112	12,937	3,464	625	46	85
May.	28	13,590	3,651	663	48	87
Jun.	0	13,416	3,599	659	44	85
Jul.	0	14,149	3,791	698	46	87
Aug.	0	14,435	3,862	716	46	87
Sep.	0	14,281	3,811	712	59	85
Oct.	43	10,246	2,809	453	61	87
Nov.	43	10,265	2,805	460	59	85
Dec.	0	7,773	2,199	301	61	87
Total	397	140,262	38,001	6,564	634	1,029

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table C.0.4. Monthly nonpoint fecal coliform loadings in sub-watershed ELC-04.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	1	19,422	5,476	764	216	257
Feb.	85	19,639	5,468	816	197	234
Mar.	423	31,791	8,534	1,529	174	257
Apr.	338	31,410	8,427	1,522	168	249
May.	86	33,046	8,880	1,615	174	257
Jun.	1	32,624	8,755	1,604	168	249
Jul.	1	34,407	9,221	1,701	174	257
Aug.	1	35,104	9,395	1,744	174	257
Sep.	1	34,713	9,270	1,732	209	249
Oct.	130	24,889	6,829	1,103	216	257
Nov.	129	24,935	6,821	1,120	209	249
Dec.	1	18,898	5,345	732	216	257
Total	1,198	340,878	92,421	15,982	2,295	3,026

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table C.0.5. Monthly nonpoint fecal coliform loadings in sub-watershed ELC-05

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	0	8,150	2,293	324	71	99
Feb.	31	8,255	2,293	346	65	90
Mar.	153	13,421	3,590	648	56	99
Apr.	122	13,257	3,546	645	55	96
May.	31	13,933	3,737	685	56	99
Jun.	0	13,757	3,685	680	55	96
Jul.	0	14,510	3,882	721	56	99
Aug.	0	14,806	3,956	740	56	99
Sep.	0	14,648	3,903	735	69	96
Oct.	47	10,479	2,867	468	71	99
Nov.	47	10,501	2,865	475	69	96
Dec.	0	7,928	2,238	310	71	99
Total	433	143,644	38,855	6,778	752	1,167

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table C.0.6. Monthly nonpoint fecal coliform loadings in sub-watershed ELC-06

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	3	38,811	10,864	1,585	198	303
Feb.	167	39,057	10,796	1,668	180	276
Mar.	823	64,531	17,166	3,160	147	303
Apr.	659	63,957	17,013	3,159	143	293
May.	167	67,030	17,903	3,345	147	303
Jun.	3	66,071	17,626	3,312	143	293
Jul.	3	69,576	18,541	3,504	147	303
Aug.	3	70,882	18,868	3,586	147	303
Sep.	3	70,045	18,593	3,554	191	293
Oct.	217	51,789	14,058	2,384	198	303
Nov.	253	51,371	13,917	2,385	191	293
Dec.	3	37,830	10,618	1,524	198	303
Total	2,308	690,950	185,964	33,166	2,030	3,567

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table C.0.7. Monthly nonpoint fecal coliform loadings in sub-watershed ELC-07

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	3	34,795	9,808	1,372	239	407
Feb.	177	35,168	9,795	1,465	218	371
Mar.	877	56,884	15,295	2,744	183	407
Apr.	702	56,224	15,103	2,731	177	394
May.	178	59,224	15,917	2,899	183	407
Jun.	3	58,469	15,692	2,878	176	394
Jul.	3	61,666	16,528	3,052	182	407
Aug.	3	62,917	16,841	3,131	182	407
Sep.	3	62,195	16,617	3,109	231	394
Oct.	269	44,563	12,236	1,979	239	407
Nov.	269	44,647	12,222	2,011	231	394
Dec.	3	33,856	9,573	1,313	239	407
Total	2,488	610,609	165,627	28,685	2,482	4,794

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table C.0.8. Monthly nonpoint fecal coliform loadings in sub-watershed ELC-08

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	4	36,248	10,144	1,484	271	409
Feb.	192	36,428	10,076	1,561	247	373
Mar.	945	60,146	16,036	2,957	214	409
Apr.	757	59,654	15,897	2,957	207	396
May.	192	62,609	16,727	3,130	214	409
Jun.	4	61,705	16,467	3,099	201	396
Jul.	4	64,972	17,319	3,278	208	409
Aug.	4	66,185	17,623	3,354	208	409
Sep.	4	65,366	17,365	3,323	263	396
Oct.	255	48,427	13,157	2,238	271	409
Nov.	290	48,002	13,016	2,236	263	396
Dec.	4	35,336	9,916	1,427	271	409
Total	2,656	645,079	173,744	31,045	2,839	4,823

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table C.0.9. Monthly nonpoint fecal coliform loadings in sub-watershed ELC-09.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	1	13,656	3,858	533	174	366
Feb.	79	13,778	3,848	569	158	333
Mar.	390	22,183	5,987	1,066	144	366
Apr.	312	21,931	5,911	1,061	139	354
May.	79	23,127	6,229	1,126	144	366
Jun.	1	22,829	6,140	1,118	134	354
Jul.	1	24,075	6,466	1,185	138	366
Aug.	1	24,560	6,587	1,216	138	366
Sep.	1	24,266	6,499	1,207	168	354
Oct.	119	17,428	4,800	769	174	366
Nov.	119	17,456	4,793	781	168	354
Dec.	1	13,292	3,767	511	174	366
Total	1,106	238,579	64,885	11,142	1,852	4,310

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table C.0.10. Monthly nonpoint fecal coliform loadings in sub-watershed ELC-10.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	1	36,081	9,878	1,639	352	652
Feb.	35	35,842	9,661	1,659	321	594
Mar.	172	63,272	16,275	3,239	287	652
Apr.	138	63,191	16,310	3,274	278	631
May.	35	65,210	17,091	3,443	287	652
Jun.	1	64,106	16,756	3,386	273	631
Jul.	1	66,938	17,555	3,559	282	652
Aug.	1	68,024	17,796	3,619	282	652
Sep.	1	67,296	17,472	3,565	341	631
Oct.	27	54,124	14,263	2,736	352	652
Nov.	53	52,378	13,768	2,638	341	631
Dec.	1	35,359	9,697	1,594	352	652
Total	468	671,822	176,523	34,349	3,748	7,683

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table C.0.11. Monthly nonpoint fecal coliform loadings in sub-watershed ELC-11.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	2	26,044	7,337	1,032	305	636
Feb.	99	26,364	7,330	1,101	278	579
Mar.	491	42,794	11,459	2,063	247	636
Apr.	393	42,271	11,316	2,053	239	615
May.	99	44,427	11,926	2,179	247	636
Jun.	2	43,863	11,759	2,163	234	615
Jul.	2	46,262	12,386	2,294	242	636
Aug.	2	47,201	12,621	2,353	242	636
Sep.	2	46,694	12,453	2,337	295	615
Oct.	150	33,444	9,161	1,488	305	636
Nov.	150	33,511	9,152	1,512	295	615
Dec.	2	25,338	7,160	988	305	636
Total	1,392	458,212	124,060	21,563	3,234	7,491

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table C.0.12. Monthly nonpoint fecal coliform loadings in sub-watershed ELC-12.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)				
	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	15,780	4,436	632	272	542
Feb.	16,047	4,437	674	248	494
Mar.	26,320	6,961	1,263	222	542
Apr.	25,949	6,875	1,257	215	524
May.	27,097	7,247	1,334	222	542
Jun.	26,757	7,146	1,325	215	524
Jul.	28,221	7,529	1,405	222	542
Aug.	28,797	7,673	1,441	222	542
Sep.	28,547	7,572	1,431	264	524
Oct.	20,425	5,553	911	272	542
Nov.	20,471	5,549	925	264	524
Dec.	15,348	4,328	605	272	542
Total	279,760	75,306	13,203	2,911	6,385

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table C.0.13. Monthly nonpoint fecal coliform loadings in sub-watershed ELC-13.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)				
	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	15,118	3,855	905	365	550
Feb.	16,165	4,078	966	332	501
Mar.	30,215	7,472	1,810	300	550
Apr.	29,925	7,430	1,801	290	532
May.	31,329	7,882	1,912	300	550
Jun.	31,083	7,818	1,898	285	532
Jul.	32,939	8,285	2,013	294	550
Aug.	33,763	8,492	2,065	294	550
Sep.	33,647	8,428	2,050	353	532
Oct.	21,771	5,456	1,306	365	550
Nov.	22,079	5,531	1,326	353	532
Dec.	14,499	3,700	867	365	550
Total	312,532	78,426	18,920	3,896	6,475

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table C.0.14. Monthly nonpoint fecal coliform loadings in sub-watershed ELC-14.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	0	7,343	1,876	437	106	159
Feb.	9	7,837	1,982	467	97	145
Mar.	44	14,594	3,623	874	86	159
Apr.	35	14,461	3,602	870	83	154
May.	9	15,165	3,821	924	86	159
Jun.	0	15,045	3,789	917	81	154
Jul.	0	15,943	4,015	972	84	159
Aug.	0	16,341	4,115	997	84	159
Sep.	0	16,275	4,084	990	103	154
Oct.	14	10,540	2,649	631	106	159
Nov.	14	10,688	2,684	640	103	154
Dec.	0	7,044	1,801	419	106	159
Total	125	151,275	38,040	9,137	1,125	1,869

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table C.0.15. Monthly nonpoint fecal coliform loadings in sub-watershed ELC-15

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)					
	Cropland	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	0	18,312	4,665	1,100	301	516
Feb.	22	19,569	4,938	1,174	275	471
Mar.	107	36,558	9,060	2,199	244	516
Apr.	85	36,227	9,009	2,188	236	500
May.	22	37,990	9,558	2,323	244	516
Jun.	0	37,694	9,481	2,306	230	500
Jul.	0	39,947	10,048	2,446	238	516
Aug.	0	40,948	10,299	2,508	238	516
Sep.	0	40,789	10,221	2,491	292	500
Oct.	33	26,357	6,610	1,586	301	516
Nov.	33	26,733	6,701	1,611	292	500
Dec.	0	17,560	4,476	1,053	301	516
Total	303	378,685	95,065	22,985	3,192	6,085

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table C.0.16. Monthly nonpoint fecal coliform loadings in sub-watershed ELC-16.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)				
	Pasture 1	Pasture 2	Pasture 3	Forest	Residential[1]
Jan.	5,771	1,476	341	155	297
Feb.	6,160	1,559	364	141	270
Mar.	11,468	2,841	682	127	297
Apr.	11,357	2,825	679	123	287
May.	11,888	2,996	721	127	297
Jun.	11,794	2,971	716	121	287
Jul.	12,496	3,148	759	125	297
Aug.	12,807	3,226	779	125	297
Sep.	12,761	3,201	773	150	287
Oct.	8,282	2,080	492	155	297
Nov.	8,396	2,108	500	150	287
Dec.	5,537	1,418	327	155	297
Total	118,718	29,850	7,134	1,654	3,494

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Appendix D – Required Reductions in Fecal Coliform Loads by Subwatershed – Allocation Scenario

Table D.0.1. Required annual reductions in nonpoint sources in sub-watershed ELC-01 of Elk Creek.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	126,494	0.2%	3,795	97%
Pasture	78,021,720	99%	2,340,649	97%
Forest	268,396	0.3%	268,396	0%
Residential	413,792	0.5%	12,414	97%
Total	78,830,402	100%	2,625,254	97%

Table D.0.2. Required annual reductions in direct nonpoint sources in sub-watershed ELC-01 of Elk Creek.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	64,272	49%	1,928	97%
Wildlife in Streams	46,845	36%	46,845	0%
Straight Pipes	19,577	15%	0	100%
Total	130,695	100%	48,774	63%

Table D.0.3. Required annual reductions in nonpoint sources in sub-watershed ELC-02 of Elk Creek.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Pasture	44,785,465	98%	1,343,563	97%
Forest	255,498	0.6%	255,498	0%
Residential	506,894	1%	15,207	97%
Total	45,547,857	100%	1,614,268	96%

Table D.0.4. Required annual reductions in direct nonpoint sources in sub-watershed ELC-02 of Elk Creek.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	36,774	37%	1,103	97%
Wildlife in Streams	36,560	37%	36,560	0%
Straight Pipes	26,590	27%	0	100%
Total	99,924	100%	37,663	62%

Table D.0.5. Required annual reductions in nonpoint sources in sub-watershed ELC-03 of Elk Creek.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	39,673	0.2%	1,190	97%
Pasture	18,482,699	99%	554,480	97%
Forest	63,369	0.3%	63,369	0%
Residential	102,927	0.6%	3,088	97%
Total	18,688,668	100%	622,128	97%

Table D.0.6. Required annual reductions in direct nonpoint sources in sub-watershed ELC-03 of Elk Creek.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	15,240	32%	457	97%
Wildlife in Streams	11,957	25%	11,957	0%
Straight Pipes	20,016	42%	0	100%
Total	47,213	100%	12,414	74%

Table D.0.7. Required annual reductions in nonpoint sources in sub-watershed ELC-04 in Elk Creek.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	119,840	0.3%	3,595	97%
Pasture	44,928,150	99%	1,347,843	97%
Forest	229,488	0.5%	229,488	0%
Residential	302,610	0.7%	9,078	97%
Total	45,580,088	100%	1,590,005	97%

Table D.0.8. Required annual reductions in direct nonpoint sources in sub-watershed ELC-04 in Elk Creek.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	37,106	26%	1,113	97%
Wildlife in Streams	35,133	25%	35,133	0%
Straight Pipes	68,521	49%	0	100%
Total	140,760	100%	36,246	74%

Table D.0.9. Required annual reductions in nonpoint sources in sub-watershed ELC-05 of Elk Creek.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	43,293	0.2%	1,299	97%
Pasture	18,927,657	99%	567,829	97%
Forest	75,167	0.4%	75,167	0%
Residential	116,697	0.6%	3,501	97%
Total	19,162,815	100%	647,796	97%

Table D.0.10. Required annual reductions in direct nonpoint sources in sub-watershed ELC-05 of Elk Creek.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	15,737	33%	472	97%
Wildlife in Streams	12,809	27%	12,809	0%
Straight Pipes	19,724	41%	0	100%
Total	48,269	100%	13,281	72%

Table D.0.11. Required annual reductions in nonpoint sources in sub-watershed ELC-06 in Elk Creek.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	230,778	0.3%	6,923	97%
Pasture	91,007,981	99%	2,730,237	97%
Forest	203,012	0.2%	203,012	0%
Residential	356,667	0.4%	10,700	97%
Total	91,798,438	100%	2,950,872	97%

Table D.0.12. Required annual reductions in direct nonpoint sources in sub-watershed ELC-06 in Elk Creek.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	76,789	45%	2,304	97%
Wildlife in Streams	43,410	26%	43,410	0%
Straight Pipes	49,309	29%	0	100%
Total	169,507	100%	45,714	73%

Table D.0.13. Required annual reductions in nonpoint sources in sub-watershed ELC-07 in Elk Creek.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	248,761	0.3%	7,463	97%
Pasture	80,492,088	99%	2,414,760	97%
Forest	248,163	0.3%	248,163	0%
Residential	479,391	0.6%	14,382	97%
Total	81,468,402	100%	2,684,768	97%

Table D.0.14. Required annual reductions in direct nonpoint sources in sub-watershed ELC-07 in Elk Creek.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	66,591	33%	1,998	97%
Wildlife in Streams	49,294	24%	49,294	0%
Straight Pipes	85,322	42%	0	100%
Total	201,208	100%	51,292	75%

Table D.0.15. Required annual reductions in nonpoint sources in sub-watershed ELC-08 of Elk Creek.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	265,588	0.3%	7,968	97%
Pasture	84,986,860	99%	2,549,603	97%
Forest	283,933	0.3%	283,933	0%
Residential	482,349	0.6%	14,470	97%
Total	86,018,730	100%	2,855,975	97%

Table D.0.16. Required annual reductions in direct nonpoint sources in sub-watershed ELC-08 of Elk Creek.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	71,819	28%	2,155	97%
Wildlife in Streams	54,383	21%	54,383	0%
Straight Pipes	128,860	51%	0	100%
Total	255,063	100%	56,538	78%

Table D.0.17. Required annual reductions in nonpoint sources in sub-watershed ELC-09 of Elk Creek.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	110,616	0.3%	3,318	97%
Pasture	31,460,667	98%	943,819	97%
Forest	185,229	0.6%	185,229	0%
Residential	430,958	1%	12,929	97%
Total	32,187,471	100%	1,145,296	96%

Table D.0.18. Required annual reductions in direct nonpoint sources in sub-watershed ELC-09 of Elk Creek.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	25,841	25%	775	97%
Wildlife in Streams	29,214	28%	29,214	0%
Straight Pipes	49,090	47%	0	100%
Total	104,145	100%	29,989	71%

Table D.0.19. Required annual reductions in nonpoint sources in sub-watershed ELC-10 of Elk Creek.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	46,832	0.1%	1,405	97%
Pasture	88,269,432	99%	2,648,080	97%
Forest	374,843	0.4%	374,843	0%
Residential	768,303	0.9%	23,049	97%
Total	89,459,410	100%	3,047,377	97%

Table D.0.20. Required annual reductions in direct nonpoint sources in sub-watershed ELC-10 of Elk Creek.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	78,845	48%	2,365	97%
Wildlife in Streams	57,218	35%	57,218	0%
Straight Pipes	27,029	17%	0	100%
Total	163,091	100%	59,583	63%

Table D.0.21. Required annual reductions in nonpoint sources in sub-watershed ELC-11 of Elk Creek.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	139,210	0.2%	4,176	97%
Pasture	60,383,424	98%	1,811,501	97%
Forest	323,410	0.5%	323,410	0%
Residential	749,128	1%	22,474	97%
Total	61,595,172	100%	2,161,561	96%

Table D.0.22. Required annual reductions in direct nonpoint sources in sub-watershed ELC-11 of Elk Creek.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	50,026	22%	1,501	97%
Wildlife in Streams	52,759	23%	52,759	0%
Straight Pipes	124,185	55%	0	100%
Total	226,970	100%	54,259	76%

Table D.0.23. Required annual reductions in nonpoint sources in sub-watershed ELC-12 of Elk Creek.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Pasture	36,826,834	98%	1,104,804	97%
Forest	291,104	0.8%	291,104	0%
Residential	638,457	2%	19,154	97%
Total	37,756,394	100%	1,415,061	96%

Table D.0.24. Required annual reductions in direct nonpoint sources in sub-watershed ELC-12 of Elk Creek.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	30,645	18%	919	97%
Wildlife in Streams	39,064	23%	39,064	0%
Straight Pipes	99,348	59%	0	100%
Total	169,058	100%	39,984	76%

Table D.0.25. Required annual reductions in nonpoint sources in sub-watershed ELC-13 of Elk Creek.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Pasture	40,987,718	98%	1,229,630	97%
Forest	389,596	0.9%	389,596	0%
Residential	647,479	2%	19,424	97%
Total	42,024,792	100%	1,638,651	96%

Table D.0.26. Required annual reductions in direct nonpoint sources in sub-watershed ELC-13 of Elk Creek.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	43,897	14%	1,317	97%
Wildlife in Streams	55,374	17%	55,374	0%
Straight Pipes	224,410	69%	0	100%
Total	323,681	100%	56,691	82%

Table D.0.27. Required annual reductions in nonpoint sources in sub-watershed ELC-14 of Elk Creek.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	12,539	0.1%	376	97%
Pasture	19,845,276	98%	595,358	97%
Forest	112,475	0.6%	112,475	0%
Residential	186,898	0.9%	5,607	97%
Total	20,157,188	100%	713,816	96%

Table D.0.28. Required annual reductions in direct nonpoint sources in sub-watershed ELC-14 of Elk Creek.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	21,203	30%	636	97%
Wildlife in Streams	19,059	27%	19,059	0%
Straight Pipes	30,389	43%	0	100%
Total	70,652	100%	19,696	72%

Table D.0.29. Required annual reductions in nonpoint sources in sub-watershed ELC-15 of Elk Creek.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	30,293	0.1%	909	97%
Pasture	49,673,626	98%	1,490,207	97%
Forest	319,163	0.6%	319,163	0%
Residential	608,470	1%	18,254	97%
Total	50,631,552	100%	1,828,534	96%

Table D.0.30. Required annual reductions in direct nonpoint sources in sub-watershed ELC-15 of Elk Creek.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	53,339	20%	1,600	97%
Wildlife in Streams	51,195	19%	51,195	0%
Straight Pipes	167,431	62%	0	100%
Total	271,965	100%	52,795	81%

Table D.0.31. Required annual reductions in nonpoint sources in sub-watershed ELC-16 of Elk Creek.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Pasture	15,570,220	97%	467,106	97%
Forest	165,370	1%	165,370	0%
Residential	349,362	2%	10,481	97%
Total	16,084,952	100%	642,957	96%

Table D.0.32. Required annual reductions in direct nonpoint sources in sub-watershed ELC-16 of Elk Creek.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	16,565	22%	497	97%
Wildlife in Streams	21,743	29%	21,743	0%
Straight Pipes	37,256	49%	0	100%
Total	75,564	100%	22,240	71%