Bacteria Total Maximum Daily Load Development for Hays Creek, Moffatts Creek, Walker Creek, and Otts Creek in Augusta County and Rockbridge County, Virginia

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Executive Summary

Background

The Hays Creek (I34) watershed (to which Moffatts Creek, Walker Creek, and Otts Creek are tributaries) is located in Augusta County and Rockbridge County. Hays Creek flows into the Maury River (USGS Hydrologic Unit Code 02080202), which discharges into the James River at Glasgow. The James River flows into the Chesapeake Bay at Hampton Roads. The watershed is approximately 51,500 acres.

Hays Creek (VAV-I34R_HYS01A00) and Moffatts Creek (VAV-I34R_MOF01A00) were first listed as impaired on Virginia's 1998 303(d) TMDL Priority List and Report due to water quality violations of the bacteria standard. Otts Creek (VAV-I34R_OTS01A00) and Walker Creek (VAV-I34R_WKS01A06) are listed as impaired on Virginia's 2006 Final 2006 305(b)/303(d) Water Quality Assessment Integrated Report (VADEQ, 2006) due to water quality violations of the bacteria standard. The impaired segments have been assessed as not supporting the Clean Water Act's Primary Contact Recreational Use Goal.

This document describes the Total Maximum Daily Loads (TMDL) for bacteria that were developed for the Hays Creek, Walker Creek, and Otts Creek watersheds in order to remedy the bacteria water quality impairment. The TMDLs were developed for the new water quality standard for bacteria, which states that the calendar-month geometric mean concentration of *E. coli* shall not exceed 126 cfu/100 mL, and that no single sample can exceed a concentration of 235 cfu/100 mL. A glossary of terms used in the development of this TMDL is listed in Appendix A.

Sources of Bacteria

There are two small point sources covered under general permits to discharge bacteria into the Hays Creek watershed. However, the majority of the bacteria load originates from nonpoint sources. The nonpoint sources of bacteria originate from livestock, wildlife, and humans. Significant bacteria loads come from cattle and wildlife

directly depositing feces in the stream. Livestock directly depositing bacteria on the land surface also contribute a significant amount of bacteria to the stream during large storm events. Wildlife contribute bacteria loadings to the stream and all land surfaces, in accordance with the habitat range for each species. Pets also contribute a small amount of bacteria to residential areas. The amounts of bacteria produced in different locations (e.g., streams, pasture, forest) were estimated on a monthly basis to account for seasonal variability in wildlife behavior and livestock production and practices. Livestock management and production factors, such as the fraction of time livestock spend in streams, were considered on a monthly basis. These sources of bacteria can be summarized in two ways. First, Table ES.1 summarizes the bacteria produced in each location (stream, cropland, pasture, residential, and forest). Land-deposited sources of bacteria then undergo die-off and must be transported by runoff from rainfall events into the stream. Direct-deposited sources enter the stream immediately without die-off and without the need for a rainfall event. The relative contributions given in Tables ES.2 through ES.4 reflect the results of modeling (see next section) that takes into account these varied fate and transport processes and represents the fraction of in-stream bacteria attributable to each source for each impaired stream segment.

Table ES. 1. Estimated annual fecal coliform loadings to the stream and the various land use categories for existing conditions in the Hays Creek watershed.

Source	Fecal coliform loading ($x10^{12}$ cfu/yr)	Percent of total loading
Direct loading to streams		
Livestock in stream	191	1%
Wildlife in stream	52	<1%
Straight pipes	1	<1%
Point Sources	<1	<1%
Loading to land surfaces		
Cropland	1,005	5%
Pasture	18,547	92%
Residential	130	<1%
Forest	222	1%
Total	**20,149**	

Table ES.2. Relative contributions of different *E. coli* sources to the overall *E. coli* concentration for existing conditions in Otts Creek.

Source	Mean Daily *E. coli* Concentration by Source, cfu/100 mL	Relative Contribution by Source
Nonpoint source loadings from pervious land segments	59	33%
Direct nonpoint source loadings to the stream from wildlife	40	23%
Direct nonpoint source loadings to the stream from livestock	62	35%
Interflow and groundwater contribution	8	4%
Straight-pipe discharges to stream	9	5%
Nonpoint source loadings from impervious land segments	0.6	<1%
All Sources	178	

Table ES.3. Relative contributions of different *E. coli* sources to the overall *E. coli* concentration for existing conditions in Walker Creek.

Source	Mean Daily *E. coli* Concentration by Source, cfu/100 mL	Relative Contribution by Source
Nonpoint source loadings from pervious land segments	51	30%
Direct nonpoint source loadings to the stream from wildlife	28	17%
Direct nonpoint source loadings to the stream from livestock	80	47%
Interflow and groundwater contribution	8	4%
Straight-pipe discharges to stream	4	2%
Nonpoint source loadings from impervious land segments	0.5	<1%
All Sources	172	

Table ES.4. Relative contributions of different *E. coli* sources to the overall *E. coli* concentration for existing conditions in Hays Creek.

Source	Mean Daily *E. coli* Concentration by Source, cfu/100 mL	Relative Contribution by Source
Nonpoint source loadings from pervious land segments	84	27%
Direct nonpoint source loadings to the stream from wildlife	71	23%
Direct nonpoint source loadings to the stream from livestock	143	46%
Interflow and groundwater contribution	8	2%
Straight-pipe discharges to stream	5	2%
Nonpoint source loadings from impervious land segments	0.6	<1%
Point sources	<0.1	<1%
All Sources	312	

Modeling

The Hydrological Simulation Program – FORTRAN (HSPF) (Bicknell et al., 2001) was used to simulate the fate and transport of fecal coliform bacteria in the Hays Creek watershed. HSPF is a continuous model that can represent fate and transport of pollutants on both the land surface and in the stream. As recommended by VADEQ, water quality modeling was conducted with fecal coliform inputs, and then a translator equation was used to convert the output to *E. coli* for the final TMDLs. To identify localized sources of fecal coliform within the watershed, the Hays Creek watershed was divided into 32 sub-watersheds based on homogeneity of land use, stream network connectivity, and monitoring station locations.

As continuous flow data for Hays Creek were not available, the hydrology component of HSPF was calibrated for a surrogate watershed. Based on the similarities in relative distance, watershed size, distribution of land use, and hydrologic soil group between the Hays Creek watershed and the Christians Creek watershed in Augusta County, the Christians Creek watershed was selected as the surrogate watershed. The hydrologic parameters were calibrated during the development of the fecal coliform TMDL for Christians Creek (VADEQ, 2002), and the calibrated parameters were transferred to the corresponding land uses in the Hays Creek watershed. The remaining

hydrologic parameters, those that have a direct relation to physical characteristics of the watershed (e.g., land slope), were obtained from digital maps of the Hays Creek watershed. The simulated flows from Hays Creek were compared to the limited observed flow data from the watershed to further validate the calibration.

The water quality component of the HSPF model was calibrated for Otts Creek, Walker Creek and Hays Creek at stations 2-OTS000.45, 2-WKS001.03, 2-HYS001.41, and 2-HYS007.46 for the period January 2002 – December 2006 (which encompassed the observed fecal coliform data collected at stations 2-OTS000.45, 2-WKS001.03, and 2-HYS007.46 by DEQ). The model was validated using fecal coliform data from station 2-HYS001.41 for the period January 1999 to December 2001. Inputs to the model included fecal coliform loadings on land and in the stream. A comparison of simulated and observed bacteria concentrations in the stream indicated that the model adequately simulated the fate and transport of fecal bacteria.

Existing Conditions

Contributions from various sources in the Hays Creek watershed were represented in HSPF to establish the existing conditions for a representative 6-year period that included both low and high-flow conditions. This 6-year period used meteorological data from 2001-2006 to represent the appropriate range of conditions. Monthly bacteria loadings to different land use categories were calculated for each sub-watershed. Direct seasonal bacteria loadings to streams by cattle were calculated for pastures adjacent to streams. Bacteria loadings to streams and land by wildlife were estimated for several species. Bacteria loadings to land from failing septic systems and directly to the stream from straight pipes were estimated based on house ages and information from the Local Steering Committee (LSC). Bacteria contributions from pet waste were also considered. Meteorological data were paired with bacterial loading and land use data for existing conditions to establish this baseline scenario. Results from the calibrated HSPF model showed routine high signatures from livestock direct deposit, wildlife direct deposit, and pervious land surfaces.

Allocation Scenarios

Different source reduction 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 violations. These scenarios were conducted using meteorological data from 2001-2006 to represent a variety of high and low flow conditions. The bacteria loadings used in modeling correspond to anticipated future conditions for the Hays Creek watershed, which do not differ from existing conditions. The reductions required for each impaired segment to meet the applicable water quality standard are presented in Table ES.5. Details on the loads to be reduced from each source are given in Tables ES.6 through ES.11.

Table ES. 5. Required fecal coliform loading reductions (%) to meet the *E. coli* standards.

Impaired Segment	Cattle Direct Deposit	Loads from Pasture	Loads from Cropland	Straight Pipes and Failing Septic Systems	Loads from Residential Areas*	Wildlife Direct Deposit
Otts Creek	65	95	95	100	0	55
Walker Creek	100	99	95	100	0	30
Hays Creek	90	95	95	100	0	90

*Primarily loads from pets

Table ES.6. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation for Otts Creek.

Land use category	Existing Conditions		Allocation Scenario	
	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total land deposited load from nonpoint sources	TMDL nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Existing Load
Cropland	281	7	14	95
Pasture	3,499	91	175	95
Residential-Pets	30	<1	30	0
Residential-Septics	4	<1	0	100
Forest	25	<1	25	0
Total	3,839		244	94

Table ES.7. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation for Walker Creek.

Land use category	Existing Conditions		Allocation Scenario	
	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total land deposited load from nonpoint sources	TMDL nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Existing Load
Cropland	242	6	12	95
Pasture	3,453	92	31	99
Residential-Pets	27	<1	27	0
Residential-Septics	5	<1	0	100
Forest	41	1	41	0
Total	3,768		111	97

Table ES.8. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation for Hays Creek.

Land use category	Existing Conditions		Allocation Scenario	
	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total land deposited load from nonpoint sources	TMDL nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Existing Load
Cropland	1,014	5	51	95
Pasture	20,743	94	1,037	95
Residential-Pets	110	<1	110	0
Residential-Septics	20	<1	0	100
Forest	153	<1	153	0
Total	22,040		1,351	94

Table ES.9. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for the TMDL allocation scenario for Otts Creek.

Source	Existing Conditions		Allocation Scenario	
	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total direct deposited load from direct nonpoint source	TMDL direct nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Existing Load
Livestock in Streams	26	88	9	65
Straight Pipes	1	2	0	100
Wildlife in Streams	3	10	1	55
Total	30		10	67

Table ES.10. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for the TMDL allocation scenario for Walker Creek.

Source	Existing Conditions		Allocation Scenario	
	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total direct deposited load from direct nonpoint source	TMDL direct nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Existing Load
Livestock in Streams	37	91	0	100
Straight Pipes	<1	1	0	100
Wildlife in Streams	3	8	2	30
Total	41		2	95

Table ES.11. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for the TMDL allocation scenario for Hays Creek.

Source	Existing Conditions		Allocation Scenario	
	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total direct deposited load from direct nonpoint source	TMDL direct nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Existing Load
Livestock in Streams	288	91	29	90
Straight Pipes	1	<1	0	100
Wildlife in Streams	28	9	3	90
Total	317		32	90

Two small point sources currently discharge at or below their permit requirements; therefore, the proposed scenario requires load reductions only for nonpoint sources of fecal coliform. The TMDL was determined as the average annual *E. coli* load at the watershed outlets for the chosen allocation scenarios. The WLAs for Otts Creek and Walker Creek were determined as less than 1% of the total TMDL load. The WLA for Hays Creek was obtained by taking the product of the permitted point sources' *E. coli* discharge concentrations and allowable annual discharges, and also reflects an allocation for potential future permits. The LAs were then determined as the TMDL-WLA. Equation ES.1 was used to calculate the TMDL allocations shown in Tables ES.12 through ES.14.

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

where:

WLA = wasteload allocation (point source contributions);

LA = load allocation (nonpoint source contributions); and

MOS = margin of safety.

Table ES.12. Estimated annual *E. coli* loadings (cfu/yr) at the watershed outlet used for the Otts Creek bacteria TMDL.

Parameter	ΣWLA	ΣLA	MOS*	TMDL
E. coli	0.09×10^{12}	8.95×10^{12}	--	9.04×10^{12}

*Implicit MOS

Table ES.13. Estimated annual *E. coli* loadings (cfu/yr) at the watershed outlet used for the Walker Creek bacteria TMDL.

Parameter	ΣWLA	ΣLA	MOS*	TMDL
E. coli	0.06×10^{12}	5.95×10^{12}	--	6.01×10^{12}

*Implicit MOS

Table ES.14. Estimated annual *E. coli* loadings (cfu/yr) at the watershed outlet used for the Hays Creek bacteria TMDL.

Parameter	ΣWLA	ΣLA	MOS*	TMDL
E. coli	0.02×10^{13}	4.46×10^{13}	--	4.48×10^{13}

*Implicit MOS

Transitional Scenario

The implementation of a transitional scenario, or Stage 1 implementation, will allow for an evaluation of the effectiveness of management practices and accuracy of model assumptions through data collection. Stage 1 implementation was developed with a target of a 10.5% violation rate of the instantaneous *E. coli* water quality criterion (235 cfu/100 mL) and no reductions in wildlife sources. The Stage 1 scenarios are given in Table ES.15 for each impaired segment.

Table ES.15. Allocation scenario for Stage 1 TMDL implementation for the Hays Creek watershed.

Impaired Segment	Single Sample Criterion Percent Violation	Required Fecal Coliform Loading Reductions to Meet the Stage 1 Goal, %				
		Livestock Direct Deposit	Loads from Pasture	Loads from Cropland	Straight Pipes and Failing Septic Systems	Loads from Residential Areas
Otts Creek	10	55	0	0	100	0
Walker Creek	9	40	0	0	100	0
Hays Creek	10	80	80	80	100	0

Implementation

The goal of the TMDL program is to establish a three-step path that will lead to attainment of water quality standards. The first step in the process is to develop TMDLs that will result in attainment of water quality standards. This report represents the culmination of that effort for the bacteria impairments on Hays Creek, Walker Creek, and Otts Creek. The second step is to develop a TMDL implementation plan. The final step is to initiate recommendations outlined in the TMDL implementation plans and to monitor stream water quality to determine if water quality standards are being attained.

Watershed stakeholders will have opportunities to provide input and to participate in the development of the implementation plan, which will also be supported by regional and local offices of VADEQ, VADCR, and other cooperating agencies.

Public Participation

Public participation was solicited at every stage of TMDL development in order to receive inputs from stakeholders and to apprise the stakeholders of the progress made. In August 2007, members of the Center for TMDL and Watershed Studies at Virginia Tech traveled to Hays Creek to become acquainted with the watershed. Throughout the process, personnel from Virginia Tech contacted stakeholders and local agency personnel via telephone and in person to acquire their input. Two public meetings were held to inform stakeholders of the TMDL process and solicit feedback. These were held on August 21, 2007 and January 29, 2008 at the Rockbridge Baths Volunteer Fire Department, located near the outlet of the watershed. Two Local Steering Committee meetings were also held, on August 23, 2007 and December 11, 2007. These meetings provided a forum for a group of interested stakeholders and agency personnel to provide detailed feedback on the estimates and methods used in these TMDLs. More details on public participation can be found in Chapter 7.

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 violate state water quality standards and to develop Total Maximum Daily Loads (TMDLs) for such water bodies. A TMDL reflects the total pollutant loading a water body can receive and still meet water quality standards. A TMDL establishes the maximum allowable pollutant loading from both point and nonpoint sources for a water body, allocates the load among the pollutant contributors, and provides a framework for taking actions to restore water quality.

1.1.2. Impairment Listing

Hays Creek (VAV-I34R_HYS01A00) and Moffatts Creek (VAV-I34R_MOF01A00) were first listed as impaired on Virginia's 1998 303(d) TMDL Priority List and Report due to water quality violations of the bacteria standard. Otts Creek (VAV-I34R_OTS01A00) and Walker Creek (VAV-I34R_WKS01A06) are listed as impaired on Virginia's 2006 Section 303(d) Total Maximum Daily Load Priority List and Report (VADEQ, 2006) due to water quality violations of the bacteria standard (Figure 1.1). The Virginia Department of Environmental Quality (VADEQ) has described the impaired segments as presented in Table 1.1.

Table 1.1. Impaired Segments Addressed in this TMDL report.

Impaired Segment	Size	Target Date for TMDL Development	Description
Hays Creek	11.99 miles	2010	Extending from the confluence with Moffatts Creek to the confluence with the Maury River
Moffatts Creek	7.66 miles	2016	Extending from the headwaters to the confluence with Hays Creek
Walker Creek	11.62 miles	2018	Extending from the headwater tributaries to the confluence with Hays Creek
Otts Creek	5.13 miles	2018	Extending from the confluence with an unnamed tributary at the Route 726 bridge crossing to the confluence with Moffatts Creek

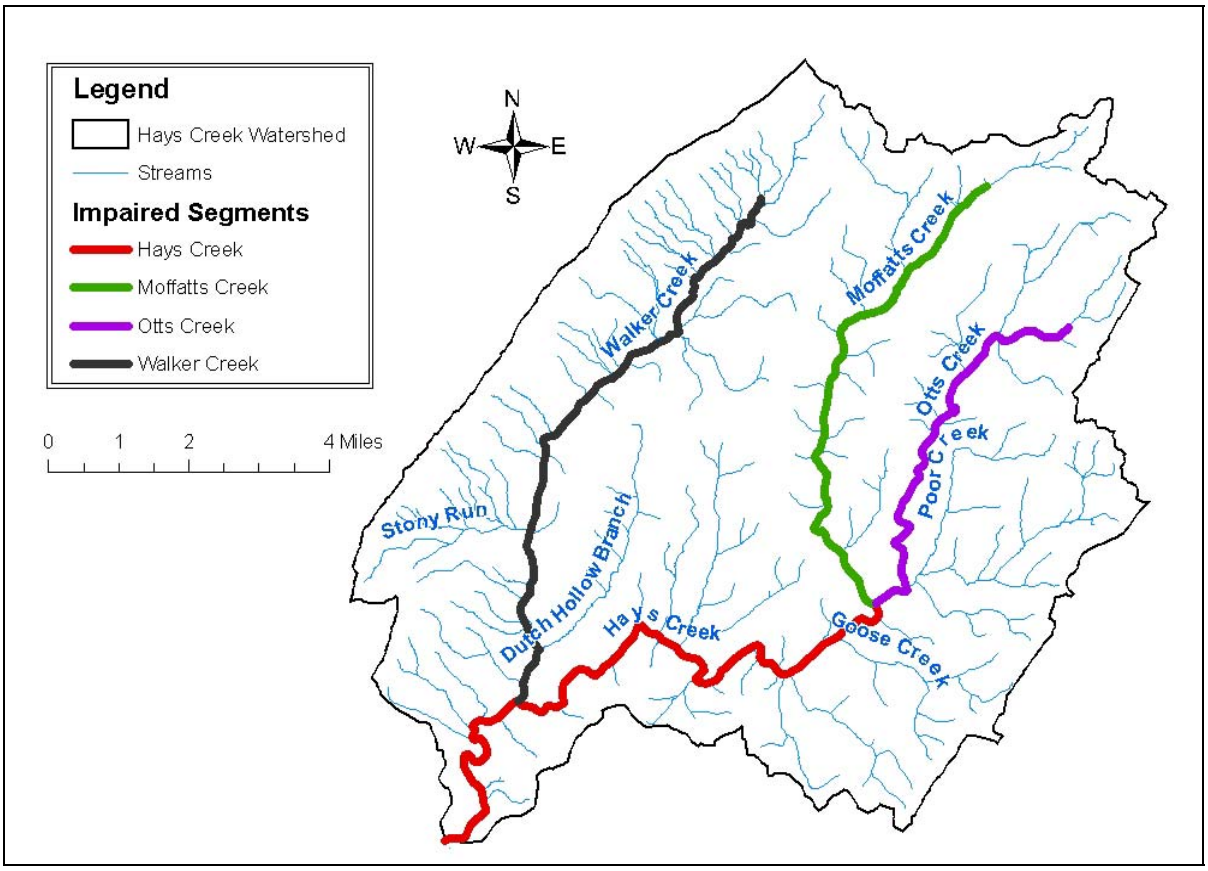

Figure 1.1. Impaired segments in the Hays Creek watershed.

1.1.3. Watershed Location and Description

The Hays Creek (I34) watershed (to which Moffatts Creek, Walker Creek, and Otts Creek are tributaries) is located in Augusta County and Rockbridge County (Figure 1.2). The watershed is approximately 51,500 acres and is part of the James River Basin.

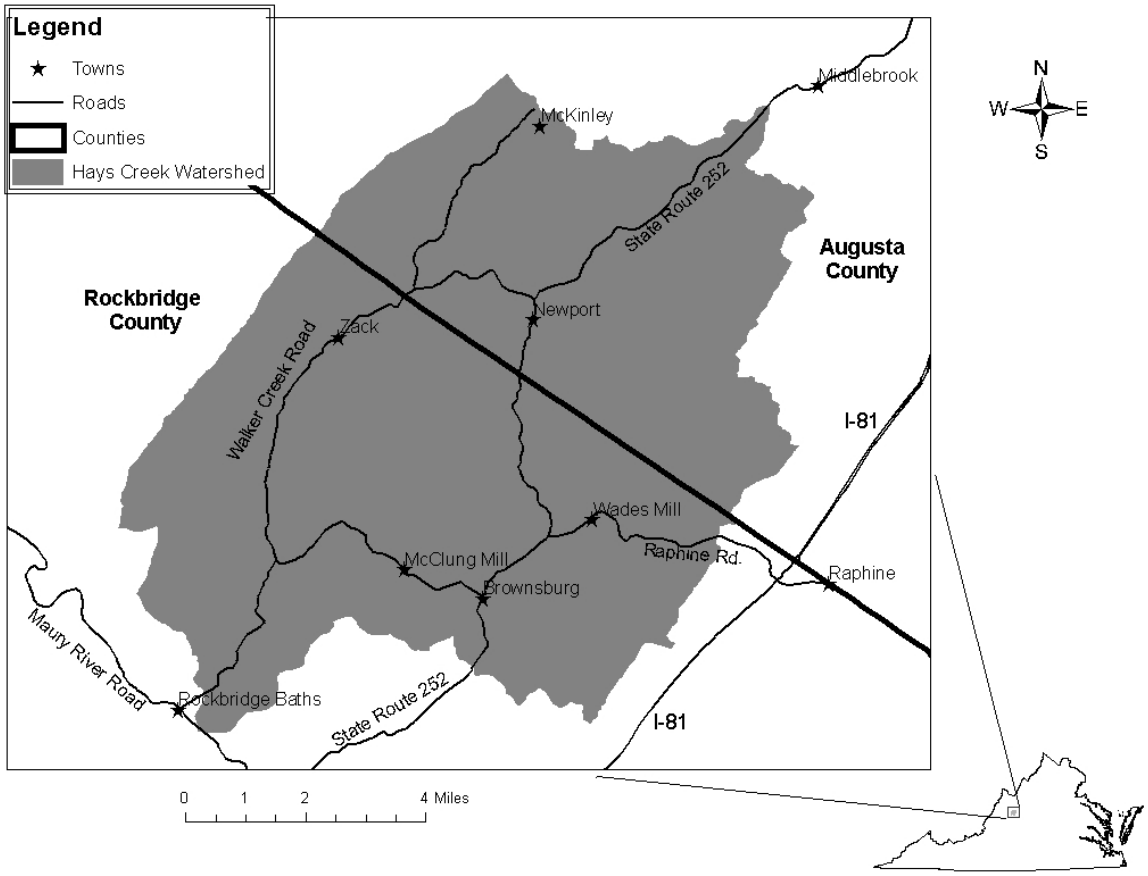

Figure 1.2. Hays Creek (I34) watershed location.

The land use distribution in the Hays Creek watershed is mainly composed of agricultural area (56%) but with a significant portion of forest (41%). Residential areas are small (3%) and scattered within the watershed. Hays Creek flows into the Maury River (USGS Hydrologic Unit Code 02080202), which discharges into the James River at Glasgow. The James River flows into the Chesapeake Bay at Hampton Roads.

1.1.4. Pollutants 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, their presence in water indicates contamination by fecal material. Because fecal material may contain pathogenic organisms, water bodies with fecal coliform bacteria are potential sources of pathogenic organisms. For contact recreational activities 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 violation of the state bacteria standard for contact recreational uses. As will be discussed in Section 1.2.2, Virginia has adopted an *Escherichia coli* (*E. coli*) water quality standard. 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, including wetlands, are designated for the following uses: recreational uses, e.g., swimming and boating; the propagation and growth of a balanced, indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them; wildlife; and the production of edible and marketable natural resources, e.g., fish and shellfish." SWCB, 2006.

Hays Creek, Moffatts Creek, Walker Creek, and Otts Creek do not support the recreational (primary contact) designated use due to violations of the bacteria standard.

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

EPA 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 bacteria 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 (SWCB, 2006):

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 a single sample maximum of 235 cfu/100mL.

During any assessment period, if more than 10.5% of a station's samples exceed the applicable standard, the stream segment associated with that station is classified as impaired and a TMDL must be developed and implemented to bring the station into compliance with the water quality standard. There are six ambient monitoring stations in the Hays Creek watershed, three on Hays Creek, two on Walker Creek and one on Otts Creek. Of these stations, one on Hays Creek was only sampled once. All of the other stations are in violation of the bacteria standard, leading to the impairment on the Hays Creek, Moffatts Creek, Walker Creek, and Otts Creek segments.

The bacteria TMDL for the impaired segments will be developed to meet the *E. coli* standard. As recommended, the modeling will be conducted with fecal coliform inputs, and then a translator equation will be used to convert the output to *E. coli* concentrations.

Chapter 2: Watershed Characterization

2.1. Selection of Sub-watersheds

To account for the spatial distribution of fecal coliform sources, the Hays Creek watershed was subdivided into 32 sub-watersheds as shown in Figure 2.1. The impaired streams and their corresponding sub-watersheds are given in Table 2.1. The stream network used to help define the sub-watersheds was obtained from the National Hydrography Dataset. Sub-watersheds were delineated based on a number of factors: continuity of the stream network, similarity of land use distribution, and monitoring station locations. It is preferable to have a sub-watershed outlet at or near monitoring station locations in order to calibrate the model chosen for this study (to be discussed in Chapter 4); the monitoring stations used in modeling are shown in Figure 2.1.

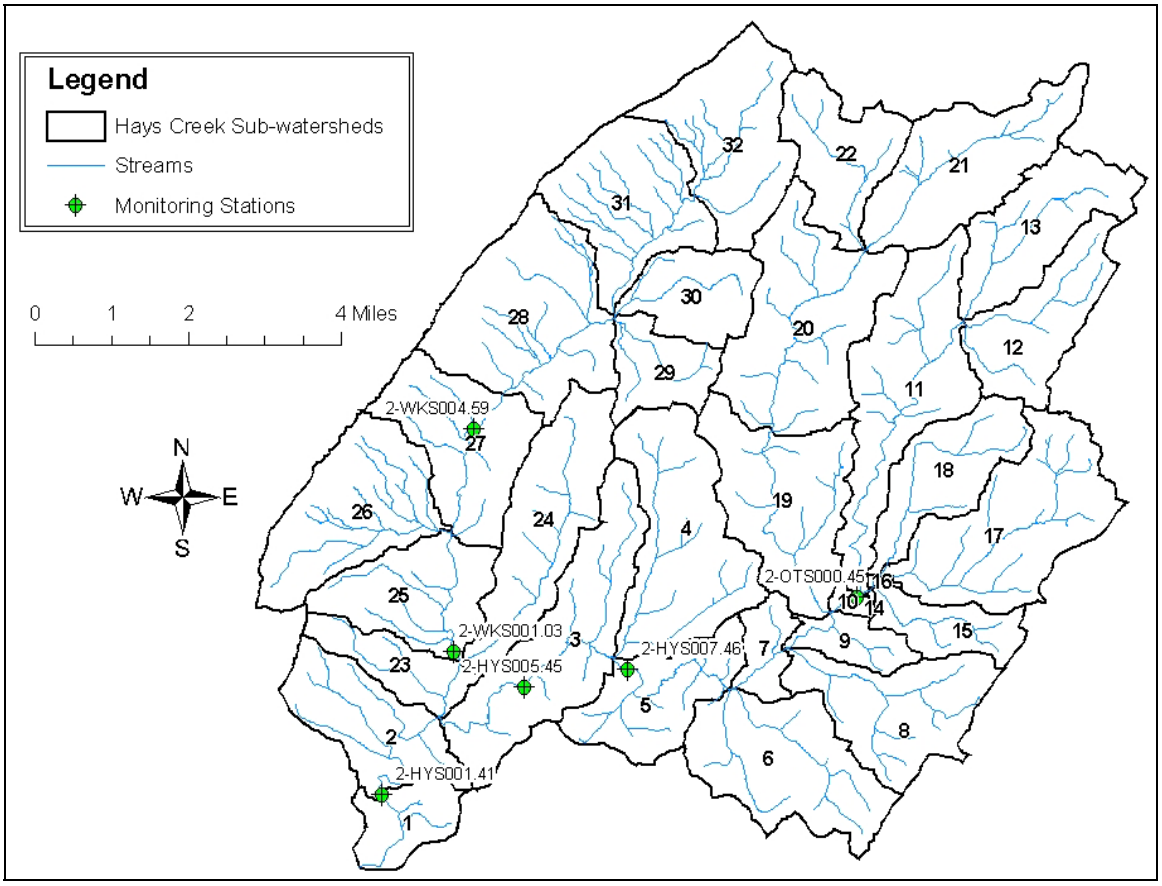

Figure 2.1. Sub-watersheds for the Hays Creek watershed.

Table 2.1. Impaired streams and corresponding sub-watersheds.

Stream Name	Corresponding Sub-watersheds
Hays Creek	1 - 9
Otts Creek	10 - 18
Moffatts Creek	19 - 22
Walker Creek	23 - 32

2.2. Ecoregion and Geology

Ecoregions in this section are classified at two levels: level III ecoregions and their subgroup level IV ecoregions. The Hays Creek watershed is located in the Ridge and Valley Level III Ecoregion with the majority of the watershed in the Northern Limestone/Dolomite Valleys Level IV Ecoregion. This level IV ecoregion is composed of "broad, level to undulating, fertile valleys that are extensively farmed" (Woods et al., 1999). Drainage density is low in this level IV ecoregion due to sinkholes, underground streams, and other karst features (Woods et al., 1999). A very small portion of the watershed is located in the Northern Sandstone Ridges Level IV Ecoregion. This ecoregion is "characterized by high, steep, forested ridges with narrow crests" (Woods et al., 1999). "The ridge-forming strata are composed of folded, interbedded Paleozoic sandstone and conglomerate." (Woods et al., 1999)

2.3. Soils

There are four State Soil Geographic (STATSGO) soil groups represented in the Hays Creek watershed (Table 2.2, Figure 2.2). In the table, "% of Soil Types" is the percent of soils in the given soil name category that have the properties given in the remaining four columns (texture, hydrologic group, slope range, and mean slope). Minimum and maximum slopes are taken directly from fields within the STATSGO database; mean slope is the calculated average of minimum and maximum slopes. One soils group, Frederick-Carbo-Timberville, is dominant, comprising 86% of the watershed soils; with three soils groups totaling the remaining 14%.

Hydrologic soil groups describe soil texture in terms of potential for surface runoff and infiltration rates (Table 2.3). For example, soils in hydrologic group "A" pass a larger

proportion of rainfall through to ground water than soils in hydrologic group "B." Conversely, soils in hydrologic group "D" inhibit infiltration such that a large proportion of rainfall contributes to surface runoff and therefore a more direct path to stream channels. These processes have consequences for bacteria residing on the land surface in terms of the potential bacteria loads transported to streams during storm events.

Table 2.2. Summary of STATSGO data for Hays Creek watershed.

Soil Name	% of Watershed	% of Soil Types	Texture	Hydrologic Group	%Slope, Range	%Slope, Mean
FREDERICK-CARBO-TIMBERVILLE	86	81	Silt loam	B	2 – 35	18
		19	Silty clay, gravelly to stoney silty clay loam	C	7 – 60	21
WALLEN-DEKALB-DRYPOND	8	58	Gravelly to very stoney loam to sandy loam	B	6 – 65	21
		42	Gravelly to stoney sandy loam to fine sandy loam	C and D	6 – 65	25
SHOTTOWER-LAIDIG-WEIKERT	4	69	Loam to fine sandy loam, some cobbles	B, minor D	0 – 25	16
		31	Channery* to stoney silt loam to fine sandy loam	C	0 – 65	11
BERKS-WEIKERT-LAIDIG	2	63	Channery* silt loam	C	2 – 70	23
		37	Loam to stoney sandy loam	B/D,B,A	0 – 70	16

*channery: coarse, flat fragments

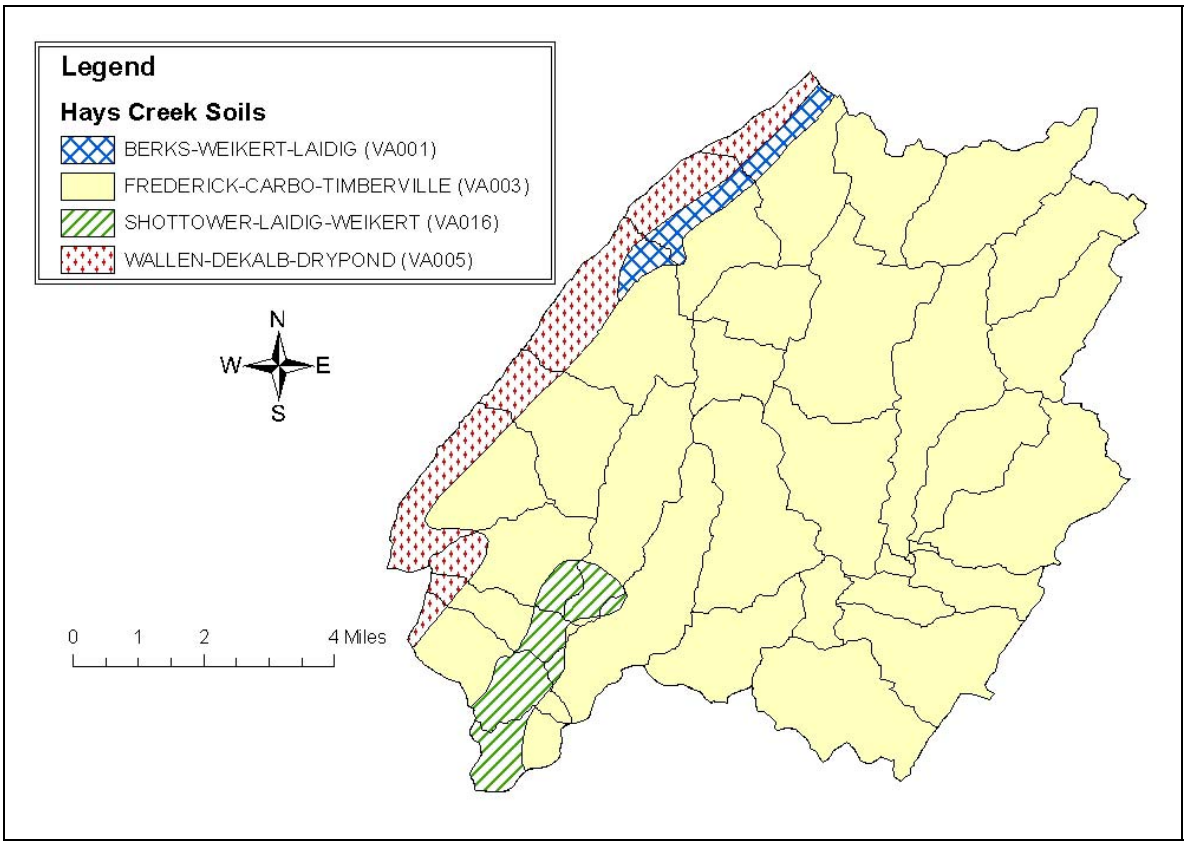

Figure 2.2. STATSGO soil groups in the Hays Creek watershed.

Table 2.3. Soil Hydrologic Groups

Hydrologic Group	Description
A	Low runoff potential, high infiltration rates. Soils are deep, well drained to excessively drained sand, loamy sand or sandy loam, and gravels.
B	Moderate infiltration rates. Deep to moderately deep, moderately well and well-drained silt or silt loam soils (moderately coarse textures).
C	Moderate to Slow infiltration rates. Sandy clay loam soils (soils with moderately fine or fine textures) or soils with layers impeding downward movement of water.
D	High runoff potential, very slow infiltration rates. Soils are clayey (sandy clay to silty clay loam), have high water table, or are shallow over an impervious cover.

2.4. Climate

The climate of the watershed was characterized based on the meteorological observations acquired from the National Climatic Data Center (NCDC) for “nearby” weather stations (NCDC, 2007). Meteorological data were obtained primarily from the National Weather Service COOP station at Staunton Sewage Plant (COOP ID 448062). The Staunton station is located approximately 23 miles northeast of the watershed outlet. Data from the following stations were used to address the missing data: Lexington, Montebello Fish Hatchery, and Lynchburg Regional Airport. The long-term record summary (8/1/1948 – 12/31/2005) at the Staunton station shows an average annual precipitation of 37.60 inches, with 54% of the precipitation occurring during the cropping season (May-October). Mean annual snowfall at the Staunton Sewage Plant is 20.2 inches. Average annual daily temperature is 53.1°F, with a highest average daily temperature of 84.6°F occurring in July, and a lowest average daily temperature of 22.2°F occurring in January (SERCC, 2007).

2.5. Land Use

The Regional Earth Science Application Center (RESAC) has mapped land use/land cover for much of the mid-Atlantic region, current as of 2000. The land cover categories from the RESAC data in the Hays Creek watershed were grouped into five major categories based on similarities in hydrologic features and waste application/production practices (Table 2.4). The five land use categories were assigned pervious and impervious percentages for use in the watershed model. Land uses for the Hays Creek watershed are presented graphically in Figure 2.3 and tabulated in Table 2.5.

Table 2.4. RESAC aggregation.

TMDL Land Use Categories	Pervious/Impervious (Percentage)	RESAC Land Use Categories (Class No.)
Cropland	Pervious (100%)	Croplands (26)
Pasture	Pervious (100%)	Pasture/Hay (25) Natural Grass (30)
Low Density Residential (LDR)	Pervious (60%) Impervious (40%)	Low Intensity Developed (3) Urban/Residential Deciduous Trees/Forests (10) Urban/Residential Evergreen Trees/Forests (11) Urban/Residential Mixed (Deciduous-Evergreen) Trees/Forests (12) Urban/Residential/Recreational Grass (15) Barren (18)
High Density Residential (HDR)	Pervious (20%) Impervious (80%)	Medium Intensity Developed (4) High Intensity Developed (5) Transportation (8)
Forest	Pervious (100%)	Open Water (1) Deciduous Forest (20) Evergreen Forest (21) Mixed (Deciduous-Evergreen) Forests (22) Deciduous Wooded Wetlands (35) Evergreen Wooded Wetlands (36) Emergent Herbaceous Wetlands (37) Mixed Wetlands (38)

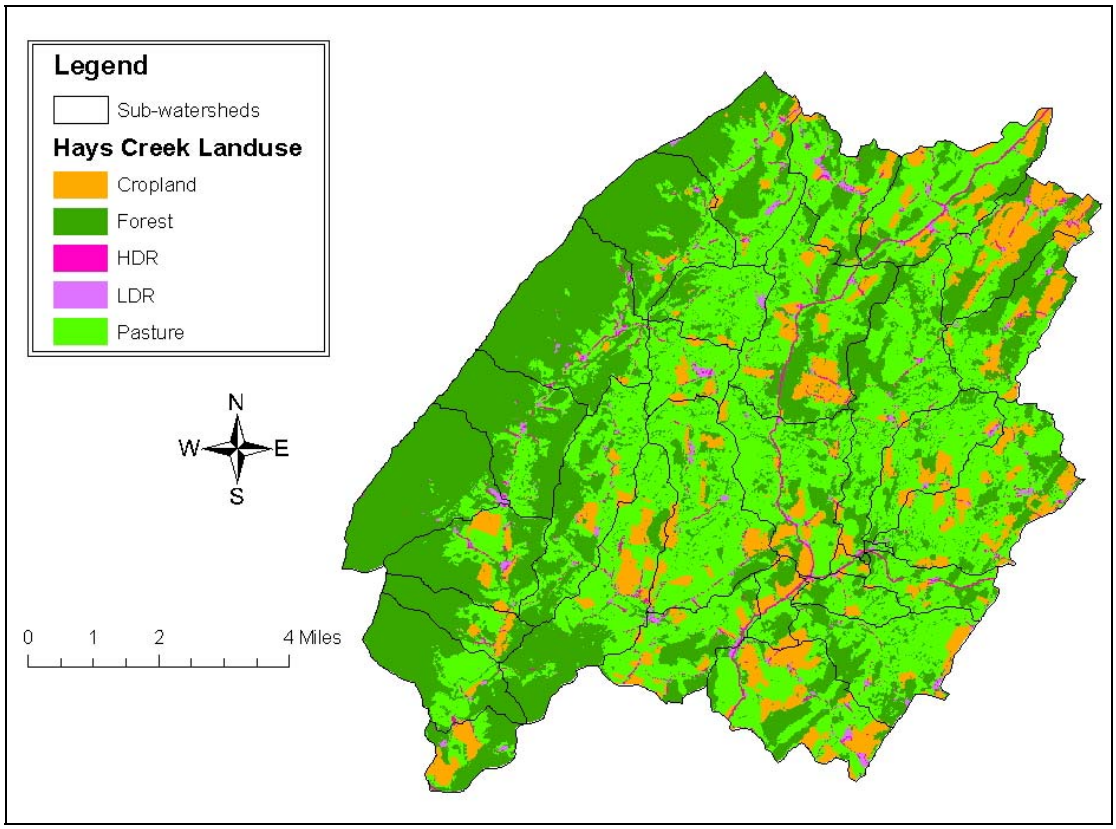

Figure 2.3 Land use in the Hays Creek watershed.

Table 2.5. Land use areas in the Hays Creek watershed (acres).

Sub-Watershed	Cropland	Forest	HDR*	LDR†	Pasture	Total
1	183.1	403.4	11.6	12.7	155.5	766.2
2	17.1	1113.6	9.1	5.3	422.9	1568.0
3	300.4	1011.7	40.9	9.3	1238.9	2601.1
4	306.1	388.9	33.3	29.9	1827.7	2585.8
5	174.4	381.7	40.3	25.1	838.3	1459.7
6	581.8	504.4	58.9	54.2	1068.0	2267.4
7	121.8	167.9	17.9	1.1	192.6	501.2
8	153.8	545.2	19.5	24.2	1115.1	1857.8
9	47.0	125.4	11.6	4.5	348.0	536.5
10	38.0	14.0	6.5	0.7	56.5	115.6
11	93.2	803.0	29.6	16.1	1649.3	2591.4
12	289.4	620.0	18.0	15.2	588.2	1530.7
13	581.6	566.6	46.6	20.4	438.1	1653.3
14	0.4	9.1	0.0	0.0	0.0	9.5
15	61.4	189.6	32.9	4.9	493.9	782.8
16	0.2	11.7	1.5	3.2	15.5	32.1
17	454.5	546.8	34.6	25.9	1599.5	2661.3
18	187.1	263.2	10.6	15.3	950.0	1426.2
19	262.2	465.4	63.5	17.9	1447.9	2256.9
20	461.6	962.2	84.2	24.1	1371.5	2903.6
21	357.8	482.0	95.0	24.4	1235.0	2194.3
22	129.3	459.2	37.3	40.7	727.8	1394.2
23	75.0	563.0	10.0	3.8	177.5	829.3
24	115.5	821.3	25.5	18.6	1169.9	2150.9
25	178.4	951.3	22.1	24.1	441.5	1617.4
26	2.0	2054.5	6.8	18.6	104.1	2186.0
27	0.7	1464.6	24.6	21.3	399.6	1910.8
28	21.1	2288.6	45.2	28.3	481.3	2864.5
29	101.3	75.0	20.3	18.0	652.6	867.3
30	36.0	260.4	6.2	16.6	796.4	1115.6
31	47.0	1513.8	20.3	10.6	463.7	2055.4
32	95.4	1068.3	37.7	36.3	892.2	2129.9
Total	5474.3	21095.8	921.8	571.6	23359.2	51422.8

*HDR - High Density Residential
†LDR - Low Density Residential

2.6. Stream Flow Data

There are no continuous flow gages within the Hays Creek watershed. Twelve flow measurements were captured at one station, VADEQ ambient monitoring station 2-HYS001.41 (Figure 2.1), on a monthly basis from July 2005 to June 2006. Flow measurements ranged from 14 cfs to 116 cfs with an average flow of 38.3 cfs. It was necessary to find a similar, gauged, watershed on which to perform the hydrologic calibration (to be discussed in more detail in Chapter 4). Christians Creek in Augusta

County was chosen for this purpose. The USGS monitored flow on Christians Creek at station 01624800, near Fishersville, VA. The drainage to the station is 73.0 mi²; the period of record extends from October 1967 to October 1997, with an average flow rate of 73 cfs (USGS, 2007).

2.7. Water Quality Data

The Virginia Department of Environmental Quality (VADEQ) monitors Hays Creek water quality at six stations. The locations of the monitoring stations were shown previously (Figure 2.1); a summary of the bacteria data, including violation rates of the appropriate single-sample standards, is presented in Table 2.6. Of these stations, station 2-HYS005.45 includes only one data point each for fecal coliform and *E. coli* and therefore will not be included in the water quality calibration or validation. Station 2-WKS004.59 includes no fecal coliform data; only *E. coli* data were collected at this station and likewise will not be used for model calibration or validation.

Table 2.6. VADEQ monitoring stations within the Hays Creek watershed.

Station ID	Stream Name	Station Description	Indicator Organism Measured	Number of Samples	Violation Rate	Period of Record
2-HYS001.41	Hays Creek	Rt. 602 Bridge	Fecal Coliform	67	33%	1991 - 2006
			E. coli	18	39%	
2-HYS005.45	Hays Creek	Approximately 0.1 miles upstream of Rt. 731	Fecal Coliform	1	0%	2007 - 2007
			E. coli	1	0%	
2-HYS007.46	Hays Creek	Rt. 726 Bridge at McClung Mill	Fecal Coliform	18	39%	2003 - 2006
			E. coli	29	59%	
2-OTS000.45	Otts Creek	Rt. 606 Bridge at Wades Mill	Fecal Coliform	18	17%	2003 - 2006
			E. coli	30	23%	
2-WKS001.03	Walker Creek	Rt. 602 Bridge near Rt. 724 intersection	Fecal Coliform	18	11%	2003 - 2006
			E. coli	30	20%	
2-WKS004.59	Walker Creek	Rt. 602 Bridge, near Zack	Fecal Coliform	0	-	2003 - 2005
			E. coli	12	33%	

As part of the TMDL effort, bacterial source tracking (BST) data were collected at station 2-HYS001.41 from July 2005 to June 2006. The commonly used Antibiotic Resistance Analysis (ARA) method was used to analyze these samples (Harwood et al., 2003; Stoeckel et al., 2004; Hagedorn, 2006). This method is lower in cost and faster

than many of the other available methods. The ARA method is classified as a biochemical or phenotype analysis. It relies on the response of the fecal bacteria to various antibiotics. The results of the BST analyses are presented at the end of Chapter 5, where they are compared with modeled results.

The assessments for Hays Creek, Moffatts Creek, Walker Creek, and Otts Creek show a potential for bacteria contributions from agriculture, wildlife, and urban sources. During the 1998 assessment period (July 1992 through June 1997) 25% of the samples collected at station 2-HYS001.41 exceeded the fecal coliform standard, causing Hays Creek and Moffatts Creek to be listed as impaired on Virginia's 1998 Clean Water Act Section 303(d) Total Maximum Daily Load Priority List of Impaired Waters (VADEQ, 1998). Walker Creek and Otts Creek were added to the Virginia 2006 305(b)/303(d) Water Quality Assessment Integrated Report for violations of the *E. coli* standard during the assessment period (January 2000 to December 2004).

Seasonality of fecal coliform concentrations in the streams was evaluated by plotting the mean monthly fecal coliform concentrations observed at station 2-HYS001.41, the station with the longest period of record (Figure 2.4). Mean monthly fecal coliform concentration was determined as the mean of all values in any given month for the period of record.

In general, the station shows peak values of fecal coliform concentrations in the summer months and lower values in winter. This pattern suggests that sources of bacteria to the impaired watersheds are affected by seasonal trends (temperature, precipitation, management practices, and migration patterns), with higher fecal coliform concentrations occurring during the low-flow period of the year. This pattern also suggests that direct sources, such as direct deposit from livestock, play a large role in fecal coliform violations.

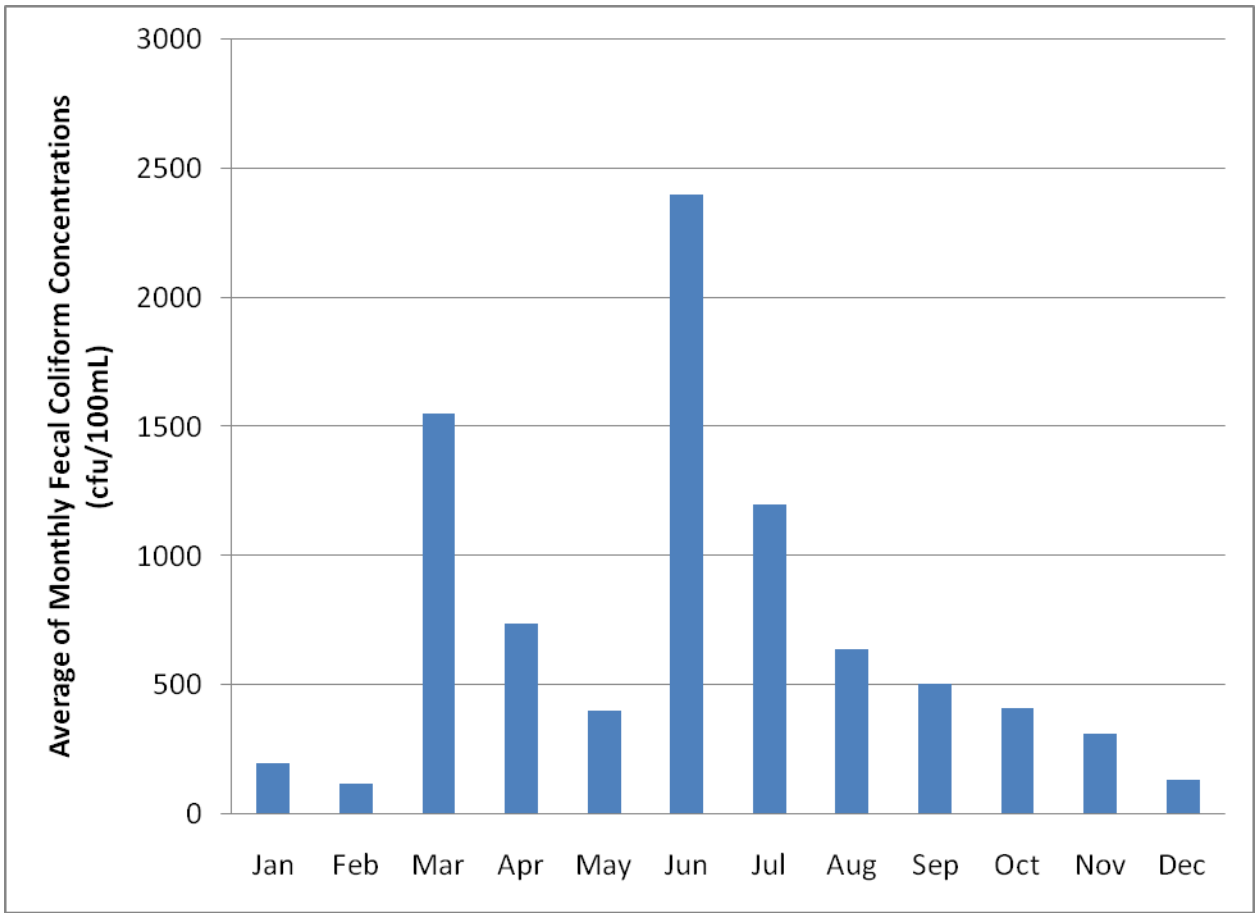

Figure 2.4. Average fecal coliform concentrations by month for station 2-HYS001.41.

Chapter 3: Source Assessment of Fecal Coliform

Fecal coliform sources and production rates in the Hays Creek watershed were assessed using information from the following sources: VADEQ, VADCR, Virginia Department of Game and Inland Fisheries (VADGIF), Virginia Department of Agricultural and Consumer Services (VDACS), Virginia Cooperative Extension (VCE), Natural Resources Conservation Service (NRCS), Soil and Water Conservation Districts (SWCD), public participation, watershed reconnaissance and monitoring, published information, and professional judgment. Potential nonpoint sources of fecal coliform in the Hays Creek watershed are summarized in Table 3.1.

Point sources of fecal coliform bacteria in the Hays Creek watershed include one multiple residence sewage discharge and one single family domestic sewage discharge (application pending), both located on Moffatts Creek (Table 3.2). Virginia issues Virginia Pollutant Discharge Elimination System (VPDES) permits for point sources of pollution. In Virginia, point sources that treat human waste are required to maintain an *E. coli* concentration of 126 cfu/100 mL or less in their effluent. In allocation scenarios for bacteria, the entire allowable point source discharge concentration of 126 cfu/100 mL was used.

3.1. Humans and Pets

The Hays Creek watershed has an estimated population of 1,668 (672 households with an average of 2.48 people per household; actual people per household varies by sub-watershed). The number of households was determined from structures data supplied by the Augusta and Rockbridge County GIS departments. The number of people per household for the watershed was determined from the 2000 Census of Population and Housing for Virginia. Fecal coliform from humans can be transported to streams from failing septic systems, and via straight pipes discharging directly into streams. Although leaky sewer lines are not explicitly accounted for in modeling for this TMDL, they are considered to be part of the residential load, and should be addressed where found during implementation.

Table 3.1. Potential fecal coliform sources and daily fecal coliform production by source for existing conditions in the Hays Creek watershed.

Potential Source	Population	Fecal coliform produced (x 10^6 cfu/head/day)
Humans	1,668	150[a]
Beef Cattle	4,720[b]	8,556[a]
Dairy Cattle		
Milk and dry cows	260	25,000
Heifers	70	11,400
Poultry – Turkey Toms	9,099	93[d]
Goats	195	28,000[d]
Sheep	714	12,000[d]
Horses	284	420[d]
Pets	1,668	450[c]
Deer	2,816	350
Raccoons	910	50
Muskrats	358	25[e]
Beavers	70	0.2
Ducks	425[f]	2,400
Geese	487[f]	800
Wild Turkeys	400	93

[a] Source: Geldreich (1978)
[b] Cow-calf pairs
[c] Source: Weiskel *et al.* (1996)
[d] Source: ASAE(1998)
[e] Source: Yagow (2001)
[f] Population given as peak

Table 3.2. Permitted facilities discharging into streams of the Hays Creek watershed.

Permit Number	Facility Name	Sub-water shed	Design Flow (mgd[*])	Permitted *E. coli* Conc. (cfu/100 mL)	*E. coli* Load (cfu/year)
VAG408084[†]	Single Family Home	20	0.001	126	1.74 x 10^9
VAG401386	Multiple Residence	20	0.001	126	1.74 x 10^9

[*]million gallons per day
[†]not currently online

3.1.1. Failing Septic Systems

Septic system failure can result in the rise of effluent to the soil surface. Surface runoff can transport the effluent, containing fecal coliform, to receiving waters. The number of failing septic systems in each sub-watershed was determined by analyzing the ages of the structures in the watershed and applying a failure rate based on the age category. The United States Geological Survey (USGS) 7.5-minute quadrangles also provide locations of houses that are color-coded according to map revision date. The USGS maps were originally developed in the 1960s, and houses present at that time

are indicated by black dots on the maps; many USGS maps were photorevised in the 1980s, and new houses present at that time were indicated by purple dots on the maps. The current structures data was compared with the USGS maps to classify the houses as old (black on the maps), middle-aged (purple on the maps), or new (not present on the USGS maps). Forty percent of old houses, 20% of middle-aged houses, and 3% of new houses were assumed to have failing septic systems.

Daily total fecal coliform load to the land from a failing septic system in each sub-watershed was determined by multiplying the average occupancy rate for that sub-watershed (occupancy rate of houses ranged from 2.44 to 2.62 persons per household (Census Bureau, 2000)) by the per capita fecal coliform production rate of 1.5×10^8 cfu/day (Geldreich, 1978). Hence, the total fecal coliform loading to the land from a single failing septic system in a sub-watershed with an occupancy rate of 1 person/household is 1.5×10^8 cfu/day. Transport of some portion of the fecal coliform to a stream by runoff may occur. The number of failing septic systems in the watershed is given Table 3.3. Note that the Rockbridge County structures data showed no houses present in sub-watershed 14.

3.1.2. Straight Pipes

Bacteria discharged from straight pipes enter the stream directly, without treatment or die-off. Of the houses in the old and middle-age categories, 10% and 2%, respectively, were estimated to have straight pipes. Based on these criteria, it was estimated that 10 houses with straight pipes exist in the Hays Creek watershed. The number of straight pipes in the watershed is given in Table 3.3.

Daily total fecal coliform load to the stream from a straight pipe in each sub-watershed was determined by multiplying the average occupancy rate for that sub-watershed by the per capita fecal coliform production rate of 1.5×10^8 cfu/day (Geldreich, 1978). Hence, the total fecal coliform loading to the stream from a single straight pipe in a sub-watershed with an occupancy rate of 1 person/household is 1.5×10^8 cfu/day. Straight pipes were assumed to discharge only between the hours of 6 AM and 9 PM (i.e., people are only defecating while they are awake).

Table 3.3. Estimated Household and Pet Population Breakdown by Sub-watershed for Hays Creek watershed.

Sub-watershed	People per House	Straight Pipes	Houses in each age category			Failing Septic Systems*	Pet Population
			Old	Mid-age	New		
1	2.44	0	11	4	1	6	16
2	2.44	0	1	3	3	2	7
3	2.44	0	6	1	12	3	19
4	2.44	0	14	3	10	7	27
5	2.44	1	26	1	9	11	37
6	2.54	0	30	0	28	13	58
7	2.44	0	3	1	0	2	4
8	2.46	0	8	1	20	4	29
9	2.44	0	4	2	1	3	7
10	2.44	0	1	0	0	1	1
11	2.57	1	15	1	10	7	27
12	2.62	0	5	0	25	3	30
13	2.61	0	13	1	4	6	18
14	0	0	0	0	0	0	0
15	2.45	0	7	0	6	3	13
16	2.44	0	1	0	0	1	1
17	2.59	2	22	0	28	10	52
18	2.60	1	11	0	27	6	39
19	2.44	0	11	5	7	6	23
20	2.61	2	38	0	12	16	52
21	2.61	0	9	1	4	4	14
22	2.61	0	17	1	16	8	34
23	2.44	0	3	2	0	2	5
24	2.44	0	11	3	13	6	27
25	2.44	0	12	0	1	5	13
26	2.44	0	4	5	2	3	11
27	2.44	0	6	3	9	4	18
28	2.46	0	13	6	3	7	22
29	2.44	0	4	0	1	2	5
30	2.60	1	2	1	10	2	14
31	2.61	2	10	1	6	5	19
32	2.61	0	13	2	15	7	30
Total	**2.48†**	**10**	**331**	**48**	**283**	**165**	**672**

* Failing septic systems are a subset of the septic systems presented in the previous three columns; these were determined based on house ages as described in Section 3.1.1.

† Average

3.1.3. Pets

The American Pet Products Manufacturers Association conducts biannual pet owner surveys in the United States. The Humane Society of the United States reports a summary of these findings: for the 2005-2006 survey: 39% of American households owned an average of 1.7 dogs, and 34% of American households owned an average of 2.4 cats (HSUS, 2007). Assuming that a unit pet is one dog or two cats, this yields (0.39*1.7 + (0.34*2.4)/2) = 1.071 unit pets per household. Therefore, the pet population in the Hays Creek watershed was calculated at a rate of one unit pet per household. Given this assumption, there are 672 pets in the Hays Creek watershed. A dog produces fecal coliform at a rate of 4.5×10^8 cfu/day (Weiskel et al., 1996); this was assumed to be representative of a 'unit pet' – one dog or several cats. The pet population distribution among the sub-watersheds is listed in Table 3.3. Pet waste is generated in residential areas; surface runoff can transport bacteria in pet waste from these areas to the stream.

3.2. Cattle

Fecal coliform in cattle waste can be directly excreted to the stream, or it can be transported to the stream via surface runoff from animal waste deposited on pastures or applied to crops or pasture. Changes may have occurred in the cattle populations between the calibration, validation, and existing conditions periods. Future conditions, however, were assumed to be the same as the existing conditions; local information suggests that cattle farming is on a decline in the watershed, but in keeping with conservative assumptions, a steady cattle population for future conditions was assumed.

3.2.1. Distribution of Dairy and Beef Cattle

There are currently two dairy farms and numerous beef farms in the Hays Creek watershed. The number of dairy farms was estimated from the VDACS data, and information provided at the first Local Steering Committee (LSC) meeting and from NRCS District Conservationists. The total number of milk and dry cows was estimated at 260. Based on information obtained from District Conservationists, the number of

heifers was estimated at 70. The dairy cattle population was distributed among the sub-watersheds based on location of dairy farms and average herd size (Table 3.4).

The number of beef farms was estimated from the 2000 Agricultural Census; it was assumed that all were cow-calf operations. District Conservationists confirmed the estimates of beef cattle population. The total number of beef cows modeled throughout the year varied due to the presence or absences of calves and their weights relative to the adult cattle. The number of beef cattle and the distribution of animals among the sub-watersheds are listed in Table 3.4 for the Hays Creek watershed.

Cattle spend varying amounts of time in confinement, streams, and pastures depending on the time of year and type of cattle. Accordingly, the proportion of fecal coliform deposited in any given land area varies throughout the year. Confinement of dairy cattle was estimated from 33% to 50% based on information provided by District Conservationists. Details about confinement of beef cattle are listed in Table 3.5. Stream access for all cattle farms was estimated based on pasture land proximity to streams.

The following assumptions and procedures were used to estimate the distribution of cattle (and thus, fecal coliform produced by cattle) among different land use types and in streams:

a) When cattle are not confined, they are on pasture.
b) Cows with stream access (determined as described earlier) will spend varying amounts of time in the stream during different seasons (Table 3.5). Cows spend more time in the stream during the three summer months to protect their hooves from hornflies, among other reasons.
c) Thirty percent of cows in and around streams directly deposit fecal coliform into the stream. The remaining 70% of the feces is deposited on pastures.

A sample calculation for determining the distribution of cattle between the pasture and the stream in sub-watershed 3 of Hays Creek is shown in Appendix B. The resulting numbers of cattle in pastures and streams for all sub-watersheds are given in Table 3.6.

Table 3.4. Dairy and Beef Cattle Populations in the Hays Creek watershed.

Sub-watershed	Dairy	Beef*
1	0	83
2	0	111
3	0	283
4	0	270
5	0	235
6	235	377
7	0	56
8	0	215
9	0	64
10	0	21
11	0	212
12	0	104
13	0	177
14	0	0
15	0	88
16	0	1
17	0	254
18	0	124
19	0	239
20	0	289
21	0	286
22	95	156
23	0	62
24	0	254
25	0	159
26	0	41
27	0	81
28	0	129
29	0	92
30	0	36
31	0	86
32	0	135
Total	**330**	**4,720**

* Cow-calf pairs

Table 3.5. Time spent by beef cattle in confinement and time spent by cattle in the stream.

Month	Beef Cattle[1] (range; typical)	Time spent in the stream (hours/day)
January	0%-40%; 0%	0.5
February	0%-40%; 0%	0.5
March	0%	0.75
April	0%	1
May	0%	1.5
June	0%	3.5
July	0%	3.5
August	0%	3.5
September	0%	1.5
October	0%	1
November	0%	0.75
December	0%-40%; 0%	0.5

[1] Fraction of day spent in confinement

Table 3.6. Distribution of the cattle population.

Month	Confinement	Pasture	Streams*
January	1,562	2,134	5
February	1,807	2,501	6
March	88	4,329	19
April	66	4,473	20
May	66	4,574	41
June	66	4,740	151
July	66	4,859	155
August	66	4,978	158
September	66	5,189	69
October	66	3,306	22
November	88	3,291	15
December	1,501	2,042	5

*Number of cow equivalent defecations in the stream

3.2.2. Direct Manure Deposition in Streams

Direct manure loading to streams is due to dairy and beef cattle (Table 3.6) defecating in the stream. Manure loading increases during the warmer months, when cattle spend more time in water. The potential average annual manure loading directly deposited by cattle in the stream for the Hays Creek watershed, using the table above, is 1.3 x 10^6 lb. The associated average daily fecal coliform loading to the stream for Hays Creek is 5.2 x 10^{11} cfu. Part of the fecal coliform deposited in the stream stays suspended, while the remainder adsorbs to the sediment in the streambed. Under base flow conditions, it is likely that suspended fecal coliform bacteria are the primary form transported with the flow. Sediment-bound fecal coliform bacteria are likely to be re-suspended and transported to the watershed outlet under high flow conditions. Die-off of fecal coliform in the stream depends on sunlight, predation, turbidity, and other environmental factors.

3.2.3. Direct Manure Deposition on Pastures

Dairy and beef cattle that graze on pastures (Table 3.6) 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 cattle on pasture by the amount of manure 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. Because the confinement schedule of cattle changes with season: loading on pasture also changes with season.

Pasture has average annual cattle manure loadings of 3,750 lb/ac for the Hays Creek watershed. The associated fecal coliform loading from cattle to pasture on a daily basis averaged over the year is 4.2 x 10^{13} cfu for the Hays Creek watershed. 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.

3.2.4. Land Application of Liquid Dairy Manure

A typical milk cow weighs 1,400 lb and produces 17 gallons of liquid manure/day (ASAE, 1998). Based on the monthly confinement schedule and the number of milk cows (Section 3.2.1), annual liquid dairy manure production in the watershed is 586,888 gallons. Based on per capita fecal coliform production of milk cows, fresh liquid dairy manure contains 3.9×10^7 cfu/gal. It was assumed that all liquid dairy manure produced in a sub-watershed was applied within the sub-watershed. Liquid dairy manure application rates are 6,600 and 3,900 gal/ac-year to cropland and pasture land use categories, 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 89 acres (12.5%) of cropland in sub-watersheds 6 and 22. Since there was insufficient liquid dairy manure for cropland, liquid dairy manure was not applied to pasture.

The typical crop rotation in the watershed is a seven-year rotation with three years of corn-rye and four years of rotational hay. 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 through 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. During June through September, liquid manure is surface-applied to pasture. It was assumed that only 10% of the subsurface-applied fecal coliform were available for removal in surface runoff. The application schedule of liquid manure is given in Table 3.7. Dry cows and heifers were assumed to produce only solid manure.

Table 3.7. Schedule of cattle and poultry waste application.

Month	Liquid or solid manure applied (%)*	Poultry litter applied (%)*
January	0	3
February	5	0
March	25	15
April	20	3
May	5	1
June	10	73
July	0	0
August	5	5
September	15	0
October	5	0
November	10	0
December	0	0

* As percent of annual production

3.2.5. 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 (Table 3.4 and Table 3.5) and their confinement schedules (Table 3.6). Solid manure from dry cows, heifers, and beef cattle contained different fecal coliform concentrations (cfu/lb).

Table 3.8. Estimated population of dry cows, heifers, and beef cattle, typical weights, per capita solid manure production, and fecal coliform concentration in fresh solid manure.

Type of cattle	Population	Typical weight (lb)	Solid manure produced (lb/animal-day)	Fecal coliform concentration in fresh manure (x 10^6 cfu/lb)
Dry cow	50	1,400[a]	115.0[b]	176[c]
Heifer	70	640[d]	40.7[a]	226[c]
Beef	4,720	1,000[a]	60.0[b]	333[c]

[a] Source: ASAE (1998)
[b] Source: MWPS (1993)
[c] Based on per capita fecal coliform production per day and manure production
[d] Based on weighted average weight assuming that 57% of the animals are older than 10 months (900 lb ea.), 28% are 1.5-10 months (400 lb ea.) and the remainder are less than 1.5 months (110 lb ea.) (MWPS, 1993)

Solid cattle manure is applied at the rate of 12 tons/ac-year to both cropland and pasture, with priority given to cropland. Solid manure is applied to cropland from February through May, and October through November. Solid manure can be applied to pasture anytime of the year. 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 rates and priority of application, it was estimated that solid cattle manure was applied to 295 acres (5%) of cropland and 35 acres (<1%) of pasture in the Hays Creek watershed.

3.3. Poultry

The poultry population (Table 3.1) was estimated based on the permitted confined poultry feeding operations located within the watershed. A complete listing of these facilities can be found in Table 3.9. Poultry litter production was estimated from the poultry population after accounting for the time when the houses are not occupied. In addition, it was estimated that 1,500 tons of poultry litter are imported into the watershed annually based on the 2004 and 2005 Virginia Poultry Waste Transfer Reports. All estimates of poultry litter in this study are a combination of the litter from the resident poultry population and the imported litter.

Table 3.9. Permitted Poultry Facilities in Hays Creek watershed.

Permit Number	Type of Bird	Sub-watershed
VPG260116	Turkey	2
VPG260247	Turkey	3
VPG260360	Turkey	3

Because poultry is raised entirely in confinement, all litter produced is collected and stored prior to land application. It is not known which poultry litter (layer or broiler or turkey) is imported to the watershed or which type of litter is applied to a land use. Hence, a weighted average fecal coliform concentration was estimated for poultry litter based on relative proportions of litter from all poultry types and their respective fecal coliform contents. The estimated production rate of poultry litter in the Hays Creek watershed is 9.0×10^6 lb/year; this corresponds to a fecal coliform application rate of 1.8×10^{16} cfu/year. The fecal coliform bacteria produced are subject to die-off in storage and losses due to incorporation prior to being subject to transport via runoff. Poultry litter was applied at the rate of 3 tons/ac-year first to cropland and then to pastures. Poultry litter receives priority after all liquid manure has been applied (i.e., it is applied before solid cattle manure is considered). The incorporation properties of poultry litter application to cropland and pastures are assumed to be identical to the incorporation properties of cattle manure application. The application schedule of poultry litter is given in Table 3.7. Poultry litter is not applied to cropland from September through December. Based on availability of land and poultry litter, as well as the assumptions regarding application rates and priority of application, it was estimated that poultry litter was applied to 1,334 acres (24%) of cropland and 163 acres (1%) of pasture.

3.4. Sheep and Goats

The sheep and goat populations (Table 3.1) were estimated based on population densities in the USDA National Agricultural Statistics Service (NASS) for Augusta and Rockbridge Counties and input from the first LSC meeting. The sheep and goats were kept on pasture at all times. Sheep and goats are not usually confined and tend not to wade or defecate in the streams. Therefore, the fecal coliform produced by sheep and goats was deposited directly on pasture.

Pasture in the Hays Creek watershed has average annual sheep and goat manure loadings of 42 lb/ac-year. Fecal coliform loadings to the pasture in the watershed from sheep and goats on a daily basis averaged over the year are 5.8×10^8 cfu/ac-day.

3.5. Horses

Horse populations for the watershed were estimated from population numbers in the 2000 Agricultural Census for Augusta and Rockbridge Counties and input from the first LSC meeting. The populations were area-weighted according to pasture areas in the counties and in each sub-watershed of Hays Creek. The distribution of horses among the sub-watersheds is given in Table 3.10. The fecal coliform originating from horses contributes to the pasture load. Fecal coliform loadings from horses on a daily basis averaged over the year and over all pastures in the watershed are 5.1×10^6 cfu/ac-day for the Hays Creek watershed.

3.6. Wildlife

Wildlife fecal coliform contributions can come from excretion of waste on land and from excretion directly into streams. Information provided by VADGIF 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. Population numbers for each species and fecal coliform amounts were determined along with preferred habitat and habitat area.

Table 3.10. Horse Population in the Hays Creek watershed.

Sub-watershed	Horses
1	1
2	3
3	10
4	15
5	7
6	29
7	2
8	15
9	3
10	0
11	21
12	8
13	6
14	0
15	14
16	0
17	20
18	17
19	12
20	18
21	16
22	10
23	1
24	9
25	4
26	1
27	3
28	4
29	6
30	11
31	6
32	12
Total	**284**

Professional judgment was used in estimating the percent of each wildlife species depositing directly into streams, by considering each habitat area occupied (Table 3.11). Fecal loading from wildlife was estimated for each sub-watershed. The wildlife populations were distributed among the sub-watersheds based on the area of appropriate habitat in each sub-watershed. For example, the deer population was evenly distributed across the watershed, whereas muskrat and raccoons had variable population densities based on land use and proximity to a water source. Therefore, a sub-watershed with more stream length and impoundments and more area in crop land use would have more muskrats than a sub-watershed with shorter stream length, fewer

impoundments, and less area in crop land use. Distribution of wildlife among sub-watersheds is given in Table 3.12 for the Hays Creek watershed.

Table 3.11. Wildlife habitat, population density, and direct fecal deposition in streams.

Wildlife type	Habitat and Estimation Method	Population Density (animal / mi² - habitat)	Direct fecal deposition in streams (%)
Deer	Entire Watershed	35	1%
Raccoon	low density on forests not in high density area; high density on forest within 600 ft of a permanent water source or 0.5 mile of cropland; highest density in residential areas	Low density: 10 High density: 30 Highest density: 50	10%
Muskrat	16/mile of ditch or medium sized stream intersecting cropland; 8/mile of ditch or medium sized stream intersecting pasture; 10/mile of pond or lake edge; 50/mile of slow-moving river edge	-see habitat column-	25%
Beaver	1/mile of perennial streams; and 3.8/mile of lake or pond shore	-see habitat column-	50%
Geese	300 ft buffer around main streams	70	25%
Wood Duck	300 ft buffer around main streams	40 – off season 60 – peak season	25%
Wild Turkey	Forest; based on kill rate per square mile of forest for each county, assuming the killed birds are 10% of the total population	4 (Augusta) 8 (Rockbridge)	0%

Table 3.12. Wildlife populations in the Hays Creek watershed.

Sub-watershed	Deer	Raccoon	Muskrat	Beaver	Goose	Wood Duck		Wild Turkey
						Peak	Off-peak	
1	42	20	9	2	11	10	7	8
2	86	30	14	3	23	19	13	21
3	142	45	22	5	35	31	20	19
4	141	23	32	4	32	28	18	7
5	80	23	16	3	21	18	12	7
6	125	33	13	2	13	12	8	10
7	27	9	6	1	7	6	4	3
8	102	29	7	2	12	11	7	10
9	29	7	2	1	8	7	4	2
10	6	1	3	0	4	3	2	0
11	142	41	37	6	41	36	23	15
12	84	32	8	2	8	7	5	12
13	91	32	3	1	1	1	1	11
14	1	0	0	0	0	0	0	0
15	43	12	12	2	17	14	9	4
16	2	1	2	0	2	2	1	0
17	146	30	29	5	27	24	16	10
18	78	14	14	3	19	16	11	5
19	123	28	29	4	36	31	20	9
20	159	54	19	4	32	28	18	18
21	120	32	19	3	12	11	7	9
22	76	28	4	1	3	3	2	9
23	45	20	2	1	6	5	4	11
24	118	41	12	3	21	18	12	16
25	88	38	8	2	17	15	10	18
26	120	45	5	3	19	16	11	39
27	105	37	11	2	17	15	10	28
28	157	70	6	2	15	13	9	44
29	47	7	1	0	1	1	0	1
30	61	14	1	0	0	0	0	5
31	113	62	14	3	25	22	14	29
32	117	51	1	0	2	2	1	20
Total	**2816**	**910**	**358**	**70**	**487**	**425**	**279**	**400**

3.7. Summary: Contributions from All Sources

Based on the inventory of sources discussed in this chapter, an estimate of the summary of the contribution by the different direct nonpoint sources to the annual fecal coliform loading to the streams is given in Table 3.13. The estimated distribution of

annual fecal coliform loading from nonpoint sources among the different land use categories is also given in Table 3.13.

From Table 3.13, it is clear that nonpoint source loadings to the land surface are greater than direct nonpoint source loadings to the stream. Pastures receive the greatest portion of this load, at 92%. However, factors such as precipitation amount and pattern, die-off rates, manure application activities, type of waste, and proximity to the streams impact the amount of fecal coliform from upland areas that reaches the streams. Due to their nature, direct nonpoint source loadings to streams are not modified before transmission to the stream. The HSPF model discussed in Chapter 4 considers these factors when estimating fecal coliform loadings in the receiving waters.

Table 3.13. Estimated annual fecal coliform loadings to the stream and the various land use categories for the Hays Creek watershed.

Source	Fecal coliform loading ($x10^{12}$ cfu/yr)	Percent of total loading
Direct loading to streams		
Livestock in stream	191	1%
Wildlife in stream	52	<1%
Straight pipes	1	<1%
Point Sources	<1	<1%
Loading to land surfaces		
Cropland	1,005	5%
Pasture	18,547	92%
Residential	130	<1%
Forest	222	1%
Total	**20,149**	

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 is 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 waterbody 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, the modeling process, input data requirements, and model calibration procedure and results are discussed.

4.1. Model Description

The TMDL development process 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) version 12 (Bicknell et al., 2001; Duda et al., 2001) was used to model fecal coliform transport and fate in the Hays Creek watershed. The ArcGIS 9.1 Geographic Information System (GIS) software was used to display and analyze landscape information for the development of input for HSPF.

The HSPF model simulates nonpoint source runoff and pollutant loadings, performs flow routing through streams, and simulates in-stream water quality processes. 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 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 general constituent pollutant (GQUAL) sub-module within the RCHRES module. Fecal coliform bacteria are simulated as dissolved pollutants in the GQUAL sub-module.

4.2. Input Data Requirements

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 TMDLs for the Hays Creek watershed are discussed below.

4.2.1. Climatological Data

Hourly precipitation data were obtained from NCDC's closest National Weather Service COOP station, the Staunton Sewage Plant in Augusta County, located 23 miles northeast of the watershed. Holes in these data were patched with data from the NCDC weather station at the Montebello Fish Hatchery in Nelson County. Because data for some parameters needed by HSPF were not available at Staunton, data from Lexington and the Lynchburg Airport were also used to complete the meteorological data set required for running HSPF. Detailed descriptions of the weather data and the procedure for converting the raw data into the required data set are presented in Appendix C.

A recommendation came from the Local Steering Committee at their second meeting (discussed in more detail in Chapter 7) that an Integrated Flood Observing and Warning System (IFLOWS) automatic rain gage near the watershed be used in the development of the model. This recommendation was considered, but discarded based on quality control issues. IFLOWS data are meant to provide warning to local communities about intense rainfall and flash flooding. The data are not intended to be used as a historical record of rainfall at the monitoring site. There is no quality control performed on the data. If the gages or the electronic transmission of data are not working properly, the archived record may indicate no precipitation (0.00) instead of missing data. NCDC data undergo extensive automated and manual quality control and

NCDC provides assurance of the quality of the data and therefore is more reliable for use in model development. When NCDC precipitation data is not available for short periods of time, it is appropriate to use IFLOWS data to supplement the NCDC data. However, for this study, the hourly precipitation data from the NCDC stations were adequate and did not need to be supplemented.

4.2.2. Model Parameters

The hydrology parameters required by HSPF were defined for every land use category. Required hydrology parameters are listed in the HSPF Version 12 User's Manual (Bicknell et al., 2001). Because there are no continuous flow monitoring stations within the Hays Creek watershed, a detailed hydrology calibration needed to be performed for a nearby watershed that has stream flow data available and characteristics similar to those of the Hays Creek watershed. Three watersheds with stream flow data available and in close proximity to Hays Creek were considered as possible surrogate watersheds for the hydrology calibration: Christians Creek watershed in Augusta County, Kerrs Creek watershed in Rockbridge County, and Linville Creek watershed in Rockingham County. Christians Creek and Linville Creek have prior TMDLs developed and therefore have calibrated data sets already available.

Several criteria were used to select the calibration watershed. These include the relative location of the watersheds, watershed size, land use distribution, underlying geology, hydrologic soil group, and average land slope. The Linville Creek watershed is the farthest (35 miles) while the other two watersheds are less than 10 miles away. The Christians Creek watershed is the closest in size to the Hays Creek watershed with Kerrs Creek and Linville Creek drainage areas being significantly smaller (Table 4.1). Pasture is the dominant land use for the Hays Creek and Linville Creek watersheds. Forest is the dominant land use for both Christians Creek and Kerrs Creek watersheds. However, the percent forest cover in Christians Creek is comparable to that in the Hays Creek watershed. Land use areas for each watershed are summarized in Table 4.1.

Table 4.1. Land use comparison and total watershed area of potential hydrologic surrogate watersheds.

Land Use	Hays Creek (acres)	% Cover	Christians Creek (acres)	% Cover	Linville Creek (acres)	% Cover	Kerrs Creek (acres)	% Cover
pasture	28,291	55%	19,090	34%	14,633	49%	3,512	16%
cropland	555	1%	9,308	16%	6,499	22%	749	3%
forest	21,105	41%	22,549	40%	4,668	16%	17,413	76%
urban	1,494	3%	5,545	10%	3,847	13%	1,116	5%
Total	51,445		56,491		29,647		22,790	

All four watersheds are located entirely in the Central Appalachian Ridge and Valleys Level III Ecoregion. Soils in the Hays Creek and Christians Creek watersheds are predominately hydrologic soil group B soils. The other watersheds contain mainly hydrologic soil group C soils. Average slopes obtained from the STATSGO soil survey show the Hays Creek Watershed has an average slope of about 25%. The Christians Creek and Linville Creek watersheds both have slightly greater slopes, averaging about 26%. The Kerrs Creek watershed had the highest average slope, 30%.

The relative distance, watershed size, distribution of land use, and hydrologic soil group favor Christians Creek over the other two watersheds. Based on the selection criteria, hydrologic parameters from the nearby Christians Creek watershed were used in the Hays Creek model. These parameters were calibrated during the development of the fecal coliform TMDL for Christians Creek (VADEQ, 2002), and the calibrated parameters were transferred to the corresponding land uses in the Hays Creek watershed. The remaining hydrologic parameters, those that have a direct relation to physical characteristics of the watershed (e.g., land slope), were obtained from digital maps of the Hays Creek watershed.

Each reach requires a function table (FTABLE) to describe the relationship between water depth, surface area, volume, and discharge (Bicknell et al., 2001). A visual assessment of stream characteristics was completed for Hays Creek in May 2007. Stream lengths and slopes were determined using GIS data. Information on the calculated stream geometry for each sub-watershed is presented in Table 4.2 for the bankfull condition. The procedures described in Staley et al. (2006) were used to

characterize the reaches in the Hays Creek watershed using NRCS bankfull equations and digital elevation models.

Required water quality parameters are also given in the HSPF User's Manual (Bicknell et al., 2001). Initial estimates for bacteria loading parameters in Hays Creek were based on estimates of bacteria production in the watershed; estimates of die-off rates and subsurface bacteria concentrations were based on values commonly used in previous TMDLs.

4.3. Accounting for Pollutant Sources

4.3.1. Overview

There are two small permitted facilities allowed to discharge bacteria into Moffatts Creek (see Table 3.2). During future conditions, flow from these facilities was modeled at the facilities' design flows and bacteria concentrations were modeled at their permitted limits (126 cfu/100 mL).

Bacteria loads that are directly deposited by cattle, wildlife, and straight pipes directly into streams were treated as direct nonpoint sources in the model. Direct nonpoint source loadings were applied to the stream reach in each sub-watershed as appropriate. The point sources permitted to discharge bacteria in the watershed were incorporated into the simulations at the stream locations designated in their permits.

Table 4.2. Reach characteristics for Hays Creek.

Sub-watershed	Stream length (mile)	Average bankfull width (ft)	Average bankfull channel depth (ft)	Slope (ft/ft)
1	1.39	25	5	0.004
2	2.03	25	5	0.003
3	3.18	75	4	0.008
4	3.14	10	3	0.025
5	2.49	40	6	0.005
6	2.73	8	2	0.032
7	0.88	25	15	0.004
8	3.20	8	3	0.034
9	0.97	40	10	0.007
10	0.53	10	5	0.007
11	4.50	10	5	0.013
12	1.16	8	3	0.033
13	1.37	5	2	0.019
14	0.13	10	3	0.005
15	2.20	10	3	0.043
16	0.21	10	3	0.013
17	3.91	6	2	0.027
18	3.52	10	3	0.034
19	2.94	15	5	0.010
20	3.00	30	5	0.013
21	2.43	10	10	0.007
22	2.68	5	1	0.014
23	0.77	25	10	0.003
24	3.88	5	2	0.028
25	1.86	25	10	0.009
26	2.83	5	2	0.075
27	2.10	20	5	0.011
28	1.84	10	3	0.011
29	1.93	5	3	0.036
30	2.23	5	2	0.028
31	2.13	8	5	0.014
32	2.35	8	2	0.037

Bacteria that were deposited on land were treated as nonpoint source loadings; all or part of that load may be transported to the stream as a result of surface runoff during rainfall events. The nonpoint source loading was applied in the model in the form of fecal coliform counts to individual land use categories by sub-watershed. Bacterial die-off on the land surface and in the stream was simulated within the model. Both direct nonpoint and nonpoint source loadings were varied by month to account for

seasonal differences in bacteria production and deposition characteristics, such as migratory behavior, management practices, and cattle time in streams.

The Bacteria Source Load Calculator (Zeckoski et al., 2005) was used to generate nonpoint source fecal coliform inputs to the HSPF model. This spreadsheet program takes inputs of animal numbers, land use, and management practices by sub-watershed and outputs hourly direct deposition to streams and monthly loads to each land use type. The BSLC allows direct deposition in the stream by cattle and waterfowl to occur only during daylight hours.

4.3.2. Modeling fecal coliform die-off

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

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

Where: C_t = concentration or load at time t;

C_o = starting concentration or load;

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 Hays 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.

Waste type	Storage/application	Decay rate (day^{-1})	Reference
Dairy manure	Pile (not covered)	0.066	Crane and Moore (1986)
	Pile (covered)	0.028	
Beef manure	Anaerobic lagoon	0.375	
Poultry litter	Soil surface	0.035	Giddens *et al*. (1973)
		0.342	Crane *et al*. (1980)

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: Because the decay rate for liquid dairy manure storage could not be found in the literature, the decay rate for beef manure in anaerobic lagoons (0.375 day^{-1}) was used.
- Solid cattle manure: Based on the range of decay rates (0.028-0.066 day^{-1}) reported for solid dairy manure, a decay rate of 0.05 day^{-1} was used, assuming that a majority of manure piles are not covered.
- Poultry waste in pile/house: Because no decay rates were found for poultry waste in storage, a decay rate of 0.035 day^{-1} was used based on the lower decay rate reported for poultry litter applied to the soil surface. The lower value was used instead of the higher value of 0.342 day^{-1} (Table 4.3) because fecal coliform die-off in storage was assumed to be lower, given the absence of UV radiation and predation by soil microbes.

The procedure for calculating fecal coliform counts in waste at the time of land application is included in Appendix D. 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 is 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 is considered to arrive at an effective survival fraction over the entire storage period. The amount of fecal coliform available for application to land per year is estimated by multiplying the survival fraction with total fecal coliform produced per year (in as-excreted manure). Monthly fecal coliform application to land is 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. A base-10 decay rate of 0.05 day^{-1} was assumed for fecal coliform on the land surface. The decay rate of 0.05 day^{-1} is represented in HSPF by specifying a maximum surface buildup of nine times the daily loading rate. An in-stream decay rate of 1.15 day^{-1} was used.

4.3.3. Modeling 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, and human populations and 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. Fecal coliform loadings to each sub-watershed in the Hays Creek watershed are presented in Appendix E for existing conditions. The sources of fecal coliform to different land use categories and how the model handled them are briefly discussed below.

1. Cropland: Liquid dairy manure and solid manure 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, the monthly fecal coliform loading assigned to cropland was distributed over the entire cropland acreage within a sub-watershed. Thus, loading rate varied by month and sub-watershed.
2. Pasture: In addition to direct deposition from livestock and wildlife, pastures receive applications of liquid dairy manure and solid manure as described in Chapter 3. Applied fecal coliform loading to pasture was reduced to account for die-off during storage. For modeling, the monthly fecal coliform loading assigned to pasture was distributed over the entire pasture acreage within a sub-watershed.
3. Low Density Residential: Fecal coliform loading on rural residential land uses 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 assumed to be uniformly applied to the low density residential pervious land use areas in each sub-watershed. Pet loads varied by sub-watershed but were constant throughout the year. Impervious areas (Table 2.4) received constant loads of 1.0×10^7 cfu/acre/day.

4. High-Density Residential: Fecal coliform loading to the pervious portion of high density residential land use came from pets in these areas; the impervious load was assumed to be a constant 1.0 x 10^7 cfu/acre/day (USEPA, 2000). These loadings varied by sub-watershed.
5. Forest: Wildlife not defecating in streams, cropland, or pastures provided fecal coliform loading to the forested land use. These loadings varied by month (to account for migration and hibernation) and by sub-watershed.

4.3.4. Modeling Direct Nonpoint Sources

Fecal coliform loads from direct nonpoint sources included cattle in streams, wildlife in streams, and direct loading to streams from straight pipes from residences. Loads from direct nonpoint sources in each sub-watershed are described in detail in Chapter 3. Contributions of fecal coliform from interflow and groundwater were modeled with a constant concentration of 15 cfu/100mL for interflow and 10 cfu/100mL for groundwater.

4.4. Model Calibration and Validation

Model calibration is the process of selecting model parameters that provide an accurate representation of the watershed. In this section, the procedures followed for calibrating the hydrology and water quality components of the Hydrological Simulation Program-FORTRAN (HSPF) model are discussed.

4.4.1. Hydrology

Hydrologic calibration could not be conducted on Hays Creek watershed due to the lack of continuous observed flow data. However, hydrological parameters in HSPF had to be set to “reasonable” values because the output of the hydrological component of HSPF impacts fecal coliform predictions. Some of those parameters were estimated based on watershed characteristics, while others were based on the characteristics of the nearby Christians Creek watershed. Table 4.4 lists the different hydrologic parameters and specifies the source of each parameter. Parameters that vary by land use and month are listed in Appendix F.

Table 4.4. Hydrology parameters for Hays Creek.

Parameter	Definition	Units	FINAL CALIBRATION	FUNCTION OF…	Christians Creek or Estimated	Appendix F Table (if applicable)
PERLND						
PWAT-PARM2						
FOREST	Fraction forest cover	none	0.0	Forest cover	Christians Creek	
LZSN	Lower zone nominal soil moisture storage	inches	9 forest; 8 pasture and crop; 7 LDR and HDR	Soil properties	Christians Creek	
INFILT	Index to infiltration capacity	in/hr	0.08 forest; 0.06 pasture and crop; 0.05 LDR and HDR	Soil and cover conditions	Christians Creek	
LSUR	Length of overland flow	feet	200 forest; 270 pasture; 300 crop, LDR and HDR	Topography	Estimated	
SLSUR	Slope of overland flowplane	none	0.083 forest; 0.06 pasture; 0.057 crop; 0.05 LDR; 0.15 HDR	Topography	Estimated	
KVARY	Groundwater recession variable	1/in	0.0	Calibrate	Christians Creek	
AGWRC	Base groundwater recession	none	0.965	Calibrate	Christians Creek	
PWAT-PARM3						
PETMAX	Temp below which ET is reduced	deg. F	40	Climate, vegetation	Christians Creek	
PETMIN	Temp below which ET is set to zero	deg. F	35	Climate, vegetation	Christians Creek	
INFEXP	Exponent in infiltration equation	none	2	Soil properties	Christians Creek	
INFILD	Ratio of max/mean infiltration capacities	none	2	Soil properties	Christians Creek	
DEEPFR	Fraction of GW inflow to deep recharge	none	0.11	Geology	Christians Creek	
BASETP	Fraction of remaining ET from baseflow	none	0.00	Riparian vegetation	Christians Creek	
AGWETP	Fraction of remaining ET from active GW	none	0.00	Marsh/wetlands ET	Christians Creek	
PWAT-PARM4						
CEPSC	Interception storage capacity	inches	monthly[a]	Vegetation	Christians Creek	1
UZSN	Upper zone nominal soil moisture storage	inches	monthly[a]	Soil properties	Christians Creek	2
NSUR	Mannings' n (roughness)	none	0.35 forest; 0.15 pasture; 0.10 crop, LDR and HDR	Land use, surface condition	Estimated	
INTFW	Interflow/surface runoff partition parameter	none	1.0-3.0	Soils, topography, land use	Christians Creek	
IRC	Interflow recession parameter	none	0.6	Soils, topography, land use	Christians Creek	
LZETP	Lower zone ET parameter	none	monthly[a]	Vegetation	Christians Creek	3

Table 4.4. Hydrology parameters for Hays Creek. (cont.)

Parameter	Definition	Units	FINAL CALIBRATION	FUNCTION OF…	Christians Creek or Estimated	Appendix F Table (if applicable)
IMPLND						
IWAT-PARM2						
LSUR	Length of overland flow	feet	150	Topography	Estimated	
SLSUR	Slope of overland flowplane	none	0.054	Topography	Estimated	
NSUR	Mannings' n (roughness)	none	0.3	Land use, surface condition	Estimated	
RETSC	Retention/inter-ception storage capacity	inches	0.02	Land use, surface condition	Christians Creek	
IWAT-PARM3						
PETMAX	Temp below which ET is reduced	deg. F	40	Climate, vegetation	Christians Creek	
PETMIN	Temp below which ET is set to zero	deg. F	35	Climate, vegetation	Christians Creek	
RCHRES						
HYDR-PARM2						
KS	Weighting factor for hydraulic routing		0.5		Christians Creek	

[a]Varies by month and with land use

VADEQ collected monthly flow samples at ambient monitoring station 2-HYS001.41 from July 2005 through June 2006 (Section 2.6). It is important to check to make sure that the model simulations made using the estimated hydrologic parameters produce results that are reasonable for the Hays Creek watershed. For instance, if the model predicted flow rates an order of magnitude greater or less than the observed flows on the observed flow dates, the parameters would not have been appropriate for use in Hays Creek. To ensure that the model parameters were appropriate for the Hays Creek watershed, observed flows at the monitoring location were compared to simulated flows at the corresponding sub-watershed outlet. The observed and simulated flows for the observation period are shown in Figure 4.1. As can be seen from the figure, the simulated flows match the few observed points. Thus, the calibrated parameters (Table 4.4) are acceptable for use in the Hays Creek watershed.

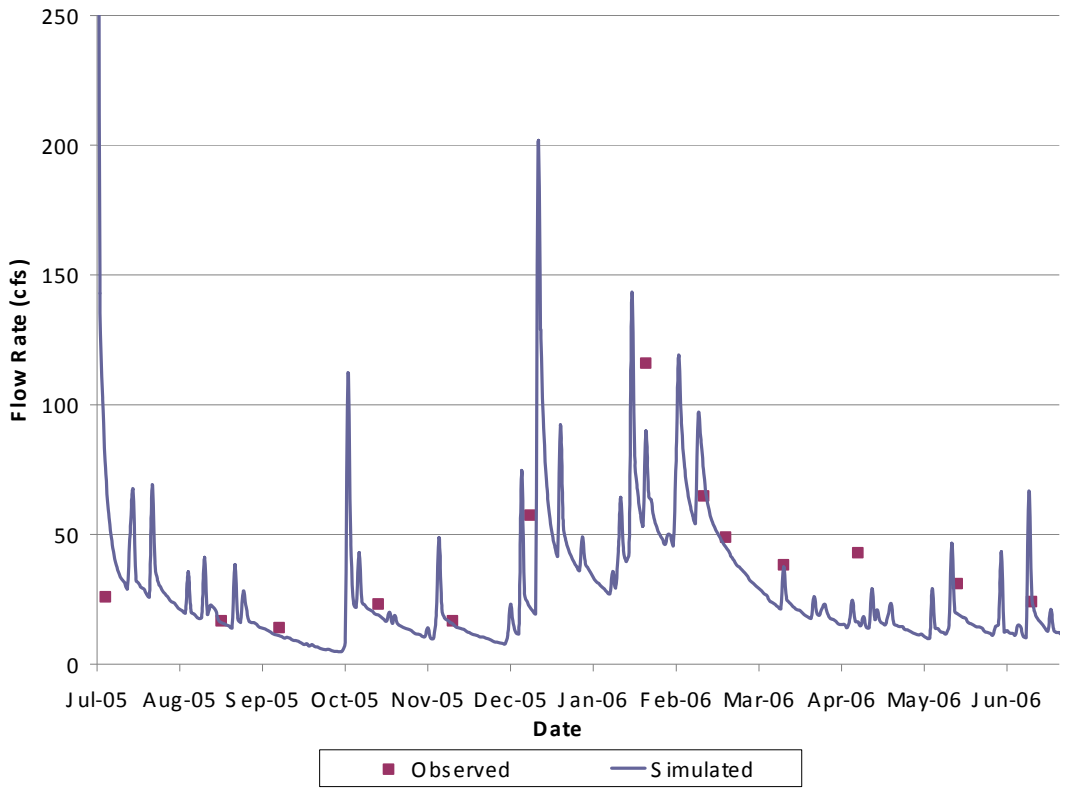

Figure 4.1. Observed and simulated flows at VADEQ station 2-HYS001.41 on Hays Creek.

4.4.2. Water Quality

The water quality calibration for the Hays Creek watershed was performed at an hourly time step using the HSPF model. Limited observations of bacterial water quality were available for a few stations throughout the watershed, as shown in Table 2.6 and discussed in Section 2.7. Because it is necessary to calibrate to fecal coliform data (and not *E. coli* data), use of the most current data is limited. There is an inherent amount of uncertainty in the *E. coli* translator regression equation. As would be expected, the equation does not perfectly describe the relationship between *E. coli* and fecal coliform. Thus, only stations 2-HYS001.41, 2-HYS007.46, 2-OTS000.45, and 2-WKS001.03 were used for the calibration. The other two stations do not have enough data for modeling purposes. The period of January 1, 2002 to December 31, 2006 was selected for calibration because it includes data from all four of the selected stations. Otts Creek and Walker Creek were calibrated first and then the Hays Creek watershed upstream from monitoring station 2-HYS007.45 was calibrated using output from Otts Creek.

Then these calibrated models were treated as inflow for the calibration of Hays Creek at monitoring station 2-HYS001.41. The largest dataset, available at station 2-HYS001.41, was the only one that allowed for both calibration and validation.

Output from the HSPF model was generated as an hourly time series and daily average time series of fecal coliform concentration at sub-watersheds 2, 5, 10, and 25, which correspond to the locations of stations 2-HYS001.41, 2-HYS007.46, 2-OTS000.45, and 2-WKS001.03, respectively. During allocation, the DEQ *E. coli* translator (Eqn. 4.2) will be implemented using the GENER block in HSPF to calculate instream *E. coli* concentration. The geometric mean of *E. coli* concentrations will then be calculated on a monthly basis.

$$\log_2 EC(cfu/100mL) = -0.0172 + 0.91905 * \log_2 FC(cfu/100mL) \qquad [4.2]$$

Observed data in the Hays Creek watershed were typically collected through grab samples collected on a monthly basis (at best). Because it is not practical to expect such data to exactly match an average simulated value on a specific day, other methods of comparison are needed. The strongest method of comparison is the use of the minimum and maximum simulated values – the observed data should fall roughly within the range of values simulated near the date of observed data collection. Other parameters to consider are violation rate, averages, medians, geometric means, etc.

Calibration

The calibration period was January 2002 – December 2006. This period included observed data at four of the stations. Initial model predictions were high. The major adjustments and reasoning behind each adjustment are given in Table 4.5. Once these adjustments had been made, the fecal coliform predictions from HSPF acceptably matched the simulated data. The final goodness-of-fit measures for the calibration at the four monitoring stations are listed in Table 4.6. Figures 4.2 through 4.5 show the daily max, min, and average of simulated values for the final calibration runs for Otts Creek (2-OTS000.45), Walker Creek (2-WKS001.03), upper Hays Creek (2-HYS007.46), and lower Hays Creek (2-HYS001.41), respectively. Based on the goodness-of-fit

parameter values and the visual comparisons, the water quality calibration was considered acceptable.

Table 4.5. Adjustments made during the Hays Creek bacteria model calibration.

Symptom	Adjustment	Rationale
Initial estimates of straight pipe contributions were too high, causing overprediction in the model	Set human fecal coliform bacteria production to 1.5 x 10^8 cfu/day	Geldreich (1978) reports a low end of human fecal coliform excretion of 1.5 x 10^8 cfu/day
	Restrict human defecation to daylight hours	Assume that humans defecate only during the day while they're awake to do so
Cattle direct deposit contributions were too high	Decrease cattle fecal coliform production to 8.556 x 10^9 cfu/day	Reported by Geldreich (1978) – in this document, it is the product of Geldreich's fecal coliform density for cattle (table 4.3 in that document) and ASAE's fecal production for cattle (table 4.1 in that document)
	Decrease livestock stream access in Walker Creek and Otts Creek	Initial stakeholder response indicated that BMPs (stream-side fencing) had been applied to significant portions of Walker Creek and Otts Creek to reduce livestock access to the streams.
Wildlife direct deposit contributions were too high	Decrease wildlife population	Initial stakeholder response that beaver and raccoon estimates looked high

Table 4.6. Water quality calibration statistics.

	Geometric Mean cfu/100ml	Average* cfu/100ml	Median* cfu/100ml	Single Sample Criterion Violation Rate (%)
Otts Creek (2-OTS000.45)				
Observed	101	199	100	17
Simulated	181	224	165	17
Walker Creek (2-WKS001.03)				
Observed	117	191	120	11
Simulated	159	226	164	12
upper Hays Creek (2-HYS007.46)				
Observed	218	451	285	39
Simulated	403	575	319	40
lower Hays Creek (2-HYS001.41)				
Observed	276	443	300	39
Simulated	348	616	438	42

* simulated values for these parameters were calculated from the average daily predictions in the 5 days surrounding each observed data collection day; this provides a more detailed comparison with the actual observations, as it targets the specific meteorological and hydrologic conditions at the time of data collection

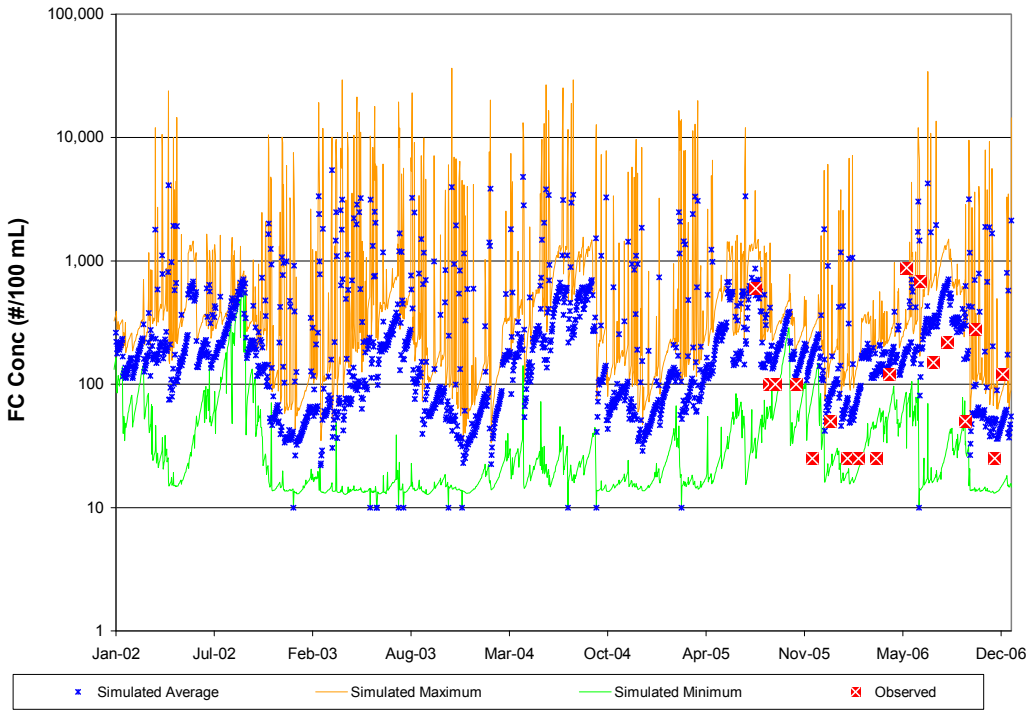

Figure 4.2. Observed fecal coliform data plotted with the daily maximum, minimum, and average simulated fecal coliform values for Otts Creek (2-OTS000.45) for the calibration (Jan. 1, 2002 to Dec. 31, 2006).

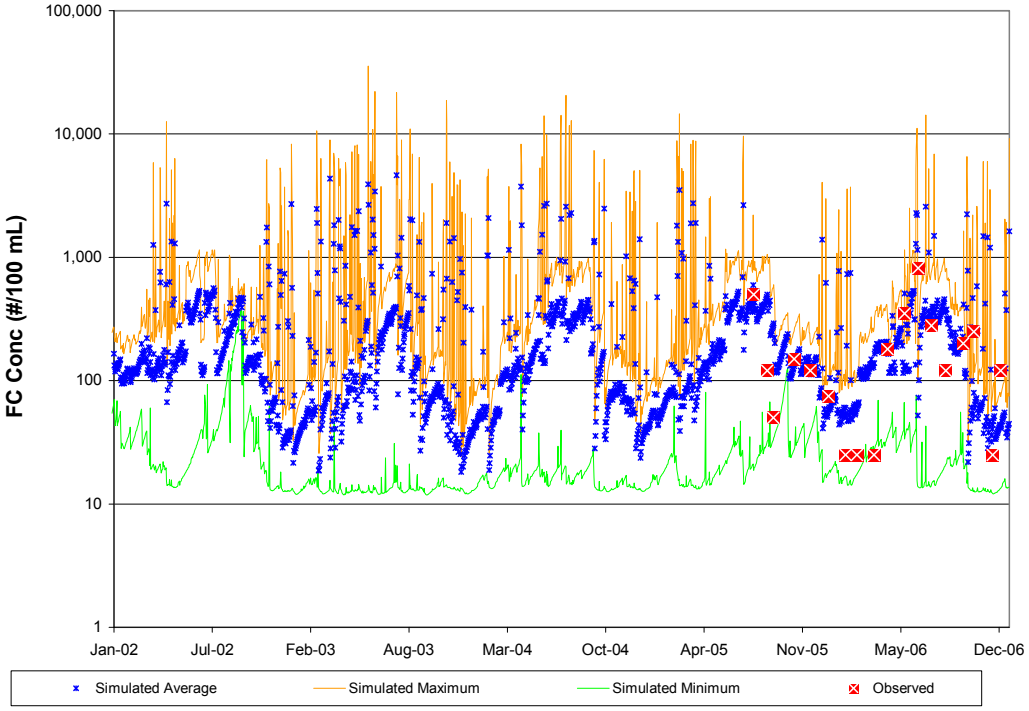

Figure 4.3. Observed fecal coliform data plotted with the daily maximum, minimum, and average simulated fecal coliform values for Walker Creek (2-WKS001.03) for the calibration (Jan. 1, 2002 to Dec. 31, 2006).

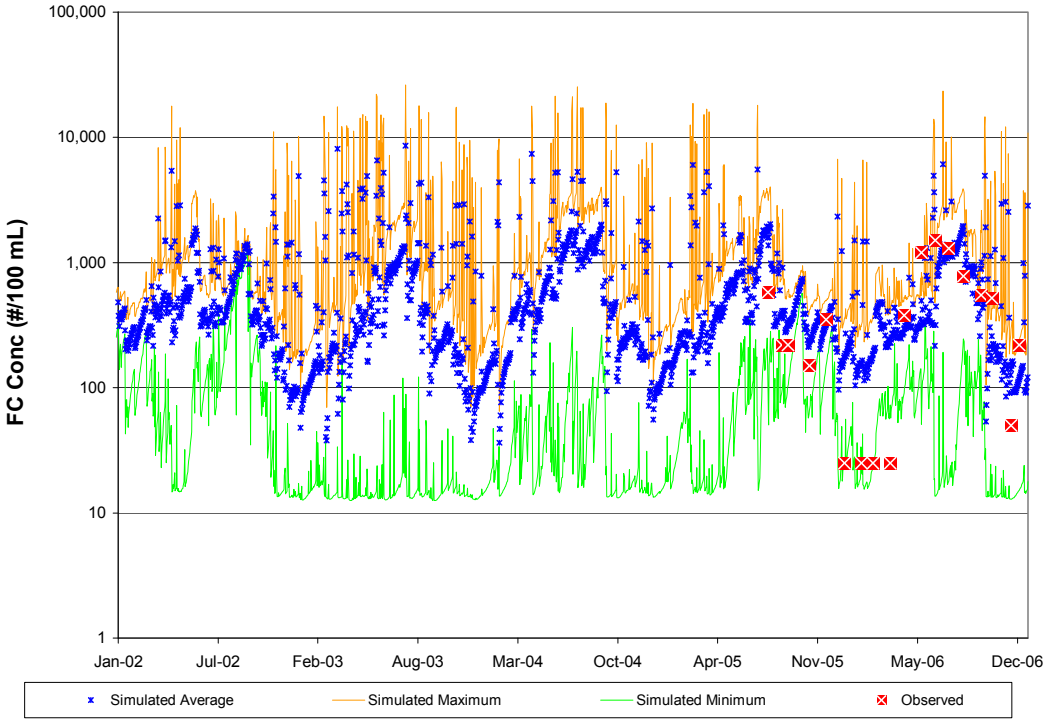

Figure 4.4. Observed fecal coliform data plotted with the daily maximum, minimum, and average simulated fecal coliform values for upper Hays Creek (2-HYS007.46) for the calibration (Jan. 1, 2002 to Dec. 31, 2006).

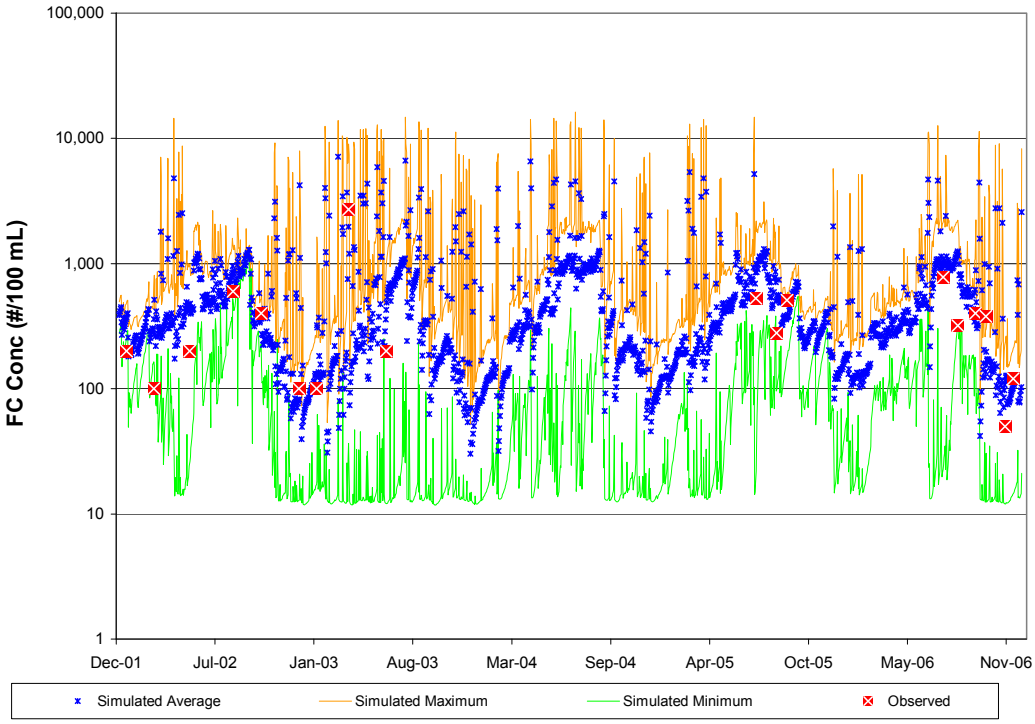

Figure 4.5. Observed fecal coliform data plotted with the daily maximum, minimum, and average simulated fecal coliform values for lower Hays Creek (2-HYS001.41) for the calibration (Jan. 1, 2002 to Dec. 31, 2006).

Validation

After the calibration of Hays Creek at VADEQ monitoring station 2-HYS001.41, the model was run for a different period (January 1, 1999 - December 31, 2001) as a validation to ensure the calibrated input parameters were appropriate. The goodness-of-fit statistics for the validation run are listed in Table 4.7. Figure 4.6 shows the daily min, max, and average of the simulated values for the validation. The simulated concentrations varied with the seasonal trend. Based on the goodness-of-fit parameter values and the visual comparisons both the water quality calibration and validation for Hays Creek were considered acceptable. The final calibrated water quality parameters are given in Table 4.8.

Table 4.7. Summarized goodness-of-fit measures for simulated and observed fecal coliform concentrations for the validation period for Hays Creek at station 2-HYS001.41.

	Geometric Mean cfu/100ml	Average* cfu/100ml	Median* cfu/100ml	Single Sample Criterion Violation Rate (%)
Observed	277	429	300	41
Simulated	403	555	435	48

* simulated values for these parameters were calculated from the average daily predictions in the 5 days surrounding each observed data collection day; this provides a more detailed comparison with the actual observations, as it targets the specific meteorological and hydrologic conditions at the time of data collection

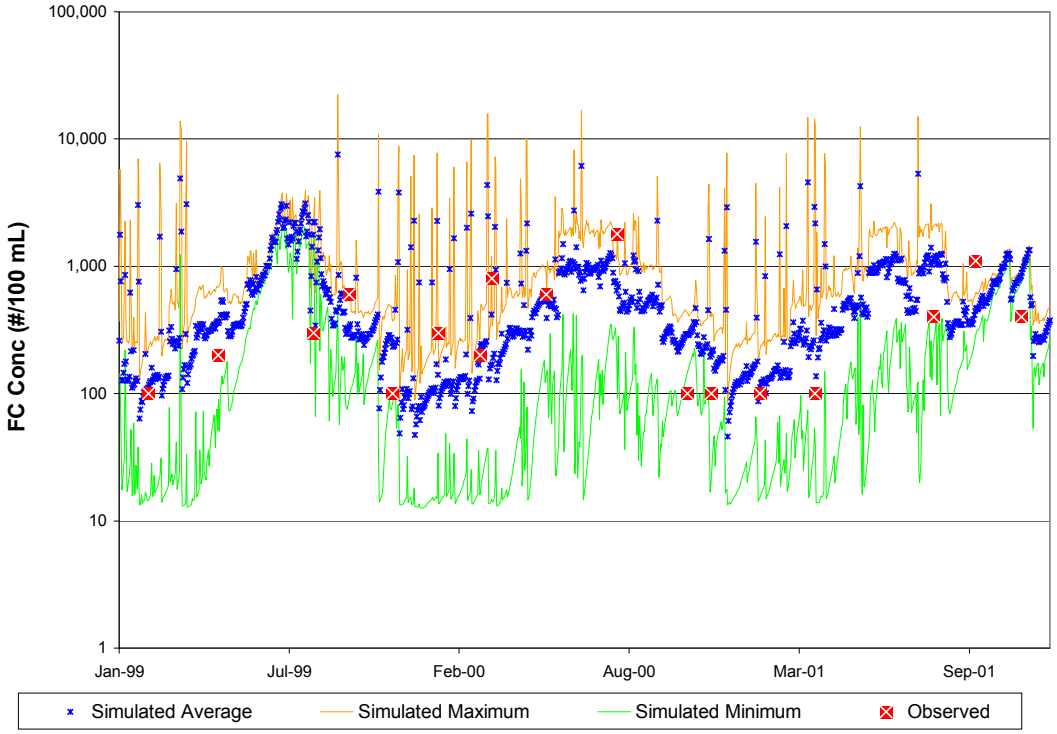

Figure 4.6. Observed fecal coliform data plotted with the daily maximum, minimum, and average simulated fecal coliform values for lower Hays Creek (2-HYS001.41) for the validation period (Jan. 1, 1999 to Dec. 31, 2001).

Table 4.8. Calibrated water quality parameters for the Hays Creek watershed.

Parameter	Definition	Units	FINAL CALIBRATION	FUNCTION OF…	Appendix F Table (if applicable)
PQUAL					
SQO	Initial storage of constituent	#/ac	0	Land use	
POTFW	Washoff potency factor	#/ton	0		
POTFS	Scour potency factor	#/ton	0		
ACQOP	Rate of accumulation of constituent	#/day	Monthly[a]	Land use	4
SQOLIM	Maximum accumulation of constituent	#	9 x ACQOP[a]	Land use	5
WSQOP	Wash-off rate	in/hr	2.0	Land use	
IOQC	Constituent conc. in interflow	#/ft3	4248		
AOQC	Constituent conc. in active groundwater	#/ft3	2832		
IQUAL					
SQO	Initial storage of constituent	#/ac	$1x10^7$		
POTFW	Washoff potency factor	#/ton	0		
ACQOP	Rate of accumulation of constituent	#/day	$1x10^7$	Land use	
SQOLIM	Maximum accumulation of constituent	#	$3x10^7$	Land use	
WSQOP	Wash-off rate	in/hr	2.0	Land use	
GQUAL					
FSTDEC	First order decay rate of the constituent	1/day	1.15		
THFST	Temperature correction coeff. for FSTDEC		1.05		

[a]Values varied by month and with land use

BST Comparison

Bacterial Source Tracking (BST) data were collected from July 2005-June 2006 at station, 2-HYS001.41. BST results are reported as a flow- and concentration-weighted average of the twelve samples. For comparison, model outputs from different bacteria sources were generated for July 2005-June 2006 at the appropriate sub-watershed outlet (sub-watershed 2) and were also flow- and concentration-weighted. The BST results are presented in Table 4.9 along with the breakdown of the simulated concentrations. The minimum and maximum observed and simulated values are also presented in this table; flow- and concentration-weighted averages are given in bold.

Table 4.9. Observed and Simulated Source Breakdown Results (percent contributions).

Source	Livestock (Min; Max)	Wildlife (Min; Max)	Human (Min; Max)	Pet (Min; Max)
Observed BST Results	**27** (0; 62)	**35** (0; 85)	**22** (0; 46)	**16** (0; 26)
Breakdown Simulated by HSPF	**92.0** (0.3; 98.2)	**6.6** (0.0; 90.6)	**0.7** (0.0; 4.7)	**0.7** (0.0; 1.6)

It is difficult to draw exact conclusions from BST analysis. The ranges of data (both simulated and observed) are evidence that the breakdown of sources will vary considerably according to the time and location a sample is collected. This variance is largely dependent on the time since the last storm event – the relative contributions from sources at high flows are not the same as those at low flows. Constant sources like straight pipes and livestock direct deposition in streams are primary contributors most of the time, but during high flow events overland sources, such as livestock loads on pasture and cropland dominate. Wildlife sources in general tend to contribute more during low flow events (via direct deposition in the streams) and only contribute a miniscule amount during high flow events, as runoff from the areas where wildlife are commonly found (forest) is minor compared to runoff from pasture, cropland, and residential areas.

For example, during above average flow periods, the signature is almost totally dominated by livestock sources (98% on average). During below average flow periods, the signature is more equally distributed between the sources that dominate the contributions at low flows (74% livestock, 25% wildlife on average). Because both the simulated and observed signatures were flow-weighted, the simulated breakdown shows a high livestock signature. However, most of the 'observed' BST samples were collected during periods of below-average flow, which might help explain the lower livestock signature seen in the 'observed' average.

To further complicate matters, as can be seen in Stoeckel et al. (2004), when the BST antibiotic resistance analysis (ARA) method is forced to classify all samples (i.e., there is not an 'unknown' category), it tends to place the unknown samples into the pet category, artificially inflating the 'pet' signature. Unknown samples forced to be classified in this way could come from any source – livestock, wildlife, human, or pet. Indeed, given a 16% average (and 26% maximum) signature for pets, it seems likely that this may be a problem in the 'observed' data for Hays Creek.

The simulated values match what we would expect from this watershed. There is a very strong livestock signature due to the fact that there is a large population of cattle in the watershed and nearly all livestock are not excluded from the stream. The simulated source breakdown represents the known conditions in the watershed.

Chapter 5: TMDL Allocations

The objective of a TMDL is to allocate allowable loads among different pollutant sources so that the appropriate control actions can be taken to achieve water quality standards (USEPA, 1991).

5.1. Background

The objective of the bacteria TMDLs for the Hays Creek watershed was to determine what reductions in fecal coliform and *E. coli* loadings from point and nonpoint sources are required to meet state water quality standards. The state water quality standard for *E. coli* used in the development of the TMDL included two criteria: 126 cfu/100 mL (calendar-month geometric mean) and 235 cfu/100 mL (single sample maximum). The TMDL considers all significant sources contributing *E. coli* to the impaired streams. The sources can be separated into nonpoint and point sources. The different sources in the TMDL are defined in the following equation:

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

Where: WLA = waste load allocation (point source contributions)
LA = load allocation (nonpoint source contributions); and
MOS = margin of safety.

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

A translator equation developed by VADEQ (equation 5.2) was used to convert the fecal coliform model output to *E. coli* for comparison with the water quality standards. The *E. coli* translator equation was implemented in the HSPF simulation using the GENER block. In order to develop the actual TMDL equation, it was

necessary to generate *loads* (rather than concentrations) of *E. coli*. 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. Annual loads were obtained by summing the daily loads and dividing by the number of years in the allocation period.

$$\log_2 EC(cfu/100mL) = -0.0172 + 0.91905 * \log_2 FC(cfu/100mL) \qquad [5.2]$$

When developing a bacteria TMDL, the required bacteria load reductions are modeled by decreasing the amount of bacteria running off the land surface that reach the stream or decreasing the amount of bacteria directly deposited in the stream; these reductions are presented in the tables in the following sections. The reductions called for in the following sections indicate the need to decrease the amount of bacteria reaching the stream in order to meet the applicable water quality standard. The reductions shown in these sections are not intended to infer that agricultural producers should reduce their herd size, or limit the use of manures as fertilizer or soil conditioner. Rather, it is assumed that the required reductions from affected agricultural source categories (cattle direct deposit, cropland, etc.) will be accomplished by implementing BMPs like filter strips, stream fencing, and off-stream watering; and that required reductions from residential source categories will be accomplished by repairing aging septic systems, eliminating straight pipe discharges, and other appropriate measures included in the TMDL Implementation Plan.

A period of six years was used for allocation modeling. Observed meteorological data from the Staunton weather station were extracted for 2001-2006 and used in the allocation simulations. These particular rainfall years were selected because they incorporate average rainfall, low rainfall, and high rainfall; and the climate during these years caused a wide range of hydrologic events including both low and high flow conditions (for a stream flow chart for the allocation period, see Appendix G). The bacteria loading in the model for allocation scenarios was representative of anticipated future conditions.

The calendar-month geometric mean values used in this report are geometric means of the simulated 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.

5.2. Existing Conditions

Analysis of the simulation results for the existing conditions in the watershed (Tables 5.1 – 5.3) shows that contributions from livestock and wildlife direct deposits are the primary source of *E. coli* to the stream. Contributions from pervious land surfaces are also contributors to the mean daily *E. coli* concentration. The results in these tables were taken as the average daily contributions for the allocation simulation period, irrespective of the magnitude of the concentration or the flow rate (factors that were considered in the earlier section detailing the source breakdown used in the calibration). Tables 5.1 – 5.3 give an idea of what sources will be the dominant contributors to the instantaneous *E. coli* concentrations, and thus what sources will control the violations of the single sample criterion: loadings from wildlife direct deposit, livestock deposit, and pervious land segments will violate the single sample criterion by themselves. Although the overall contribution from pervious land sources is not as high as loading from livestock direct deposits, it dominates the concentration during high flow events and in fact by itself will violate the instantaneous standard multiple times throughout the allocation period.

The contribution of each of the sources listed in Tables 5.1 – 5.3 to the calendar-month geometric mean *E. coli* concentration is shown in Figures 5.1 – 5.3. The pervious land surface (PLS_IntGr) category in the figures includes both the ‘nonpoint source loadings from pervious land segments’ and the ‘interflow and groundwater contribution’ categories from the tables.

Table 5.1. Relative contributions of different *E. coli* sources to the overall *E. coli* concentration for existing conditions in Otts Creek.

Source	Mean Daily *E. coli* Concentration by Source, cfu/100 mL	Relative Contribution by Source
Nonpoint source loadings from pervious land segments	59	33%
Direct nonpoint source loadings to the stream from wildlife	40	23%
Direct nonpoint source loadings to the stream from livestock	62	35%
Interflow and groundwater contribution	8	4%
Straight-pipe discharges to stream	9	5%
Nonpoint source loadings from impervious land segments	0.6	<1%
All Sources	178	

Table 5.2. Relative contributions of different *E. coli* sources to the overall *E. coli* concentration for existing conditions in Walker Creek.

Source	Mean Daily *E. coli* Concentration by Source, cfu/100 mL	Relative Contribution by Source
Nonpoint source loadings from pervious land segments	51	30%
Direct nonpoint source loadings to the stream from wildlife	28	17%
Direct nonpoint source loadings to the stream from livestock	80	47%
Interflow and groundwater contribution	8	4%
Straight-pipe discharges to stream	4	2%
Nonpoint source loadings from impervious land segments	0.5	<1%
All Sources	172	

Table 5.3. Relative contributions of different *E. coli* sources to the overall *E. coli* concentration for existing conditions in Hays Creek.

Source	Mean Daily *E. coli* Concentration by Source, cfu/100 mL	Relative Contribution by Source
Nonpoint source loadings from pervious land segments	84	27%
Direct nonpoint source loadings to the stream from wildlife	71	23%
Direct nonpoint source loadings to the stream from livestock	143	46%
Interflow and groundwater contribution	8	2%
Straight-pipe discharges to stream	5	2%
Nonpoint source loadings from impervious land segments	0.6	<1%
Point sources	<0.1	<1%
All Sources	312	

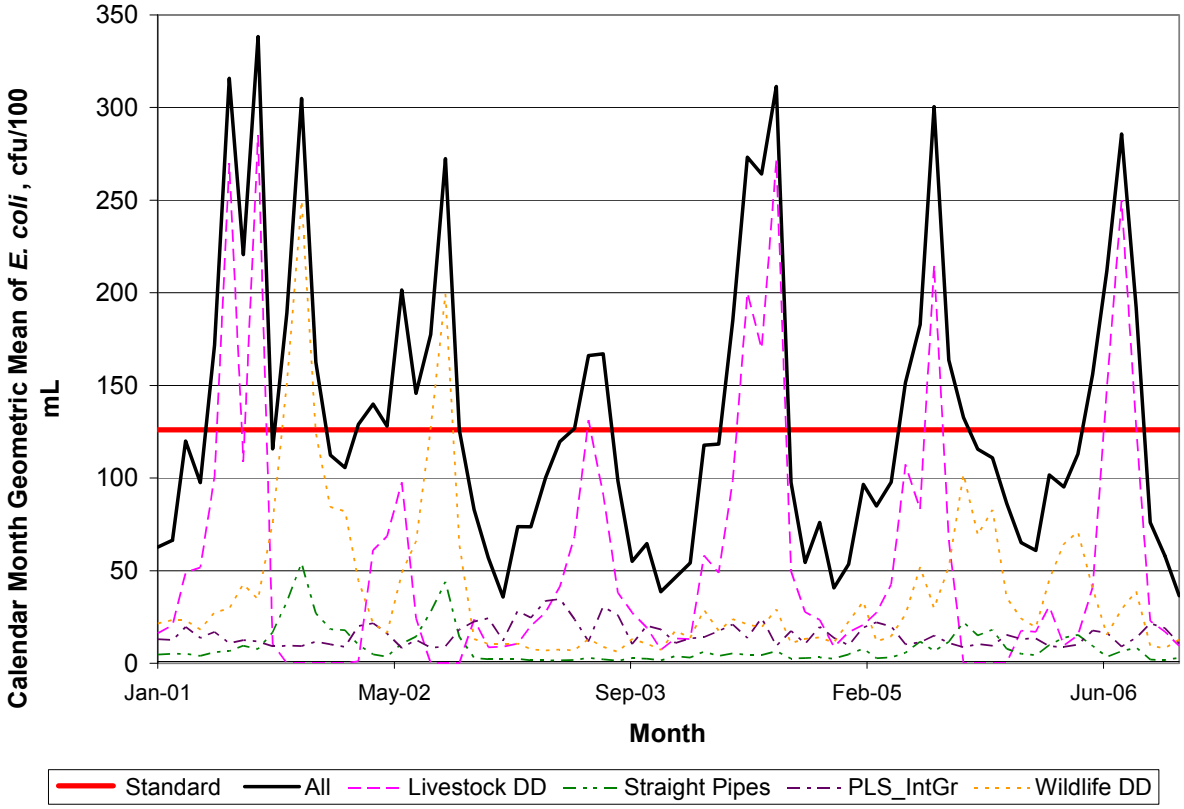

Figure 5.1. Contributions of different sources to the calendar-month geometric mean *E. coli* concentration at the outlet of Otts Creek for existing conditions.

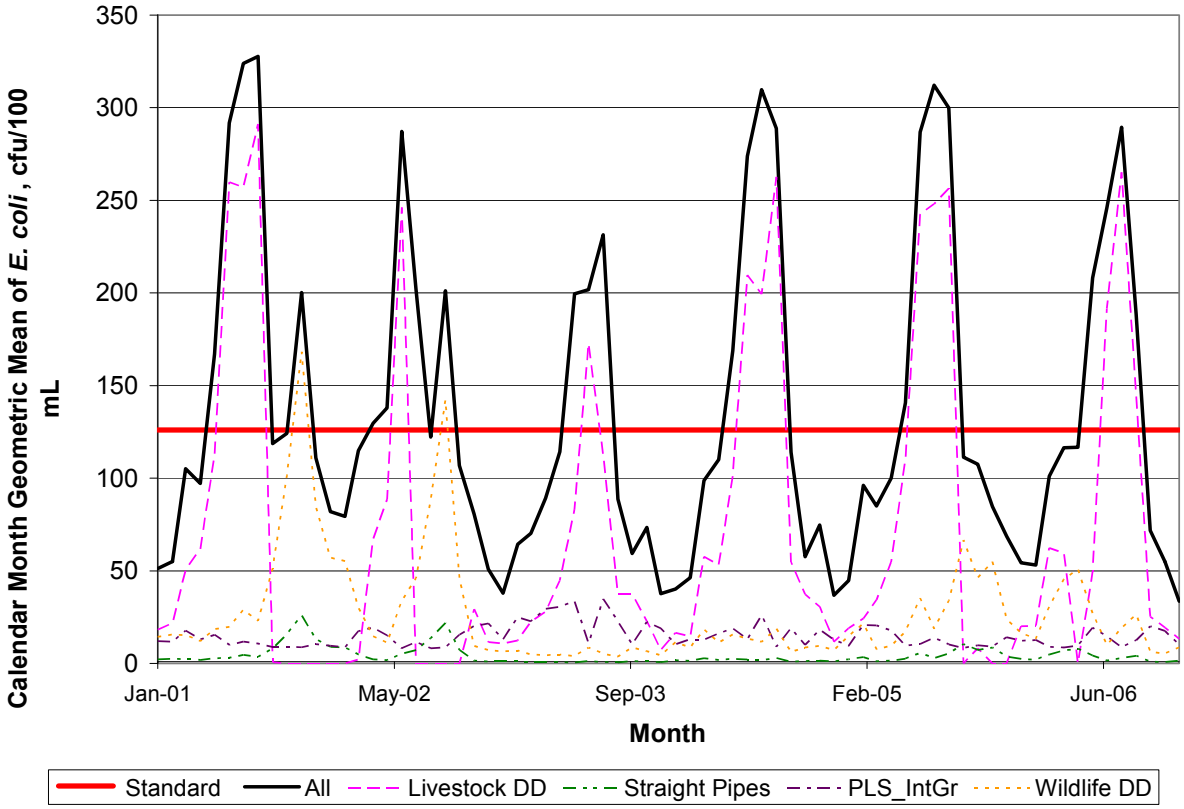

Figure 5.2. Contributions of different sources to the calendar-month geometric mean *E. coli* concentration at the outlet of Walker Creek for existing conditions.

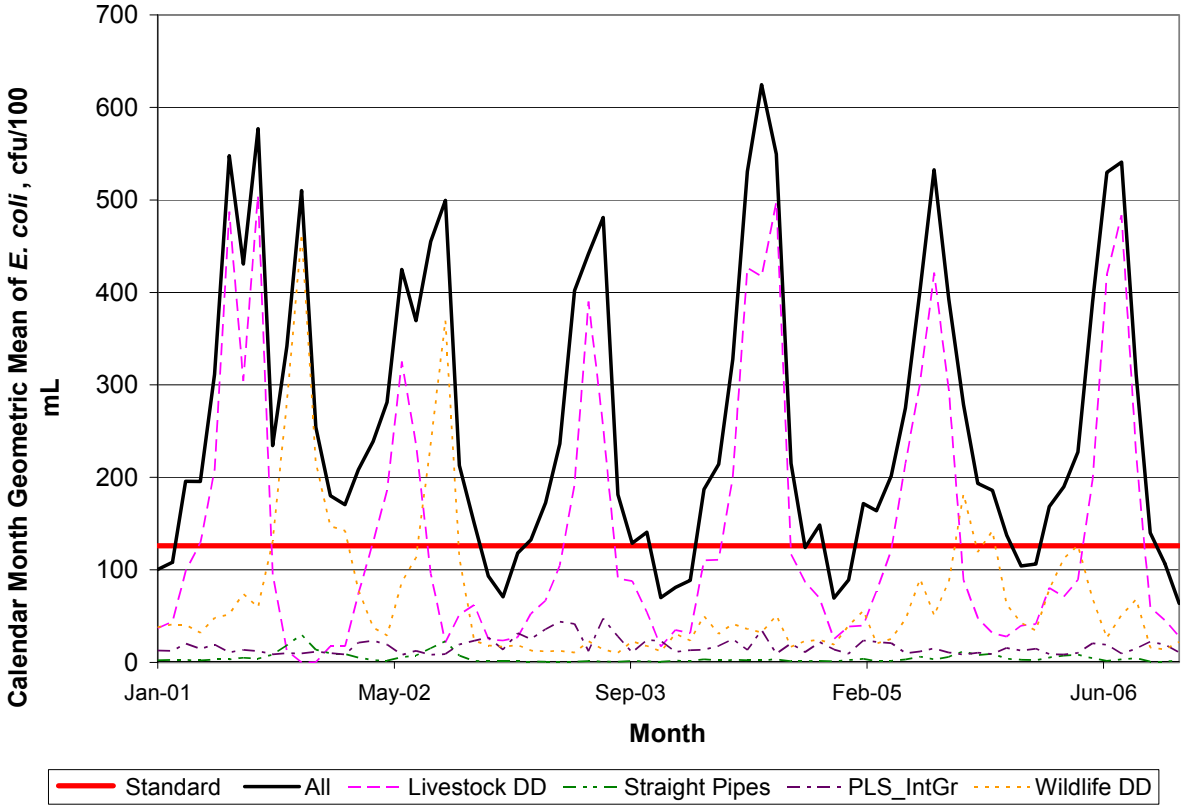

Figure 5.3. Contributions of different sources to the calendar-month geometric mean *E. coli* concentration at the outlet of Hays Creek for existing conditions.

The contributions from livestock direct deposit and wildlife direct deposit alternatively dominate the calendar-month geometric mean concentration. The cyclic nature of livestock direct deposit contributions is due to increased time spent in streams by livestock during summer months, combined with lower flow volumes; these two factors combine to increase bacteria concentrations during the summer months. Contributions from pervious land surfaces contribute a less significant amount to the geometric mean concentration. From these graphs, it is evident that violations of the calendar-month geometric mean criterion will be most controlled by contributions from direct in-stream sources (livestock direct deposit and wildlife direct deposit), and further, that it will be impossible to meet the calendar-month geometric mean criterion without reducing contributions from each of the direct in-stream sources, as each of those sources alone violates the criterion during the allocation period.

5.3. Future Conditions

The Augusta County Comprehensive Plan for 2007-2027 shows no future changes to land uses in the Augusta County portion of the Hays Creek watershed. Likewise, the Proposed Zoning Draft for Rockbridge County dated June 18, 2007 shows no future changes in zoning for the Rockbridge County portion of the Hays Creek watershed. Therefore, allocation scenarios were developed using existing conditions in the watershed.

5.3.1. Allocation Scenarios

A variety of allocation scenarios were evaluated to meet the *E. coli* TMDL goal of a calendar-month geometric mean concentration less than 126 cfu/100 mL and a single-sample maximum concentration of less than 235 cfu/100 mL. The scenarios and results are summarized in Tables 5.4 – 5.6 for Otts Creek, Walker Creek, and Hays Creek, respectively; recall that these reductions are those used for modeling, and implementation of these reductions will require implementation of BMPs as discussed at the beginning of this chapter. The recommended scenarios are highlighted in yellow in Tables 5.4 – 5.6. Note that none of the successful scenarios require reductions in loads from residential areas; this is because bacteria loads to the residential areas are minimal in this watershed. Because there was such a small load on residential land, changing the reductions from 100% (in the unsuccessful runs) to 0% (in the successful runs) had no effect on attainment of the standard.

Table 5.4. Bacteria allocation scenarios for the Otts Creek watershed.

Scenario Number	Required Fecal Coliform Loading Reductions to Meet the *E. coli* Standards, %						% Violation of *E. coli* Standard	
	Livestock Direct Deposit	Loads from Pasture	Loads from Cropland	Straight Pipes & Failing Septics	Loads from Residential Areas*	Wildlife Direct Deposit	Geo. Mean	Single Sample
Unsuccessful Scenarios								
Baseline Future Conditions	0	0	0	0	0	0	43	22
1	100	100	100	100	100	0	7	2
Successful Scenario								
2	65	95	95	100	0	55	0	0

*Primarily loads from pets

Table 5.5. Bacteria allocation scenarios for the Walker Creek watershed.

Scenario Number	Required Fecal Coliform Loading Reductions to Meet the *E. coli* Standards, %						% Violation of *E. coli* Standard	
	Livestock Direct Deposit	Loads from Pasture	Loads from Cropland	Straight Pipes & Failing Septics	Loads from Residential Areas*	Wildlife Direct Deposit	Geo. Mean	Single Sample
Unsuccessful Scenarios								
Baseline Future Conditions	0	0	0	0	0	0	35	23
1	100	100	100	100	100	0	3	0
Successful Scenario								
2	100	99	95	100	0	30	0	0

*Primarily loads from pets

Table 5.6. Bacteria allocation scenarios for the Hays Creek watershed.

Scenario Number	Required Fecal Coliform Loading Reductions to Meet the *E. coli* Standards, %						% Violation of *E. coli* Standard	
	Livestock Direct Deposit	Loads from Pasture	Loads from Cropland	Straight Pipes & Failing Septics	Loads from Residential Areas*	Wildlife Direct Deposit	Geo. Mean	Single Sample
Unsuccessful Scenarios								
Baseline Future Conditions	0	0	0	0	0	0	79	46
1	100	100	100	100	100	0	15	6
Successful Scenarios								
2	90	95	95	100	0	90	0	0

*Primarily loads from pets

Unsuccessful scenarios labeled "1" are shown in Tables 5.4 – 5.6 to illustrate the need for reductions in wildlife loads. Scenario 1 demonstrates that compliance with the standard cannot be achieved through anthropogenic reductions alone. Successful scenarios labeled "2" show the minimum modeled reductions needed to attain compliance with the *E. coli* standard. However, the true measure of water quality improvement in this watershed will not be based on modeled results, but rather on the results of in-stream monitoring.

As a general rule, direct deposit sources (livestock, wildlife, and straight pipes) control violations of the calendar-month geometric mean standard. These sources control the constant inputs to the water body, and thus control the geometric mean of

the daily average predictions over the entire month. Overland sources (runoff from pasture, cropland, forest, and residential areas) are generally more important to the violations of the single sample standard, as these sources control the large spikes in bacteria concentration predictions that occur after storm events. Figures 5.4 – 5.6 display the simulated daily average and calendar month geometric mean concentrations at the Otts Creek, Walker Creek, and Hays Creek outlets for scenario 2, as well as the two *E. coli* standards.

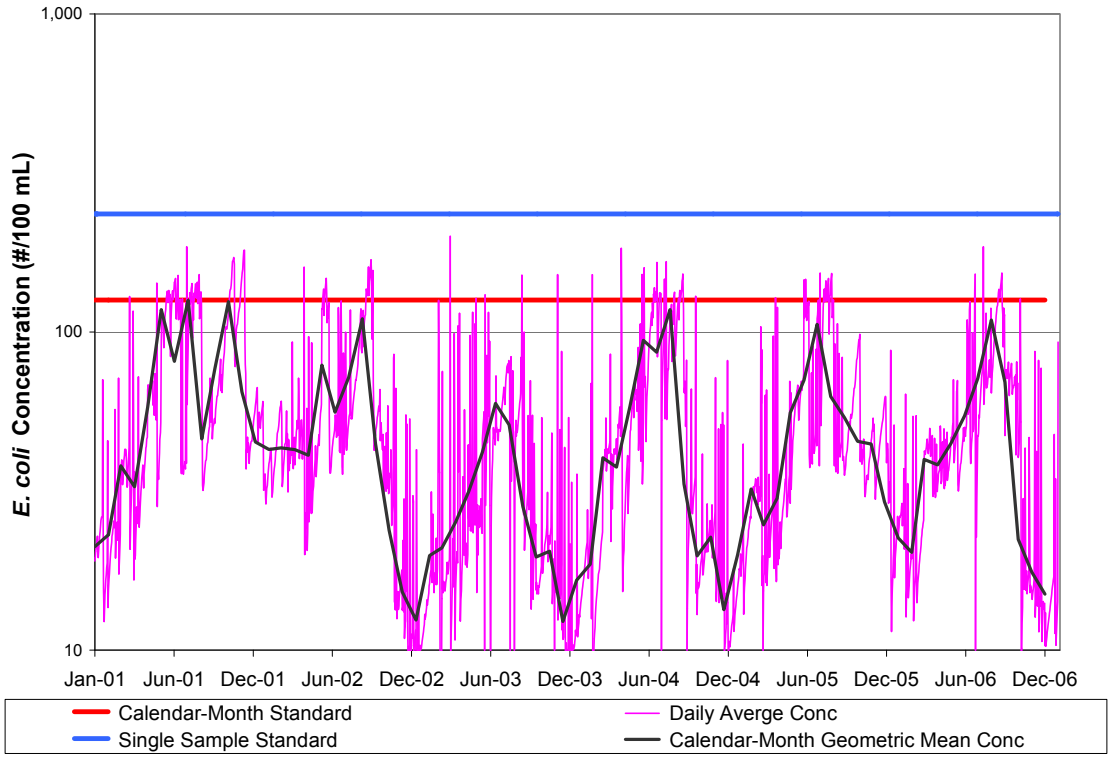

Figure 5.4. Bacteria concentrations for successful allocation scenario 2 for Otts Creek.

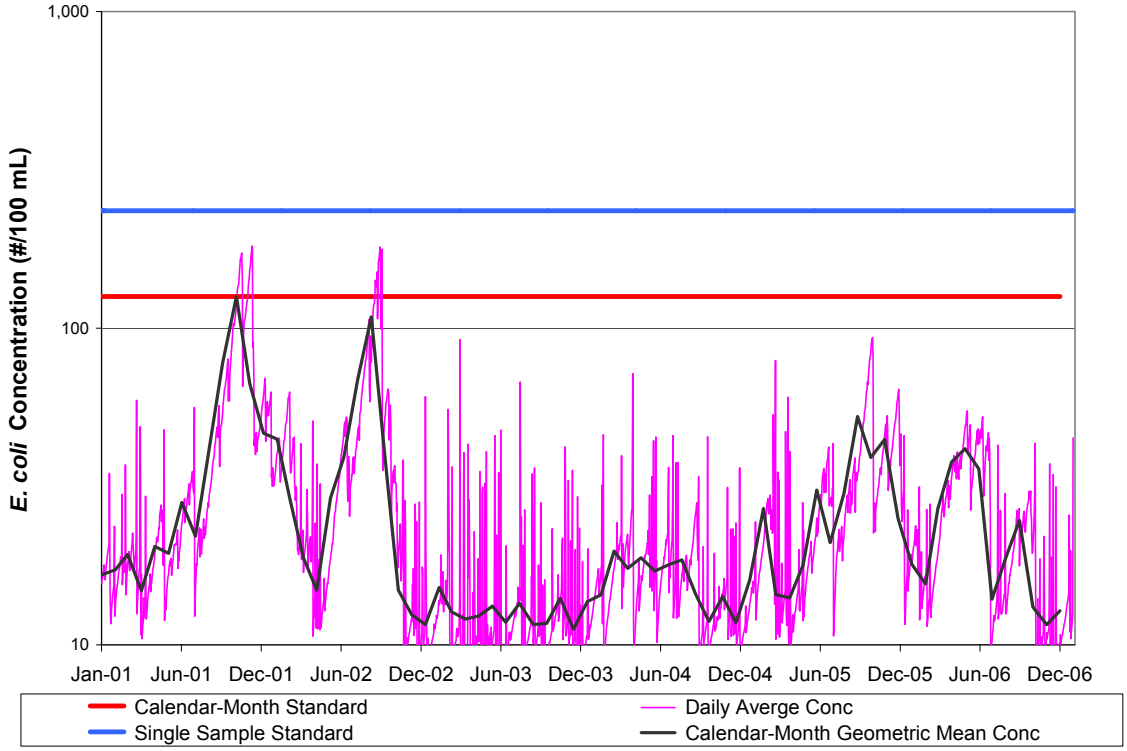

Figure 5.5. Bacteria concentrations for successful allocation scenario 2 for Walker Creek.

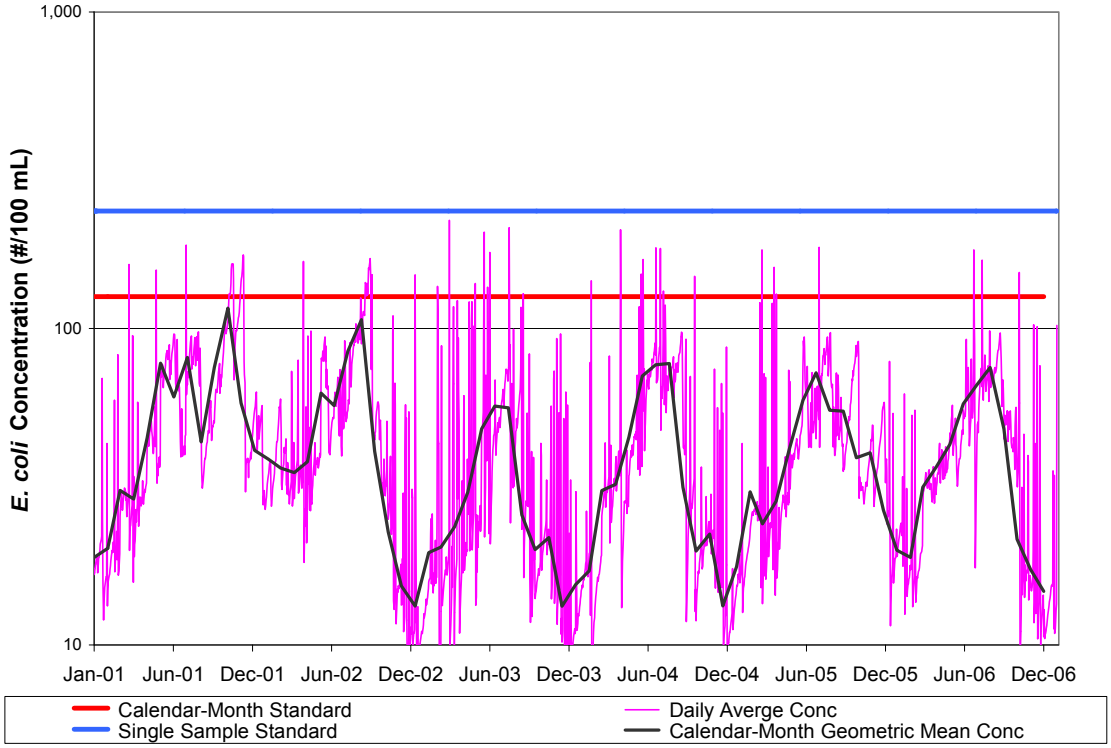

Figure 5.6. Bacteria concentrations for successful allocation scenario 2 for Hays Creek.

Loadings for the existing conditions and the chosen successful TMDL allocation scenario (2) are presented for nonpoint sources by land use in Tables 5.7 – 5.9 and for direct nonpoint sources in Tables 5.10 – 5.12. For sub-watershed specific loadings and reductions, see Appendix H.

Table 5.7. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for Otts Creek.

Land use category	Existing Conditions		Allocation Scenario	
	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total land deposited load from nonpoint sources	TMDL nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Existing Load
Cropland	281	7	14	95
Pasture	3,499	91	175	95
Residential-Pets	30	<1	30	0
Residential-Septics	4	<1	0	100
Forest	25	<1	25	0
Total	3,839		244	94

Table 5.8. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for Walker Creek.

Land use category	Existing Conditions		Allocation Scenario	
	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total land deposited load from nonpoint sources	TMDL nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Existing Load
Cropland	242	6	12	95
Pasture	3,453	92	31	99
Residential-Pets	27	<1	27	0
Residential-Septics	5	<1	0	100
Forest	41	1	41	0
Total	3,768		111	97

Table 5.9. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for Hays Creek.

Land use category	Existing Conditions		Allocation Scenario	
	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total land deposited load from nonpoint sources	TMDL nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Existing Load
Cropland	1,014	5	51	95
Pasture	20,743	94	1,037	95
Residential-Pets	110	<1	110	0
Residential-Septics	20	<1	0	100
Forest	153	<1	153	0
Total	22,040		1,351	94

Table 5.10. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for Otts Creek.

Source	Existing Conditions		Allocation Scenario	
	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total direct deposited load from direct nonpoint source	TMDL direct nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Existing Load
Livestock in Streams	26	88	9	65
Straight Pipes	1	2	0	100
Wildlife in Streams	3	10	1	55
Total	30		10	67

Table 5.11. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for Walker Creek.

Source	Existing Conditions		Allocation Scenario	
	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total direct deposited load from direct nonpoint source	TMDL direct nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Existing Load
Livestock in Streams	37	91	0	100
Straight Pipes	<1	1	0	100
Wildlife in Streams	3	8	2	30
Total	41		2	95

Table 5.12. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for Hays Creek.

Source	Existing Conditions		Allocation Scenario	
	Existing Conditions Load ($x10^{12}$ cfu/yr)	Percent of total direct deposited load from direct nonpoint source	TMDL direct nonpoint source allocation load ($x10^{12}$ cfu/yr)	Percent Reduction from Existing Load
Livestock in Streams	288	91	29	90
Straight Pipes	1	<1	0	100
Wildlife in Streams	28	9	3	90
Total	317		32	90

The fecal coliform loads presented in Tables 5.7 – 5.12 are the fecal coliform loads that result in in-stream *E. coli* concentrations that meet the applicable *E. coli* water quality standards after application of the VADEQ fecal coliform to *E. coli* translator to the HSPF-predicted mean daily fecal coliform concentrations.

5.3.2. Waste Load Allocation

There are currently no permitted facilities in the Otts Creek or Walker Creek watersheds. However, to account for future growth in the area, a waste load allocation (WLA) of 1% of the TMDL was modeled for Otts Creek and Walker Creek. These WLAs were also included in the final TMDL for Hays Creek.

A WLA was assigned to the two permitted point source facilities in the Hays Creek watershed (Table 5.13). The point sources were represented in the allocation scenario by their current permit conditions; no reductions were required from the point sources in the TMDL. Current permit requirements are expected to result in attainment of the *E. coli* WLA as required by the TMDL. Point source contributions to bacteria concentrations, even in terms of maximum flow, are minimal. In addition, the point source facilities are required to discharge at or below the bacteria water quality criteria and therefore cannot cause a violation of those criteria without also violating their discharge permits. Because the permits for these facilities already protect against violating the bacteria water quality standard, there is no need to modify the existing permits.

Table 5.13. Point sources discharging into the Hays Creek watershed.

Permit Number	Facility Name	Design Flow (gpd)	Permitted *E. coli* Conc. (cfu/100 mL)	Permitted *E. coli* Load (cfu/yr)
VAG408084	Single Family Home	1,000	126	1.75×10^9
VAG401386	Multiple Residence	1,000	126	1.75×10^9

A scenario has also been developed to account for future growth in permitted operations in the Hays Creek watershed. The point source flows permitted by VADEQ were increased by a factor of 5, while retaining the 126 cfu/100mL limit on *E. coli* bacteria. This effectively increased the WLA for Hays Creek by a factor of 5. The WLA for Hays Creek is also increased with the addition of the WLAs for both Otts Creek and Walker Creek.

5.3.3. Summary of the TMDL Allocation Scenarios for Bacteria

TMDLs for *E. coli* have been developed for Otts Creek, Walker Creek, and Hays Creek. The TMDLs address the following issues:

1. The TMDLs meet both the calendar-month geometric mean and single sample components of the water quality standard.
2. Because *E. coli* loading data were not available to quantify nonpoint source bacterial loads, available fecal coliform loading data were used as input to HSPF. HSPF was then used to simulate in-stream fecal coliform concentrations. The VADEQ fecal coliform to *E. coli* concentration translator equation was then used to convert the simulated fecal coliform concentrations to *E. coli* concentrations.
3. The TMDLs were developed taking into account all fecal bacteria sources (anthropogenic and natural) from both point and nonpoint sources.
4. An implicit margin of safety (MOS) was incorporated by utilizing professional judgment and conservative estimates of model parameters.
5. Both high- and low-flow stream conditions were considered while developing the TMDLs. In the Hays Creek watershed, violations of the water quality standard were caused during low stream flow and high stream flow; because

the TMDL was developed using a continuous simulation model, it applies to both high- and low-flow conditions.

6. Both the flow regime and bacteria loading to the streams are seasonal. The TMDLs account for these seasonal effects.

Using equation 5.1, the summary of the bacteria TMDLs for Otts Creek, Walker Creek and Hays Creek for the selected allocation scenario (2) are given in Tables 5.14 – 5.16, respectively.

Table 5.14. Estimated annual *E. coli* loadings (cfu/yr) at the watershed outlet used for the Otts Creek bacteria TMDL.

Parameter	ΣWLA	ΣLA	MOS*	TMDL
E. coli	0.09×10^{12}	8.95×10^{12}	--	9.04×10^{12}

*Implicit MOS

Table 5.15. Estimated annual *E. coli* loadings (cfu/yr) at the watershed outlet used for the Walker Creek bacteria TMDL.

Parameter	ΣWLA	ΣLA	MOS*	TMDL
E. coli	0.06×10^{12}	5.95×10^{12}	--	6.01×10^{12}

*Implicit MOS

Table 5.16. Estimated annual *E. coli* loadings (cfu/yr) at the watershed outlet used for the Hays Creek bacteria TMDL.

Parameter	ΣWLA	ΣLA	MOS*	TMDL
E. coli	0.02×10^{13}	4.46×10^{13}	--	4.48×10^{13}
VAG408084	*1.75×10^{9}*			
VAG401386	*1.75×10^{9}*			
Future Growth- Hays Creek†	*1.75×10^{10}*			
Future Growth- Otts Creek	*0.09×10^{12}*			
Future Growth- Walker Creek	*0.06×10^{12}*			

*Implicit MOS
†excluding Otts Creek and Walker Creek

5.3.4. Daily *E. coli* TMDL

The USEPA has mandated that TMDL studies completed in 2007 and later include a daily maximum load as well as the average annual load shown in the previous section. The daily load was determined as the product of a representative flow rate from the watershed and the appropriate concentration criterion from the water quality

standard. This section summarizes the daily maximum loads for Otts Creek, Walker Creek, and Hays Creek.

Hydrologic Considerations

According to guidance from EPA (USEPA, 2006) it was necessary to assess the flow duration curve to determine an appropriate flow rate to use in the load calculation. EPA guidance suggests that the flow duration curve should be plotted using observed continuous flow data; because continuous flow data were not available for the Hays Creek watershed, flows from the surrogate watershed used in calibration (Christians Creek) were used instead. As is specified in the EPA guidance, the observed flows from Christians Creek were multiplied by the ratio of the Hays Creek watershed area to the drainage area above the Christians Creek gage. The flow rate corresponding to the 99th percentile flow (that is, the flow rate exceeded by only 1% of the observed flows) was used in calculation in order to determine the *maximum* daily load. The flow rate corresponding to the 99th percentile flow for Christians Creek is 596 cfs. For Otts Creek, the corresponding flow rate was 138 cfs. For Walker Creek, the flow rate was 226 cfs, and for Hays Creek, the flow rate was 656 cfs.

Daily Load

Setting a *maximum daily* load will help ensure that the annual loads given in Tables 5.14 – 5.16 are appropriately distributed such that on any given day the single sample component of the bacteria water quality standard will be met. The loadings in the annual load tables, being of a long-term nature, will more directly assure compliance with the geometric mean component of the standard. Thus, the maximum daily load was computed as the product of the critical flow condition and the single sample criterion (235 cfu/100 mL). Since the annual WLA is already based on a maximum daily permitted flow and a maximum daily permitted concentration the daily WLA is calculated as the annual WLA divided by 365; the daily LA is then the TMDL less the WLA. The resulting daily maximum loadings are shown in Table 5.17. The actual maximum daily load is dependent upon flow conditions, and progress toward water quality improvement

will be assessed against the numeric water quality criteria (126 cfu *E. coli*/100 mL for a calendar month geometric mean, and 235 cfu *E. coli*/100 mL for a single sample).

Table 5.17. Maximum daily *E. coli* loadings (cfu/day) at the watershed outlets.

Watershed	ΣWLA†	ΣLA	MOS*	TMDL
Otts	2.47×10^{8}	7.92×10^{11}	--	7.92×10^{11}
Walker	1.64×10^{8}	1.30×10^{12}	--	1.30×10^{12}
Hays	4.66×10^{8}	3.77×10^{12}	--	3.77×10^{12}

†the WLA will be implemented in accordance with permitting regulations
*Implicit MOS

Chapter 6: TMDL Implementation and Reasonable Assurance

Once a TMDL has been approved by EPA, measures must be taken to reduce pollution levels from both point and non point sources in the stream (see Section 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 EPA for approval. The measures for non point source reductions, which can include the use of better treatment technology and the installation of best management practices (BMPs), are implemented in an iterative process that is described along with specific BMPs in the implementation plan. The process for developing an implementation plan has been described in the "TMDL Implementation Plan Guidance Manual", published in July 2003 and available upon request from the 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 best 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 straight pipe discharges and failing septic systems should be a primary implementation focus because of their health implications. These components could be implemented through education on septic tank pump-outs, a septic system installation/repair/replacement program, and the use of alternative waste treatment systems.

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

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

1. It enables tracking of water quality improvements following BMP implementation through follow-up stream monitoring;
2. It provides a measure of quality control, given the uncertainties inherent in computer simulation modeling;
3. It provides a mechanism for developing public support through periodic updates on BMP implementation and water quality improvements;
4. It helps ensure that the most cost effective practices are implemented first; and
5. It allows for the evaluation of the adequacy of the TMDL in achieving water quality standards.

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

In addition to traditional BMPs used for reducing bacteria sources in agricultural watersheds, members of the Hays Creek Local Steering Committee felt strongly that stream restoration practices were needed in the watershed. Local Steering Committee members explained that in several areas of the lower Hays Creek watershed, sedimentation, debris, and bridge structures have altered the flow path and reduced the conveyance ability of the channel during high flow events. These changes have resulted in an increase in pasture area being inundated during high flow events and an increased frequency of inundation. This results in higher bacteria loads to the stream during high flow events. During the development of the Implementation Plan (IP), the

Steering Committee and the IP developers should consider the need for and practicality of stream restoration efforts in the Hays Creek watershed.

6.2. Stage 1 Scenarios

The goal of the Stage 1 scenarios is to reduce the bacteria loadings from controllable sources (excluding wildlife) such that violations of the instantaneous criterion (235 cfu/100mL) are less than 10.5 percent while requiring no reductions from wildlife sources. The Stage 1 scenarios were generated with the same model setup as was used for the TMDL allocation scenarios.

There was one successful scenario selected for the Otts Creek watershed (Table 6.1). The staged implementation goal can be reached with a 55% reduction in contributions from livestock direct deposition, and 100% elimination of straight pipe discharges and failing septic systems. *E. coli* concentrations resulting from application of the fecal coliform to *E. coli* translator equation to the fecal coliform concentrations are presented graphically in Figure 6.1.

Table 6.1. Allocation scenario for Stage 1 TMDL implementation for Otts Creek.

Required Fecal Coliform Loading Reductions to Meet the Stage 1 Goal, %							% Violation of *E. coli* Single Sample Standard
Livestock Direct Deposit	Loads from Cropland	Loads from Pasture	Straight Pipes & Failing Septics	Loads from Residential Areas	Wildlife Direct Deposit	Loads from Forested Areas	
55	0	0	100	0	0	0	10

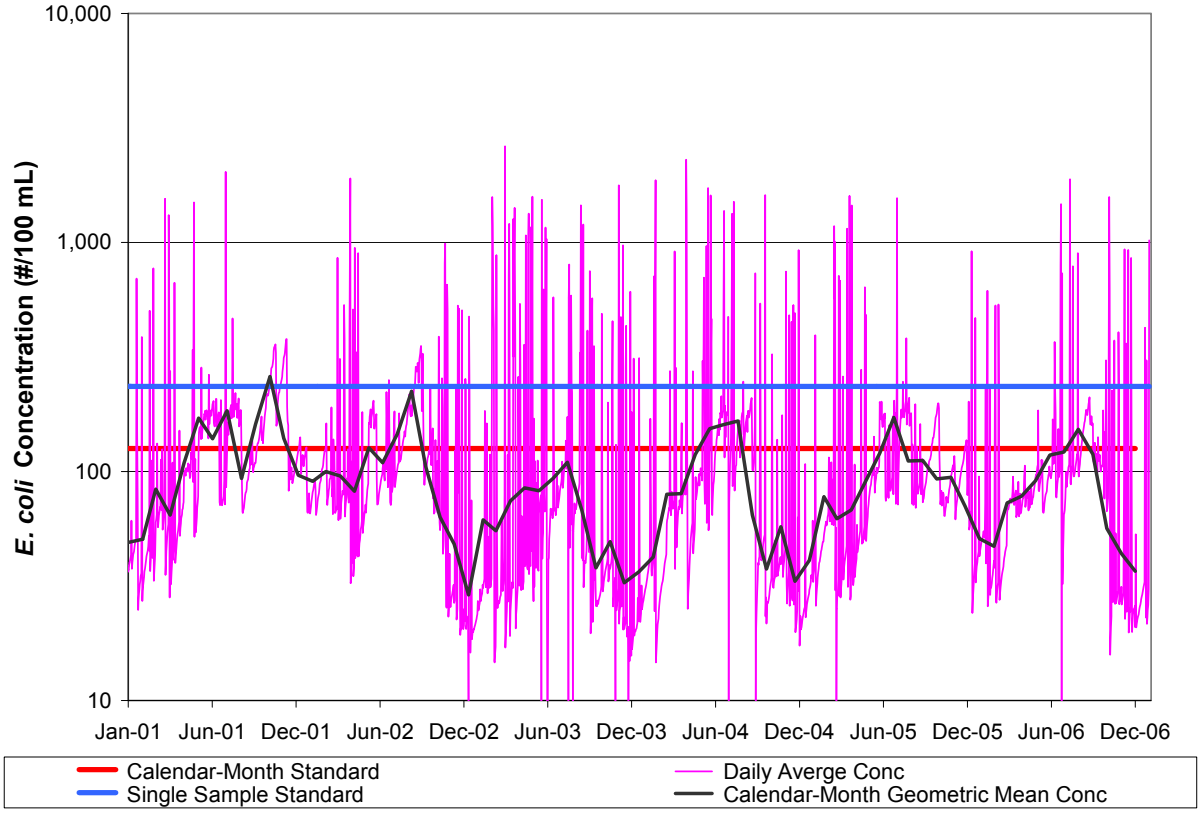

Figure 6.1. Simulated *E. coli* concentrations with the two components of the bacteria standard for Stage 1 implementation scenario for Otts Creek.

One successful scenario was selected for the Walker Creek watershed (Table 6.2). The staged implementation goal can be reached with a 40% reduction in contributions from livestock direct deposition, and 100% elimination of straight pipe discharges and failing septic systems. *E. coli* concentrations are presented graphically in Figure 6.2.

Table 6.2. Allocation scenarios for Stage 1 TMDL implementation for Walker Creek.

Required Fecal Coliform Loading Reductions to Meet the Stage 1 Goal, %							% Violation of *E. coli* Single Sample Standard
Livestock Direct Deposit	Loads from Cropland	Loads from Pasture	Straight Pipes & Failing Septics	Loads from Residential Areas	Wildlife Direct Deposit	Loads from Forested Areas	
40	0	0	100	0	0	0	9

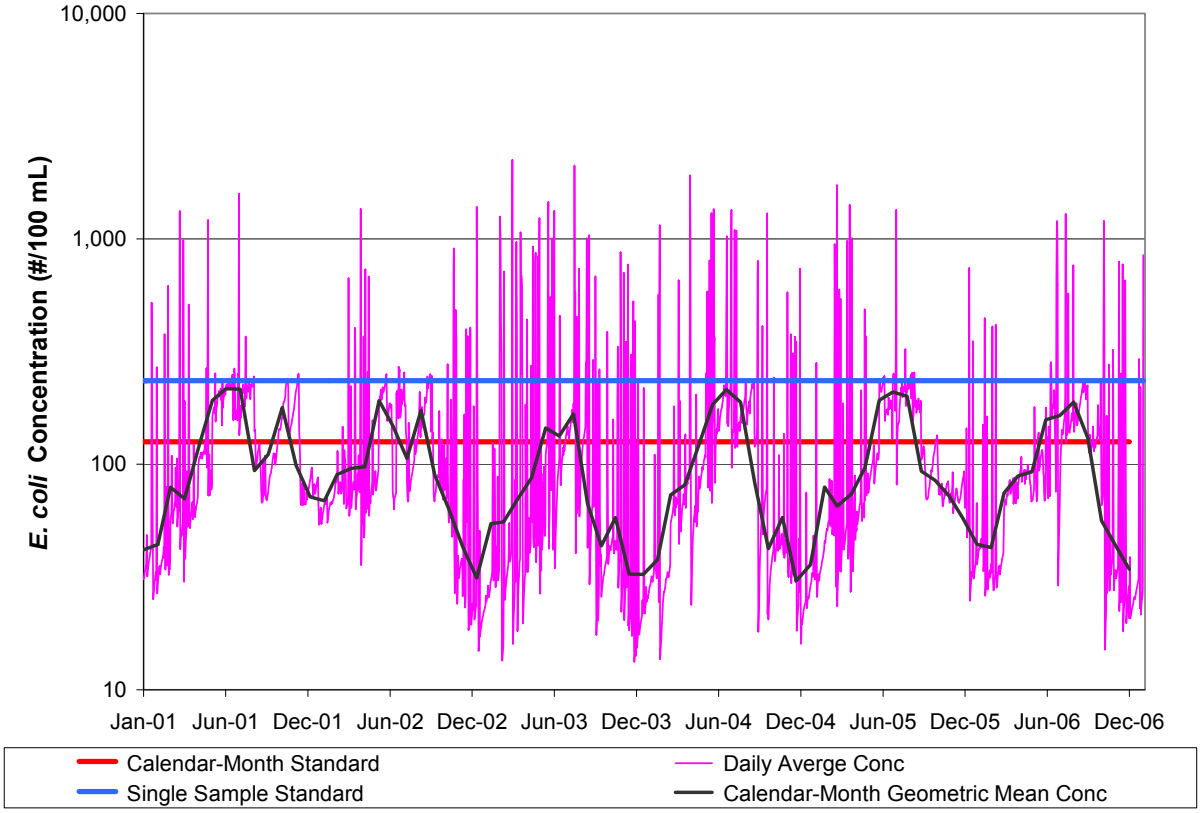

Figure 6.2. Simulated *E. coli* concentrations with the two components of the bacteria standard for Stage 1 implementation scenario for Walker Creek.

One scenario was selected for the Hays Creek watershed which calls for a more equal effort from all agricultural loads (Table 6.3). The staged implementation goal can be accomplished with an 80% reduction in contributions from livestock direct deposition, loads from cropland, and loads from pasture, in addition to 100% elimination of straight pipe discharges and failing septic systems. *E. coli* concentrations are presented graphically in Figure 6.3.

Table 6.3. Allocation scenarios for Stage 1 TMDL implementation for Hays Creek.

Required Fecal Coliform Loading Reductions to Meet the Stage 1 Goal, %							% Violation of *E. coli* Single Sample Standard
Livestock Direct Deposit	Loads from Cropland	Loads from Pasture	Straight Pipes & Failing Septics	Loads from Residential Areas	Wildlife Direct Deposit	Loads from Forested Areas	
80	80	80	100	0	0	0	10

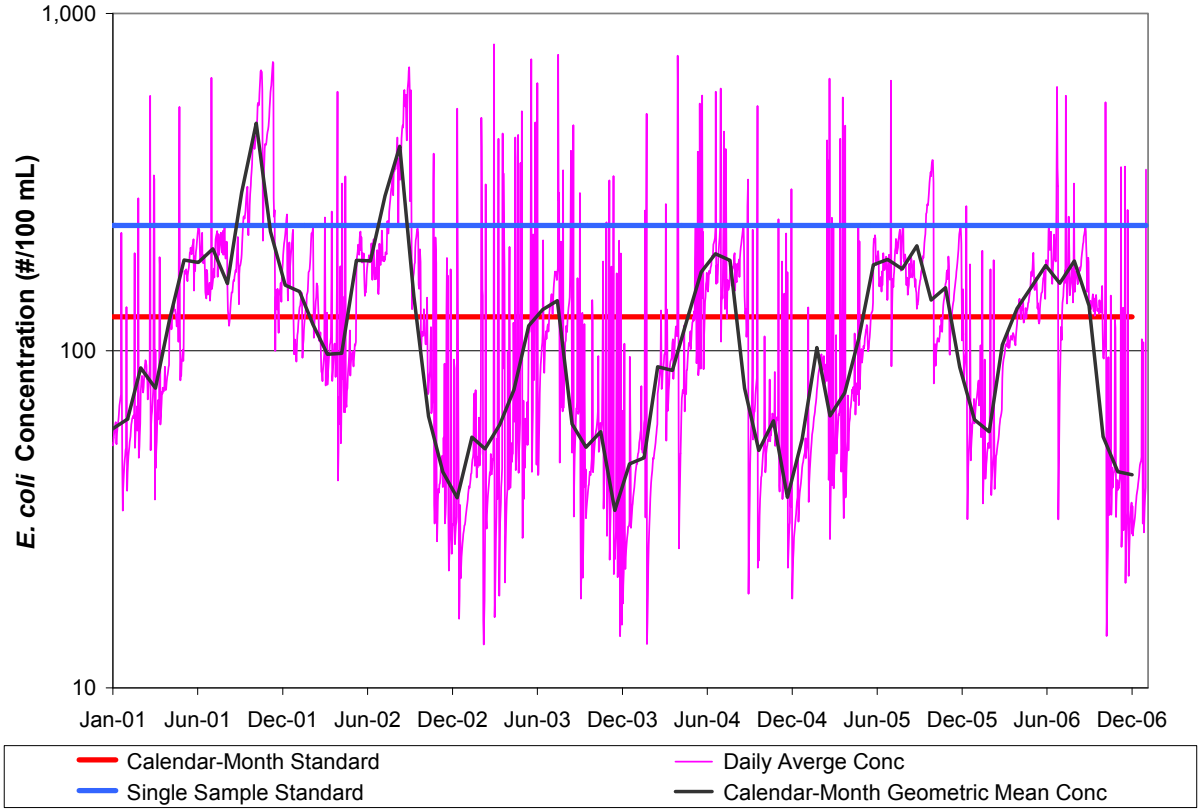

Figure 6.3. Simulated *E. coli* concentrations with the two components of the bacteria standard for Stage 1 implementation scenario for Hays Creek.

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 Chesapeake Bay. Several BMPs known to be effective in controlling bacteria have been identified for implementation as part of the Tributary Strategy for the James River Basin. Management of on-site waste management systems, management of livestock and manure, and pet waste management are examples. Up-to-date information on the tributary strategy can be found at the tributary strategy web site under http://www.naturalresources.virginia.gov/Initiatives/WaterQuality/FinalizedTribStrats/james.pdf.

6.4. Reasonable Assurance for Implementation

6.4.1. Follow-up Monitoring

Following the development of the TMDL, the Department of Environmental Quality (DEQ) will make every effort to continue to monitor the impaired stream in accordance with its ambient monitoring program. VADEQ's Ambient Watershed Monitoring Plan for conventional pollutants calls for watershed monitoring to take place on a rotating basis, bi-monthly for two consecutive years of a six-year cycle. In accordance with VADEQ Guidance Memo No. 03-2004, 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.

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

DEQ staff, in cooperation with DCR staff, the Implementation Plan Steering Committee, and local stakeholders, will continue to use data from the ambient monitoring stations to evaluate reductions in pollutants ("water quality milestones" as established in the 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.

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

To demonstrate that the watershed is meeting water quality standards in watersheds where corrective actions have taken place (whether or not a TMDL or TMDL Implementation Plan has been completed), 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 EPA regulations do not require the development of TMDL implementation plans as part of the TMDL process, they do require reasonable assurance that the load and wasteload allocations can and will be implemented. EPA also requires that all new or revised National Pollutant Discharge Elimination System (NPDES) permits must be consistent with the TMDL WLA pursuant to 40 CFR §122.44 (d)(1)(vii)(B). All such permits should be submitted to EPA for review.

Additionally, Virginia's 1997 Water Quality Monitoring, Information and

Restoration Act (WQMIRA) directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters" (Section 62.1-44.19.7). WQMIRA also establishes that the implementation plan shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments. EPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process." The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans and milestones for attaining water quality standards.

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

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

Watershed stakeholders will have opportunities to provide input and to participate in the development of the 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 EPA and VADEQ, VADEQ also submitted a draft Continuous Planning Process to EPA in which VADEQ commits to regularly updating the Water Quality Management Plans (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 EPA-approved TMDLs and TMDL implementation plans to the State Water Control Board for inclusion in the appropriate 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 State Water Control Board (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. Stormwater Permits

DEQ and DCR 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 from municipal separate storm sewer systems (MS4s).

It is the intent of the Commonwealth that TMDLs implement existing regulations and programs where they apply. However, since there are no MS4s permitted in the Hays Creek watershed at the time of this TMDL, they are not included in this study. More information is available on VADCR's web site through the following link: http://www.dcr.virginia.gov/soil_&_water/vsmp.shtml. 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.

6.4.4. Implementation Funding Sources

Cooperating agencies, organizations and stakeholders must identify potential funding sources available for implementation during the development of the implementation plan in accordance with the "Virginia Guidance Manual for Total Maximum Daily Load Implementation Plans". Potential sources for implementation may include the U.S. Department of Agriculture's Conservation Reserve Enhancement and Environmental Quality Incentive Programs, EPA Section 319 funds, the Virginia State Revolving Loan Program, Virginia Agricultural Best Management Practices Cost-Share

Programs, the Virginia Water Quality Improvement Fund, tax credits and landowner contributions. The TMDL Implementation Plan Guidance Manual contains additional information on funding sources, as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

6.4.5. Attainability of Primary Contact Recreation Use

In some streams for which TMDLs have been developed, including Hays Creek, water quality modeling indicates that even after removal of all bacteria sources (other than wildlife), the stream will not attain standards under all flow regimes at all times. These streams may not be able to attain standards without some reduction in wildlife load.

With respect to these potential reductions in bacteria loads attributed to wildlife, Virginia and EPA are not proposing the elimination of wildlife to allow for the attainment of water quality standards. However, if bacteria levels remain high and localized overabundant populations of wildlife are identified as the source, then measures to reduce such populations may be an option if undertaken in consultation with the Department of Game and Inland Fisheries (DGIF) or the United States Fish and Wildlife Service (USFWS). Additional information on DGIF's wildlife programs can be found at http://www.dgif.virginia.gov/wildlife/game/. While managing such overpopulations of wildlife remains as an option to local stakeholders, the reduction of wildlife or changing a natural background condition is not the intended goal of a TMDL.

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

In order for the new criteria to apply to a specific stream segment, the primary contact recreational use must be removed. To remove a designated use, the state must demonstrate 1) that the use is not an existing use, 2) that downstream uses are protected, and 3) that the source of contamination is natural and uncontrollable by effluent limitations and by implementing cost-effective and reasonable best management practices for nonpoint source control (9 VAC 25-260-10). This and other information is collected through a special study called a Use Attainability Analysis (UAA). All site-specific criteria or designated use changes must be adopted as amendments to the water quality standards regulations. Watershed stakeholders and EPA will be able to provide comment during this process. Additional information can be obtained at http://www.deq.virginia.gov/wqs/documents/WQS06_EDIT_001.pdf.

The process to address potentially unattainable reductions based on the above is as follows: First is the development of a stage 1 scenario such as those presented previously in this chapter. The pollutant reductions in the stage 1 scenario are targeted primarily at the controllable, anthropogenic bacteria sources identified in the TMDL, setting aside control strategies for wildlife except for cases of nuisance populations. During the implementation of the stage 1 scenario, all controllable sources would be reduced to the maximum extent practicable using the iterative approach described in Section 6.1 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, and no additional cost-effective and reasonable best management practices can be identified, a UAA may be initiated with the goal of re-designating the stream for secondary contact recreation.

Chapter 7: Public Participation

The first public meeting was held on August 21, 2007 at the Rockbridge Baths Volunteer Fire Department in Rockbridge Baths, Virginia, located near the mouth of the watershed. The purpose of this meeting was to inform the general public about the TMDL process and to gain general information about the watershed. Approximately 91 people attended this meeting.

Two Local Steering Committee (LSC) meetings were held. The first LSC meeting was held on August 23, 2007 at the Rockbridge Baths Volunteer Fire Department. The purpose of the meeting was to gain general information about the watershed and specific information on animal populations in Hays Creek. During this meeting, and during the 30-day comment period following the first public meeting, stakeholders provided detailed information on human and animal populations, which were incorporated into the TMDL. Approximately 30 people attended this meeting.

The second LSC meeting was held on December 11, 2008 at the Walker's Creek Fire Department in Middlebrook, Virginia, located in the watershed. The purpose of this meeting was to present the water quality calibration and the proposed allocation scenarios, and to solicit feedback from the interested stakeholders and agency personnel on the allocations. Approximately 21 people attended this meeting.

The final public meeting was held on January 29, 2008 at the Rockbridge Baths Volunteer Fire Department in Rockbridge Baths, Virginia. Final allocation and stage 1 scenarios were presented at this meeting. The report was available online prior to the meeting and copies of the executive summary were available at the meeting itself. Approximately 76 people attended the final public meeting.

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Appendix A: Glossary of Terms

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.

ARA (Antibiotic Resistance Analysis)
A bacterial source tracking technique that uses the expected varying antibiotic resistance of bacteria from different sources to identify the contributors of fecal bacteria. Bacteria from humans are expected to have the highest antibiotic resistance, while domestic and wildlife animal sources are expected to have lower antibiotic resistance (Hagedorn, 2006).

Background levels
Levels representing the chemical, physical, and biological conditions that would result from natural geomorphological processes such as weathering and dissolution.

BASINS (Better Assessment Science Integrating Point and Nonpoint Sources)
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.

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.

Bacteria Source Tracking
A collection of scientific methods used to track sources of fecal coliform.

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 deposits of fecal material to streams from livestock and wildlife.

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. *E. coli* bacteria are a subset of this group found to more closely correlate with human health problems.

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.

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).

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.

Instantaneous or Single Sample 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 *E. coli* is 235 cfu/100 mL. If this value is exceeded at any time, the water body is in violation 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).

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 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, 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.

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. This follows the calibration of the model and ensures that the calibrated values adequately represent the watershed.

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.

For more definitions, see the Virginia Cooperative Extension publications available online:

Glossary of Water-Related Terms. Publication 442-758.
http://www.ext.vt.edu/pubs/bse/442-758/442-758.html

and

TMDLs (Total Maximum Daily Loads) - Terms and Definitions. Publication 442-550.
http://www.ext.vt.edu/pubs/bse/442-550/442-550.html

Appendix B: Sample Calculation of Cattle (Sub-watershed 3)

Sample Calculation: Distribution of Cattle

(Sub-watershed 3 during October for Existing Conditions)

(Note: Due to rounding, the numbers may not add up.)

There are 283 beef cattle in sub-watershed 3.

1. During October, there is no confinement of beef cattle (Table 3.5); cattle are on pasture or in the stream.

   Beef cattle on pasture and in the stream = 283

2. Ninety percent of beef cattle in sub-watershed 3 have stream access. Hence beef cattle with stream access are calculated as:

   Beef cattle on pastures with stream access = 283 * 90% = 254.7

3. Beef cattle in and around the stream are calculated using the numbers in Step 3 and the number of hours cattle spend in the stream in October (Table 3.5) as:

   Beef cattle in and around streams = 254.7 * 1/24 =10.6125

4. Number of cattle defecating in the stream is calculated by multiplying the number of cattle in and around the stream by 30% (Section 3.2.1):

   Beef cattle defecating in streams = 10.6125 * 30% =3.18375

5. After calculating the number of cattle defecating in the stream, the number of cattle defecating on the pasture is calculated by subtracting the number of cattle defecating in the stream (Step 4) from the number of cattle in pasture and stream (Step 1):

   Beef cattle defecating on pasture = 283 – 3.18375 =279.81625

Now, obviously there are not fractions of cows standing and defecating in the stream. This number (3.18375) represents the fraction of fecal coliform produced in one day by one cow that will be deposited in the stream in sub-watershed 3.

Appendix C: Weather Data Preparation

Weather Data Preparation – Hays Creek

Introduction

A weather data file for providing the weather data inputs into the HSPF Model was created for the period January 1990 through June 2007 using the Watershed Data Management Utility (WDMUtil). Raw data required for creating the weather data file included daily precipitation (in.), average daily temperatures (maximum, minimum, and dew point) (°F), average daily wind speed (mi/hr), total daily solar radiation (Langleys), and percent sun. The primary data source was the National Climatic Data Center's (NCDC) Cooperative Weather Station 448062 located at the Staunton Sewage Treatment Plant (STP) in Staunton, Virginia, which was located about 23 miles northwest of the Hays Creek watershed. Data from other NCDC stations were also used where Staunton data were missing. The raw data required varying amounts of preprocessing within WDMUtil to obtain the following hourly values: precipitation (PREC) (in), air temperature (ATEM) (°F), dew point temperature (DEWP) (°F), solar radiation (SOLR) (Langleys), wind speed (WIND) (mi/hr), potential evapotranspiration (PEVT) (in), potential evaporation (EVAP) (in), and cloud cover (CLOU) (tenths, range 0-10). The final WDM file contains these hourly datasets.

Raw data collection and processing

Weather data were obtained from the NCDC's weather stations in Staunton, VA (448062, Lat./Long. 38°11'N / 79°05'W, elevation 500 ft); Lexington, VA (444876 Lat./Long. 37°48'N / 79°25'W, elevation 343 ft); Montebello Fish Hatchery, VA (445690 Lat./Long. 37°51'N / 79°08'W, elevation 807 ft); Williamsville, VA (449160 Lat./Long. 38°16'N / 79°33'W, elevation 595 ft); and Lynchburg Airport, VA (445120, Lat./Long. 37°19'N/79°12'W, elevation 286 ft). While deciding on the period of record for the weather WDM file, availability of flow and water quality data was considered in addition to the availability and quality of weather data. Data collection for many of the parameters did not being until 1990, which set the starting point of the period of record. Percent sun (PSUN) data were available only from Lynchburg Airport and then only through July 1996. The majority of the water quality data were collected from 2001

through 2006. In order to make the best use of the available water quality data, the period of record was chosen to be January 1990 - June 2007. There are 6,389 days within this period. Substitutions for missing data are described below. The procedures used to process the raw data to obtain finished data required for input to HSPF are also described in the following sections.

1. Hourly Precipitation

   Hourly precipitation (HPCP) data were downloaded from NCDC's web site for the Staunton STP for the entire January 1990 – June 2007 period. Of the 153,336 possible hourly values in this period, 32,557 values were missing. The Williamsville and Montebello Fish Hatchery stations were used to patch the hourly recorded precipitation. The resulting file was imported into WDMUtil and given the constituent label "PREC."

2. Temperature

   Separate daily maximum temperature (TMAX) and daily minimum temperature (TMIN) files were downloaded from the NCDC website for Staunton STP for the entire period. The TMAX dataset was missing 212 days of data; the TMIN dataset was missing 225 days of data. Data from the Lexington station was used to fill in the missing days. Daily dew point temperature (DPTP) was taken from the Lynchburg Regional Airport station, the closest station that recorded dew point temperature. These data had units of tenths of degrees Fahrenheit and were divided by a factor of 10 prior to use in the WDM file. The *disaggregate temperature* function in WDMUtil was used to create an hourly average temperature file (ATEM). The *disaggregate dewpoint temperature* function in WDMUtil was used to create an hourly dewpoint temperature file (DEWP).

3. Average Daily Wind Speed

   Average daily wind speed (AWND) was not recorded at the Staunton STP; therefore, average daily wind speed was obtained from the Lynchburg Regional Airport station. The units of the data were tenths of miles per hour; therefore, the

time series was divided by a factor of 10 prior to use in the WDM file. The *compute wind travel* function in WDMUtil was used to calculate the total wind travel in miles/day. Then the *disaggregate wind travel* function in WDMUtil was used to calculate the hourly wind speed throughout the day (WIND) using the distribution coefficients shown in Table C.1.

Table C.1. Hourly Distribution Coefficients for Wind Speed.

Hour	12	1	2	3	4	5	6	7	8	9	10	11
AM	0.035	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.035	0.037	0.041	0.046
PM	0.05	0.053	0.054	0.058	0.057	0.056	0.05	0.043	0.04	0.038	0.036	0.036

4. <u>Cloud cover and solar radiation</u>

   In the absence of daily cloud cover, percent sun (PSUN) can be used to estimate DCLO. DCLO is used by WDMUtil to estimate hourly cloud cover in tenths (CLOU) as well as solar radiation (SOLR) in Langleys. The closest weather station that recorded PSUN was Lynchburg Regional Airport station, and this data was used to develop the weather file. PSUN was only available at this station for the period January 1984-July 1996. It is the experience of the authors that the model is rather insensitive to the parameters derived from PSUN; therefore, to bridge the gap of missing data, values from August 1996-December 2005 were filled in by copying the values from the measured period.

   The *compute percent cloud cover* function in WDMUtil was used to calculate the daily percent cloud cover in tenths (DCLO) from PSUN. Because there is no *disaggregate percent cloud cover* function available, the *disaggregate wind travel* function was used with hourly distribution coefficients all set to 1 to calculate the hourly percent cloud cover in tenths (CLOU).

   The *compute solar radiation* function in WDMUtil was used to calculate the daily solar radiation in Langleys (DSOL) from DCLO and the Charlottesville 2W latitude (38°02'N). The *disaggregate solar radiation* function was then used to calculate the hourly solar radiation (SOLR).

5. Evaporation/Evapotranspiration

   Two types of evaporation/evapotranspiration are required for input to HSPF: potential evaporation from a reach or reservoir surface (EVAP), represented as Penman pan evaporation; and potential evapotranspiration (PEVT), represented as Hamon potential evapotranspiration.

   The *compute Penman pan evaporation* function in WDMUtil was used to calculate daily Penman pan evaporation (DEVP) from TMIN, TMAX, DPTP, TWND, and DSOL. Then the *disaggregate evapotranspiration* function was used to calculate EVAP from DEVP.

   The *compute Hamon PET* function in WDMUtil was used to calculate daily potential evapotranspiration (DEVT) from TMIN, TMAX, the Staunton STP latitude (38°11'N), and monthly coefficients all equal to 0.005. Then the *disaggregate evapotranspiration* function was used to calculate PEVT from DEVT.

Summary of weather data preparation

The weather data were prepared for input to HSPF as described in the previous section. A summary of the NCDC input parameters, WDMUtil functions used, and final HSPF parameters is presented in Table C.

Table C.2. Weather parameters and processing in WDMUtil required for HSPF modeling.

NCDC Input Parameters	Intermediate Input	WDMUtil Functions	Intermediate Output	Final HSPF Parameter
HPCP	--	None	--	PREC
TMAX, TMIN	--	Disaggregate temperature	--	ATEM
DPTP	--	Disaggregate dewpoint temperature	--	DEWP
PSUN	--	Compute percent cloud cover	DCLO	--
	DCLO	Disaggregate wind travel[1]	--	CLOU
	DCLO	Compute solar radiation	DSOL	--
	DSOL	Disaggregate solar radiation	--	SOLR
AWND	--	Compute wind travel	TWND	--
	TWND	Disaggregate wind travel	--	WIND
TMAX, TMIN, DPTP	TWND, DSOL	Compute Penman pan evaporation	DEVP	--
	DEVP	Disaggregate evapotranspiration	--	EVAP
TMAX, TMIN	--	Compute Hamon PET	DEVT	--
	DEVT	Disaggregate evapotranspiration	--	PEVT

[1]all hourly coefficients set to 1

.

Appendix D: Die-off of Fecal Coliform During Storage

Die-off of Fecal Coliform During Storage

The following procedure was used to calculate amount of fecal coliform produced in confinement in dairy manure applied to cropland and pasture. All calculations were performed on spreadsheet for each sub-watershed with dairy operations in a watershed.

1. Using a decay rate of 0.375 for liquid dairy manure, the die-off of fecal coliform in storage capacity at the end of the storage period was calculated using Eq. [4.1].
2. Based on fecal coliform die-off, the surviving fraction of fecal coliform at the end of storage period was estimated to be 0.0078 in dairy manure.
3. The annual production of fecal coliform based on 'as-excreted' values was calculated for dairy manure.

The annual fecal coliform production from dairy manure was multiplied by the fraction of surviving fecal coliform to obtain the amount of fecal coliform that was available for land application on annual basis. For monthly application, the annual figure was multiplied by the fraction of dairy applied during that month based on the application schedule given in Table 3.7.

Appendix E: Fecal Coliform Loading in Sub-watersheds

Table E.1. Monthly nonpoint fecal coliform loadings in sub-watershed HYS-1.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture 1	Forest	Residential[1]
Jan.	566	700	41	28
Feb.	10	736	38	26
Mar.	2,091	1,324	41	28
Apr.	440	1,312	40	27
May.	128	1,384	41	28
Jun.	6	1,344	40	27
Jul.	6	1,424	41	28
Aug.	6	1,458	41	28
Sep.	6	1,477	40	27
Oct.	61	972	41	28
Nov.	61	987	40	27
Dec.	84	673	41	28
Total	3,465	13,789	486	330

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

Table E.2. Monthly nonpoint fecal coliform loadings in sub-watershed HYS-2.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture 1	Forest	Residential[1]
Jan.	185	2,134	89	11
Feb.	1	2,213	81	10
Mar.	681	3,843	89	11
Apr.	138	3,806	86	11
May.	39	4,012	89	11
Jun.	1	3,905	86	11
Jul.	1	4,130	89	11
Aug.	1	4,225	89	11
Sep.	1	4,259	86	11
Oct.	16	2,882	89	11
Nov.	16	2,914	86	11
Dec.	26	2,060	89	11
Total	1,105	40,384	1,043	128

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

Table E.3. Monthly nonpoint fecal coliform loadings in sub-watershed HYS-3.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture 1	Forest	Residential[1]
Jan.	907	6,219	114	29
Feb.	45	6,452	103	26
Mar.	3,497	11,213	114	29
Apr.	823	11,100	110	28
May.	235	11,696	114	29
Jun.	9	11,356	110	28
Jul.	9	12,011	114	29
Aug.	9	12,289	114	29
Sep.	9	12,417	110	28
Oct.	142	8,403	114	29
Nov.	142	8,497	110	28
Dec.	135	6,004	114	29
Total	5,963	117,657	1,338	339

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

Table E.4. Monthly nonpoint fecal coliform loadings in sub-watershed HYS-4.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture 1	Forest	Residential[1]
Jan.	589	9,037	85	46
Feb.	63	9,392	78	42
Mar.	2,412	16,399	85	46
Apr.	656	16,237	82	44
May.	185	17,111	85	46
Jun.	9	16,614	82	44
Jul.	9	17,576	85	46
Aug.	9	17,985	85	46
Sep.	9	18,178	82	44
Oct.	142	12,256	85	46
Nov.	141	12,400	82	44
Dec.	91	8,720	85	46
Total	4,315	171,907	1,002	537

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

Table E.5. Monthly nonpoint fecal coliform loadings in sub-watershed HYS-5.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture 1	Forest	Residential[1]
Jan.	559	4,176	53	63
Feb.	29	4,336	49	57
Mar.	2,170	7,554	53	63
Apr.	516	7,478	52	61
May.	146	7,880	53	63
Jun.	5	7,651	52	61
Jul.	5	8,094	53	63
Aug.	5	8,282	53	63
Sep.	5	8,369	52	61
Oct.	90	5,653	53	63
Nov.	90	5,718	52	61
Dec.	83	4,030	53	63
Total	3,703	79,222	630	742

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

Table E.6. Monthly nonpoint fecal coliform loadings in sub-watershed HYS-6.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture 1	Forest	Residential[1]
Jan.	645	9,422	44	96
Feb.	201	9,264	40	88
Mar.	3,261	20,203	44	96
Apr.	1,229	21,033	42	93
May.	335	21,862	44	96
Jun.	16	20,927	42	93
Jul.	16	21,864	44	96
Aug.	16	22,103	44	96
Sep.	16	22,105	42	93
Oct.	251	19,085	44	96
Nov.	354	17,518	42	93
Dec.	104	9,236	44	96
Total	6,444	214,622	515	1,134

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

Table E.7. Monthly nonpoint fecal coliform loadings in sub-watershed HYS-7.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture 1	Forest	Residential[1]
Jan.	549	4,678	19	7
Feb.	9	4,384	17	6
Mar.	2,041	5,449	19	7
Apr.	431	5,312	18	6
May.	124	5,524	19	7
Jun.	3	5,351	18	6
Jul.	3	5,573	19	7
Aug.	3	5,615	19	7
Sep.	3	5,515	18	6
Oct.	59	5,015	19	7
Nov.	59	4,910	18	6
Dec.	80	4,645	19	7
Total	3,365	61,973	223	79

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

Table E.8. Monthly nonpoint fecal coliform loadings in sub-watershed HYS-8.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture 1	Forest	Residential[1]
Jan.	553	5,452	41	45
Feb.	37	5,675	37	41
Mar.	2,188	9,950	41	45
Apr.	544	9,853	40	44
May.	152	10,385	41	45
Jun.	4	10,083	40	44
Jul.	4	10,669	41	45
Aug.	4	10,919	41	45
Sep.	4	11,039	40	44
Oct.	102	7,419	41	45
Nov.	102	7,509	40	44
Dec.	81	5,258	41	45
Total	3,774	104,211	483	531

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

Table E.9. Monthly nonpoint fecal coliform loadings in sub-watershed HYS-9.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture 1	Forest	Residential[1]
Jan.	530	5,377	18	12
Feb.	7	5,119	16	11
Mar.	1,977	6,772	18	12
Apr.	417	6,623	17	12
May.	118	6,907	18	12
Jun.	1	6,694	17	12
Jul.	1	6,995	18	12
Aug.	1	7,073	18	12
Sep.	1	6,991	17	12
Oct.	56	5,987	18	12
Nov.	56	5,896	17	12
Dec.	75	5,317	18	12
Total	3,241	75,750	208	142

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

Table E.10. Monthly nonpoint fecal coliform loadings in sub-watershed HYS-10.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture 1	Forest	Residential[1]
Jan.	475	185	5	1
Feb.	1	186	5	1
Mar.	1,748	295	5	1
Apr.	353	291	5	1
May.	100	306	5	1
Jun.	1	299	5	1
Jul.	1	315	5	1
Aug.	1	321	5	1
Sep.	1	321	5	1
Oct.	41	233	5	1
Nov.	41	234	5	1
Dec.	67	180	5	1
Total	2,829	3,164	60	16

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

Table E.11. Monthly nonpoint fecal coliform loadings in sub-watershed HYS-11.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture 1	Forest	Residential[1]
Jan.	539	7,522	67	45
Feb.	21	7,271	61	41
Mar.	2,075	10,183	67	45
Apr.	478	9,996	65	43
May.	134	10,468	67	45
Jun.	1	10,225	65	43
Jul.	1	10,716	67	45
Aug.	1	10,866	67	45
Sep.	1	10,717	65	43
Oct.	77	8,694	67	45
Nov.	77	8,602	65	43
Dec.	77	7,408	67	45
Total	3,483	112,668	789	528

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

Table E.12. Monthly nonpoint fecal coliform loadings in sub-watershed HYS-12.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture 1	Forest	Residential[1]
Jan.	589	2,228	22	46
Feb.	11	2,172	20	41
Mar.	2,187	3,130	22	46
Apr.	465	3,076	21	44
May.	134	3,222	22	46
Jun.	4	3,135	21	44
Jul.	5	3,290	22	46
Aug.	5	3,341	22	46
Sep.	4	3,316	21	44
Oct.	65	2,624	22	46
Nov.	65	2,604	21	44
Dec.	86	2,189	22	46
Total	3,619	34,328	262	536

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

Table E.13. Monthly nonpoint fecal coliform loadings in sub-watershed HYS-13.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture 1	Forest	Residential[1]
Jan.	660	1,698	12	31
Feb.	13	1,653	11	28
Mar.	2,430	2,370	12	31
Apr.	512	2,328	12	30
May.	151	2,438	12	31
Jun.	9	2,372	12	30
Jul.	9	2,489	12	31
Aug.	9	2,527	12	31
Sep.	9	2,507	12	30
Oct.	73	1,993	12	31
Nov.	72	1,977	12	30
Dec.	100	1,669	12	31
Total	4,049	26,020	145	367

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

Table E.14. Monthly nonpoint fecal coliform loadings in sub-watershed HYS-14.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)	
	Cropland	Forest
Jan.	5	0
Feb.	0	0
Mar.	18	0
Apr.	4	0
May.	1	0
Jun.	0	0
Jul.	0	0
Aug.	0	0
Sep.	0	0
Oct.	0	0
Nov.	0	0
Dec.	1	0
Total	30	3

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

Table E.15. Monthly nonpoint fecal coliform loadings in sub-watershed HYS-15.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture 1	Forest	Residential[1]
Jan.	533	1,545	25	22
Feb.	8	1,564	22	20
Mar.	1,995	2,539	25	22
Apr.	425	2,508	24	21
May.	120	2,639	25	22
Jun.	1	2,574	24	21
Jul.	1	2,715	25	22
Aug.	1	2,771	25	22
Sep.	1	2,773	24	21
Oct.	58	1,981	25	22
Nov.	58	1,989	24	21
Dec.	75	1,502	25	22
Total	3,276	27,098	290	254

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

Table E.16. Monthly nonpoint fecal coliform loadings in sub-watershed HYS-16.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture 1	Forest	Residential[1]
Jan.	3	28	3	1
Feb.	0	30	3	1
Mar.	9	55	3	1
Apr.	2	55	3	1
May.	1	58	3	1
Jun.	0	57	3	1
Jul.	0	60	3	1
Aug.	0	62	3	1
Sep.	0	62	3	1
Oct.	0	40	3	1
Nov.	0	40	3	1
Dec.	0	26	3	1
Total	15	573	35	16

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

Table E.17. Monthly nonpoint fecal coliform loadings in sub-watershed HYS-17.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture 1	Forest	Residential[1]
Jan.	626	5,599	46	85
Feb.	27	5,533	42	77
Mar.	2,387	8,346	46	85
Apr.	547	8,219	45	82
May.	157	8,630	46	85
Jun.	7	8,422	45	82
Jul.	7	8,857	46	85
Aug.	7	9,011	46	85
Sep.	7	8,957	45	82
Oct.	91	6,806	46	85
Nov.	91	6,783	45	82
Dec.	94	5,481	46	85
Total	4,048	90,643	546	997

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

Table E.18. Monthly nonpoint fecal coliform loadings in sub-watershed HYS-18.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture 1	Forest	Residential[1]
Jan.	563	3,529	30	60
Feb.	14	3,458	27	55
Mar.	2,120	5,075	30	60
Apr.	464	4,990	29	58
May.	132	5,230	30	60
Jun.	3	5,088	29	58
Jul.	3	5,344	30	60
Aug.	3	5,430	30	60
Sep.	3	5,401	29	58
Oct.	68	4,206	30	60
Nov.	68	4,183	29	58
Dec.	81	3,462	30	60
Total	3,522	55,396	353	712

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

Table E.19. Monthly nonpoint fecal coliform loadings in sub-watershed HYS-19.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture 1	Forest	Residential[1]
Jan.	579	7,192	84	38
Feb.	49	7,457	77	34
Mar.	2,321	12,938	84	38
Apr.	600	12,807	82	37
May.	169	13,494	84	38
Jun.	7	13,102	82	37
Jul.	7	13,857	84	38
Aug.	7	14,176	84	38
Sep.	7	14,323	82	37
Oct.	121	9,705	84	38
Nov.	120	9,813	82	37
Dec.	87	6,945	84	38
Total	4,075	135,809	993	445

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

Table E.20. Monthly nonpoint fecal coliform loadings in sub-watershed HYS-20.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture 1	Forest	Residential[1]
Jan.	632	7,278	92	91
Feb.	43	7,310	84	83
Mar.	2,449	11,587	92	91
Apr.	599	11,425	89	88
May.	174	11,995	92	91
Jun.	12	11,617	89	88
Jul.	13	12,242	92	91
Aug.	13	12,481	92	91
Sep.	12	12,555	89	88
Oct.	114	9,159	92	91
Nov.	114	9,181	89	88
Dec.	99	7,092	92	91
Total	4,276	123,921	1,089	1,069

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

Table E.21. Monthly nonpoint fecal coliform loadings in sub-watershed HYS-21.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture 1	Forest	Residential[1]
Jan.	606	6,633	40	24
Feb.	37	6,638	36	22
Mar.	2,342	10,410	40	24
Apr.	563	10,260	38	24
May.	163	10,767	40	24
Jun.	10	10,428	38	24
Jul.	10	10,985	40	24
Aug.	10	11,194	40	24
Sep.	10	11,250	38	24
Oct.	104	8,282	40	24
Nov.	103	8,293	38	24
Dec.	93	6,470	40	24
Total	4,051	111,609	468	287

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

Table E.22. Monthly nonpoint fecal coliform loadings in sub-watershed HYS-22.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture 1	Forest	Residential[1]
Jan.	544	6,981	21	56
Feb.	64	6,714	19	51
Mar.	2,295	11,201	21	56
Apr.	646	11,283	20	54
May.	177	11,736	21	56
Jun.	4	11,281	20	54
Jul.	4	11,782	21	56
Aug.	4	11,907	21	56
Sep.	4	11,851	20	54
Oct.	115	10,281	21	56
Nov.	142	9,783	20	54
Dec.	79	6,884	21	56
Total	4,076	121,682	248	659

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

Table E.23. Monthly nonpoint fecal coliform loadings in sub-watershed HYS-23.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture 1	Forest	Residential[1]
Jan.	537	590	14	8
Feb.	4	601	12	7
Mar.	1,988	994	14	8
Apr.	411	982	13	8
May.	117	1,035	14	8
Jun.	1	1,009	13	8
Jul.	1	1,065	14	8
Aug.	1	1,088	14	8
Sep.	1	1,090	13	8
Oct.	52	767	14	8
Nov.	52	771	13	8
Dec.	76	572	14	8
Total	3,241	10,564	160	96

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

Table E.24. Monthly nonpoint fecal coliform loadings in sub-watershed HYS-24.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture 1	Forest	Residential[1]
Jan.	544	3,808	42	43
Feb.	21	3,888	38	39
Mar.	2,094	6,469	42	43
Apr.	482	6,397	41	42
May.	135	6,738	42	43
Jun.	2	6,573	41	42
Jul.	2	6,941	42	43
Aug.	2	7,090	42	43
Sep.	2	7,107	41	42
Oct.	78	4,975	42	43
Nov.	78	5,007	41	42
Dec.	78	3,693	42	43
Total	3,518	68,686	494	511

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

Table E.25. Monthly nonpoint fecal coliform loadings in sub-watershed HYS-25.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture 1	Forest	Residential[1]
Jan.	562	1,429	39	24
Feb.	10	1,460	36	22
Mar.	2,096	2,434	39	24
Apr.	447	2,407	38	23
May.	127	2,536	39	24
Jun.	3	2,473	38	23
Jul.	3	2,612	39	24
Aug.	3	2,668	39	24
Sep.	3	2,675	38	23
Oct.	62	1,870	39	24
Nov.	62	1,882	38	23
Dec.	81	1,386	39	24
Total	3,458	25,833	462	281

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

Table E.26. Monthly nonpoint fecal coliform loadings in sub-watershed HYS-26.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture 1	Forest	Residential[1]
Jan.	25	313	60	19
Feb.	0	323	54	17
Mar.	92	551	60	19
Apr.	19	546	58	18
May.	5	576	60	19
Jun.	0	562	58	18
Jul.	0	594	60	19
Aug.	0	607	60	19
Sep.	0	609	58	18
Oct.	2	418	60	19
Nov.	2	421	58	18
Dec.	4	303	60	19
Total	149	5,822	705	221

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

Table E.27. Monthly nonpoint fecal coliform loadings in sub-watershed HYS-27.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture 1	Forest	Residential[1]
Jan.	9	1,335	48	29
Feb.	0	1,360	44	26
Mar.	32	2,247	48	29
Apr.	7	2,221	47	28
May.	2	2,339	48	29
Jun.	0	2,281	47	28
Jul.	0	2,408	48	29
Aug.	0	2,459	48	29
Sep.	0	2,464	47	28
Oct.	1	1,735	48	29
Nov.	1	1,745	47	28
Dec.	1	1,296	48	29
Total	52	23,891	569	336

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

Table E.28. Monthly nonpoint fecal coliform loadings in sub-watershed HYS-28.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture 1	Forest	Residential[1]
Jan.	264	1,549	60	38
Feb.	0	1,583	55	34
Mar.	970	2,637	60	38
Apr.	196	2,607	58	36
May.	56	2,747	60	38
Jun.	0	2,679	58	36
Jul.	0	2,830	60	38
Aug.	0	2,890	60	38
Sep.	0	2,898	58	36
Oct.	23	2,026	60	38
Nov.	23	2,040	58	36
Dec.	37	1,503	60	38
Total	1,571	27,989	709	442

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

Table E.29. Monthly nonpoint fecal coliform loadings in sub-watershed HYS-29.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture 1	Forest	Residential[1]
Jan.	542	2,190	2	9
Feb.	12	2,220	2	8
Mar.	2,043	3,619	2	9
Apr.	445	3,576	2	9
May.	125	3,764	2	9
Jun.	2	3,670	2	9
Jul.	2	3,872	2	9
Aug.	2	3,952	2	9
Sep.	2	3,957	2	9
Oct.	64	2,817	2	9
Nov.	64	2,829	2	9
Dec.	77	2,129	2	9
Total	3,378	38,595	23	109

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

Table E.30. Monthly nonpoint fecal coliform loadings in sub-watershed HYS-30.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture 1	Forest	Residential[1]
Jan.	450	3,202	4	21
Feb.	1	3,134	4	19
Mar.	1,656	4,578	4	21
Apr.	334	4,500	4	20
May.	95	4,715	4	21
Jun.	1	4,584	4	20
Jul.	1	4,814	4	21
Aug.	1	4,891	4	21
Sep.	1	4,866	4	20
Oct.	39	3,805	4	21
Nov.	39	3,782	4	20
Dec.	64	3,143	4	21
Total	2,680	50,015	53	244

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

Table E.31. Monthly nonpoint fecal coliform loadings in sub-watershed HYS-31.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture 1	Forest	Residential[1]
Jan.	530	1,833	59	31
Feb.	7	1,797	54	29
Mar.	1,977	2,640	59	31
Apr.	417	2,595	57	30
May.	118	2,720	59	31
Jun.	1	2,645	57	30
Jul.	1	2,778	59	31
Aug.	1	2,823	59	31
Sep.	1	2,810	57	30
Oct.	55	2,186	59	31
Nov.	55	2,174	57	30
Dec.	75	1,798	59	31
Total	3,235	28,798	695	369

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

Table E.32. Monthly nonpoint fecal coliform loadings in sub-watershed HYS-32.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)			
	Cropland	Pasture 1	Forest	Residential[1]
Jan.	541	3,630	22	48
Feb.	13	3,550	20	44
Mar.	2,042	5,171	22	48
Apr.	447	5,083	21	46
May.	126	5,325	22	48
Jun.	1	5,177	21	46
Jul.	2	5,436	22	48
Aug.	2	5,522	22	48
Sep.	1	5,493	21	46
Oct.	65	4,305	22	48
Nov.	65	4,278	21	46
Dec.	77	3,563	22	48
Total	3,381	56,532	254	565

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

Appendix F: HSPF Parameters that Vary by Month or Land Use

Table F. 1. MON-INTERCEP (monthly CEPSC) - Monthly Interception Storage.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Forest	0.06	0.06	0.06	0.1	0.16	0.16	0.16	0.16	0.16	0.1	0.06	0.06
Residential	0.093	0.093	0.093	0.093	0.096	0.096	0.096	0.096	0.096	0.093	0.093	0.093
Pasture	0.063	0.06	0.065	0.078	0.095	0.098	0.098	0.094	0.095	0.077	0.072	0.067
Crop	0.03	0.03	0.025	0.025	0.01	0.045	0.12	0.143	0.135	0.098	0.05	0.04

Table F. 2. MON-UZSN - Monthly Upper Zone Nominal Soil Moisture Storage Parameter.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Forest	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Residential	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Pasture	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Crop	0.70	0.70	0.70	0.75	0.80	1.00	1.30	1.30	1.25	1.25	0.70	0.70

Table F. 3. MON-LZETP - Monthly Lower Zone Evapotranspiration Parameter.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Forest	0.1	0.1	0.2	0.3	0.45	0.65	0.75	0.75	0.65	0.3	0.15	0.1
Residential	0.1	0.1	0.2	0.2	0.3	0.55	0.6	0.6	0.55	0.3	0.15	0.1
Pasture	0.1	0.1	0.2	0.25	0.4	0.55	0.6	0.6	0.55	0.3	0.15	0.1
Crop	0.1	0.1	0.1	0.1	0.3	0.6	0.65	0.65	0.55	0.25	0.15	0.1

Table F. 4. MON-ACCUM (monthly accumulation) table - values in cfu/acre/day for fecal coliform.

Sub	Land Use	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	Cropland	1.00E+09	1.90E+07	3.70E+09	8.00E+08	2.30E+08	1.10E+07	1.10E+07	1.10E+07	1.10E+07	1.10E+08	1.10E+08	1.50E+08
1	Pasture	1.50E+09	1.70E+09	2.70E+09	2.80E+09	2.90E+09	2.90E+09	3.00E+09	3.00E+09	3.20E+09	2.00E+09	2.10E+09	1.40E+09
1	LDR	1.20E+09	1.20E+09	1.20E+09	1.20E+09	1.20E+09	1.20E+09	1.20E+09	1.20E+09	1.20E+09	1.20E+09	1.20E+09	1.20E+09
1	HDR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1	Forest	3.30E+07	3.30E+07	3.30E+07	3.30E+07	3.30E+07	3.30E+07	3.30E+07	3.30E+07	3.30E+07	3.30E+07	3.30E+07	3.30E+07
2	Cropland	3.50E+09	1.10E+07	1.30E+10	2.70E+09	7.40E+08	1.10E+07	1.10E+07	1.10E+07	1.10E+07	3.10E+08	3.20E+08	5.00E+08
2	Pasture	1.70E+09	1.90E+09	3.30E+09	3.10E+09	3.10E+09	4.60E+09	3.20E+09	3.30E+09	3.40E+09	2.20E+09	2.30E+09	1.60E+09
2	LDR	1.10E+09	1.10E+09	1.10E+09	1.10E+09	1.10E+09	1.10E+09	1.10E+09	1.10E+09	1.10E+09	1.10E+09	1.10E+09	1.10E+09
2	HDR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2	Forest	2.60E+07	2.60E+07	2.60E+07	2.60E+07	2.60E+07	2.60E+07	2.60E+07	2.60E+07	2.60E+07	2.60E+07	2.60E+07	2.60E+07
3	Cropland	9.70E+08	5.30E+07	3.80E+09	9.10E+08	2.50E+08	1.00E+07	1.00E+07	1.00E+07	1.00E+07	1.50E+08	1.60E+08	1.50E+08
3	Pasture	1.60E+09	1.80E+09	2.90E+09	3.00E+09	3.00E+09	3.10E+09	3.10E+09	3.20E+09	3.30E+09	2.20E+09	2.30E+09	1.60E+09
3	LDR	1.70E+09	1.70E+09	1.70E+09	1.70E+09	1.70E+09	1.70E+09	1.70E+09	1.70E+09	1.70E+09	1.70E+09	1.70E+09	1.70E+09
3	HDR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3	Forest	3.60E+07	3.60E+07	3.60E+07	3.60E+07	3.60E+07	3.60E+07	3.60E+07	3.60E+07	3.60E+07	3.60E+07	3.60E+07	3.60E+07
4	Cropland	6.20E+08	7.30E+07	2.50E+09	7.10E+08	2.00E+08	1.00E+07	1.00E+07	1.00E+07	1.00E+07	1.50E+08	1.50E+08	9.50E+07
4	Pasture	1.60E+09	1.80E+09	2.90E+09	3.00E+09	3.00E+09	3.00E+09	3.10E+09	3.20E+09	3.30E+09	2.20E+09	2.30E+09	1.50E+09
4	LDR	8.20E+08	8.20E+08	8.20E+08	8.20E+08	8.20E+08	8.20E+08	8.20E+08	8.20E+08	8.20E+08	8.20E+08	8.20E+08	8.20E+08
4	HDR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4	Forest	7.10E+07	7.10E+07	7.10E+07	7.10E+07	7.10E+07	7.10E+07	7.10E+07	7.10E+07	7.10E+07	7.10E+07	7.10E+07	7.10E+07
5	Cropland	1.00E+09	5.90E+07	4.00E+09	9.90E+08	2.70E+08	9.00E+06	9.00E+06	9.00E+06	9.00E+06	1.70E+08	1.70E+08	1.50E+08
5	Pasture	1.60E+09	1.80E+09	2.90E+09	3.00E+09	3.00E+09	3.00E+09	3.10E+09	3.20E+09	3.30E+09	2.20E+09	2.30E+09	1.60E+09
5	LDR	1.40E+09	1.40E+09	1.40E+09	1.40E+09	1.40E+09	1.40E+09	1.40E+09	1.40E+09	1.40E+09	1.40E+09	1.40E+09	1.40E+09
5	HDR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
5	Forest	4.50E+07	4.50E+07	4.50E+07	4.50E+07	4.50E+07	4.50E+07	4.50E+07	4.50E+07	4.50E+07	4.50E+07	4.50E+07	4.50E+07
6	Cropland	3.60E+08	1.20E+08	1.80E+09	7.00E+08	1.90E+08	9.00E+06	9.00E+06	9.00E+06	9.00E+06	1.40E+08	2.00E+08	5.80E+07
6	Pasture	2.80E+09	3.10E+09	6.10E+09	6.60E+09	6.60E+09	6.50E+09	6.60E+09	6.70E+09	6.90E+09	5.80E+09	5.50E+09	2.80E+09
6	LDR	9.50E+08	9.50E+08	9.50E+08	9.50E+08	9.50E+08	9.50E+08	9.50E+08	9.50E+08	9.50E+08	9.50E+08	9.50E+08	9.50E+08
6	HDR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
6	Forest	2.80E+07	2.80E+07	2.80E+07	2.80E+07	2.80E+07	2.80E+07	2.80E+07	2.80E+07	2.80E+07	2.80E+07	2.80E+07	2.80E+07
7	Cropland	1.50E+09	2.50E+07	5.40E+09	1.20E+09	3.30E+08	8.90E+06	8.90E+06	8.90E+06	8.90E+06	1.60E+08	1.60E+08	2.10E+08
7	Pasture	7.80E+09	8.10E+09	9.10E+09	9.20E+09	9.30E+09	9.30E+09	9.30E+09	9.40E+09	9.50E+09	8.40E+09	8.50E+09	7.80E+09
7	LDR	3.20E+09	3.20E+09	3.20E+09	3.20E+09	3.20E+09	3.20E+09	3.20E+09	3.20E+09	3.20E+09	3.20E+09	3.20E+09	3.20E+09
7	HDR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Sub	Land Use	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
7	Forest	3.60E+07	3.60E+07	3.60E+07	3.60E+07	3.60E+07	3.60E+07	3.60E+07	3.60E+07	3.60E+07	3.60E+07	3.60E+07	3.60E+07
8	Cropland	1.20E+09	8.50E+07	4.60E+09	1.20E+09	3.20E+08	8.80E+06	8.80E+06	8.80E+06	8.80E+06	2.10E+08	2.20E+08	1.70E+08
8	Pasture	1.60E+09	1.80E+09	2.90E+09	2.90E+09	3.00E+09	3.00E+09	3.10E+09	3.20E+09	3.30E+09	2.10E+09	2.20E+09	1.50E+09
8	LDR	1.00E+09	1.00E+09	1.00E+09	1.00E+09	1.00E+09	1.00E+09	1.00E+09	1.00E+09	1.00E+09	1.00E+09	1.00E+09	1.00E+09
8	HDR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
8	Forest	2.40E+07	2.40E+07	2.40E+07	2.40E+07	2.40E+07	2.40E+07	2.40E+07	2.40E+07	2.40E+07	2.40E+07	2.40E+07	2.40E+07
9	Cropland	3.60E+09	5.30E+07	1.40E+10	3.00E+09	8.10E+08	8.60E+06	8.60E+06	8.60E+06	8.60E+06	3.80E+08	3.90E+08	5.20E+08
9	Pasture	5.00E+09	5.20E+09	6.30E+09	6.40E+09	6.40E+09	6.40E+09	6.50E+09	6.60E+09	6.70E+09	5.60E+09	5.70E+09	4.90E+09
9	LDR	1.40E+09	1.40E+09	1.40E+09	1.40E+09	1.40E+09	1.40E+09	1.40E+09	1.40E+09	1.40E+09	1.40E+09	1.40E+09	1.40E+09
9	HDR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
9	Forest	4.50E+07	4.50E+07	4.50E+07	4.50E+07	4.50E+07	4.50E+07	4.50E+07	4.50E+07	4.50E+07	4.50E+07	4.50E+07	4.50E+07
10	Cropland	4.00E+09	5.00E+06	1.50E+10	3.10E+09	8.50E+08	5.00E+06	5.00E+06	5.00E+06	5.00E+06	3.50E+08	3.60E+08	5.70E+08
10	Pasture	1.10E+09	1.20E+09	2.00E+09	1.80E+09	1.80E+09	3.40E+09	1.80E+09	2.00E+09	1.90E+09	1.30E+09	1.40E+09	1.00E+09
10	LDR	1.10E+09	1.10E+09	1.10E+09	1.10E+09	1.10E+09	1.10E+09	1.10E+09	1.10E+09	1.10E+09	1.10E+09	1.10E+09	1.10E+09
10	HDR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
10	Forest	1.20E+08	1.20E+08	1.20E+08	1.20E+08	1.20E+08	1.20E+08	1.20E+08	1.20E+08	1.20E+08	1.20E+08	1.20E+08	1.20E+08
11	Cropland	1.90E+09	7.90E+07	7.20E+09	1.70E+09	4.60E+08	5.10E+06	5.10E+06	5.10E+06	5.10E+06	2.70E+08	2.80E+08	2.70E+08
11	Pasture	1.50E+09	1.60E+09	2.00E+09	2.00E+09	2.00E+09	2.10E+09	2.10E+09	2.10E+09	2.20E+09	1.70E+09	1.70E+09	1.40E+09
11	LDR	1.50E+09	1.50E+09	1.50E+09	1.50E+09	1.50E+09	1.50E+09	1.50E+09	1.50E+09	1.50E+09	1.50E+09	1.50E+09	1.50E+09
11	HDR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
11	Forest	2.70E+07	2.70E+07	2.70E+07	2.70E+07	2.70E+07	2.70E+07	2.70E+07	2.70E+07	2.70E+07	2.70E+07	2.70E+07	2.70E+07
12	Cropland	6.60E+08	1.30E+07	2.40E+09	5.40E+08	1.50E+08	5.10E+06	5.10E+06	5.10E+06	5.10E+06	7.20E+07	7.50E+07	9.60E+07
12	Pasture	1.20E+09	1.30E+09	1.70E+09	1.70E+09	1.80E+09	1.80E+09	1.80E+09	1.80E+09	1.90E+09	1.40E+09	1.50E+09	1.20E+09
12	LDR	1.60E+09	1.60E+09	1.60E+09	1.60E+09	1.60E+09	1.60E+09	1.60E+09	1.60E+09	1.60E+09	1.60E+09	1.60E+09	1.60E+09
12	HDR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
12	Forest	1.20E+07	1.20E+07	1.20E+07	1.20E+07	1.20E+07	1.20E+07	1.20E+07	1.20E+07	1.20E+07	1.20E+07	1.20E+07	1.20E+07
13	Cropland	3.70E+08	8.10E+06	1.30E+09	2.90E+08	8.40E+07	5.10E+06	5.10E+06	5.10E+06	5.10E+06	4.00E+07	4.20E+07	5.60E+07
13	Pasture	1.30E+09	1.30E+09	1.70E+09	1.80E+09	1.80E+09	1.80E+09	1.80E+09	1.90E+09	1.90E+09	1.50E+09	1.50E+09	1.20E+09
13	LDR	8.20E+08	8.20E+08	8.20E+08	8.20E+08	8.20E+08	8.20E+08	8.20E+08	8.20E+08	8.20E+08	8.20E+08	8.20E+08	8.20E+08
13	HDR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
13	Forest	7.00E+06	7.00E+06	7.00E+06	7.00E+06	7.00E+06	7.00E+06	7.00E+06	7.00E+06	7.00E+06	7.00E+06	7.00E+06	7.00E+06
14	Cropland	4.00E+09	9.10E+06	1.50E+10	3.10E+09	8.50E+08	9.10E+06	9.10E+06	9.10E+06	9.10E+06	3.60E+08	3.70E+08	5.70E+08
14	Forest	9.60E+06	9.60E+06	9.60E+06	9.60E+06	9.60E+06	9.60E+06	9.60E+06	9.60E+06	9.60E+06	9.60E+06	9.60E+06	9.60E+06
15	Cropland	2.80E+09	4.70E+07	1.00E+10	2.30E+09	6.30E+08	5.20E+06	5.20E+06	5.20E+06	5.20E+06	3.00E+08	3.10E+08	4.00E+08
15	Pasture	1.00E+09	1.10E+09	1.70E+09	1.70E+09	1.70E+09	1.70E+09	1.80E+09	1.80E+09	1.90E+09	1.30E+09	1.30E+09	9.80E+08
15	LDR	2.30E+09	2.30E+09	2.30E+09	2.30E+09	2.30E+09	2.30E+09	2.30E+09	2.30E+09	2.30E+09	2.30E+09	2.30E+09	2.30E+09

Sub	Land Use	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
15	HDR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
15	Forest	4.20E+07	4.20E+07	4.20E+07	4.20E+07	4.20E+07	4.20E+07	4.20E+07	4.20E+07	4.20E+07	4.20E+07	4.20E+07	4.20E+07
16	Cropland	4.00E+09	6.80E+06	1.50E+10	3.10E+09	8.50E+08	6.80E+06	6.80E+06	6.80E+06	6.80E+06	3.50E+08	3.60E+08	5.70E+08
16	Pasture	1.50E+09	6.70E+08	5.30E+09	2.10E+09	1.40E+09	2.30E+10	1.30E+09	2.90E+09	1.30E+09	9.60E+08	1.00E+09	6.80E+08
16	LDR	2.30E+08	2.30E+08	2.30E+08	2.30E+08	2.30E+08	2.30E+08	2.30E+08	2.30E+08	2.30E+08	2.30E+08	2.30E+08	2.30E+08
16	HDR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
16	Forest	8.20E+07	8.20E+07	8.20E+07	8.20E+07	8.20E+07	8.20E+07	8.20E+07	8.20E+07	8.20E+07	8.20E+07	8.20E+07	8.20E+07
17	Cropland	4.40E+08	2.10E+07	1.70E+09	4.00E+08	1.10E+08	5.00E+06	5.00E+06	5.00E+06	5.00E+06	6.50E+07	6.70E+07	6.70E+07
17	Pasture	1.10E+09	1.20E+09	1.70E+09	1.70E+09	1.70E+09	1.80E+09	1.80E+09	1.80E+09	1.90E+09	1.40E+09	1.40E+09	1.10E+09
17	LDR	1.80E+09	1.80E+09	1.80E+09	1.80E+09	1.80E+09	1.80E+09	1.80E+09	1.80E+09	1.80E+09	1.80E+09	1.80E+09	1.80E+09
17	HDR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
17	Forest	2.70E+07	2.70E+07	2.70E+07	2.70E+07	2.70E+07	2.70E+07	2.70E+07	2.70E+07	2.70E+07	2.70E+07	2.70E+07	2.70E+07
18	Cropland	9.70E+08	2.60E+07	3.70E+09	8.30E+08	2.30E+08	5.00E+06	5.00E+06	5.00E+06	5.00E+06	1.20E+08	1.20E+08	1.40E+08
18	Pasture	1.20E+09	1.30E+09	1.70E+09	1.80E+09	1.80E+09	1.80E+09	1.80E+09	1.80E+09	1.90E+09	1.40E+09	1.50E+09	1.20E+09
18	LDR	2.10E+09	2.10E+09	2.10E+09	2.10E+09	2.10E+09	2.10E+09	2.10E+09	2.10E+09	2.10E+09	2.10E+09	2.10E+09	2.10E+09
18	HDR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
18	Forest	3.70E+07	3.70E+07	3.70E+07	3.70E+07	3.70E+07	3.70E+07	3.70E+07	3.70E+07	3.70E+07	3.70E+07	3.70E+07	3.70E+07
19	Cropland	7.10E+08	6.60E+07	2.90E+09	7.60E+08	2.10E+08	8.90E+06	8.90E+06	8.90E+06	8.90E+06	1.50E+08	1.50E+08	1.10E+08
19	Pasture	1.60E+09	1.80E+09	2.90E+09	2.90E+09	3.00E+09	3.00E+09	3.10E+09	3.20E+09	3.30E+09	2.20E+09	2.30E+09	1.50E+09
19	LDR	1.10E+09	1.10E+09	1.10E+09	1.10E+09	1.10E+09	1.10E+09	1.10E+09	1.10E+09	1.10E+09	1.10E+09	1.10E+09	1.10E+09
19	HDR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
19	Forest	5.80E+07	5.80E+07	5.80E+07	5.80E+07	5.80E+07	5.80E+07	5.80E+07	5.80E+07	5.80E+07	5.80E+07	5.80E+07	5.80E+07
20	Cropland	4.40E+08	3.30E+07	1.70E+09	4.30E+08	1.20E+08	9.00E+06	9.00E+06	9.00E+06	9.00E+06	8.00E+07	8.20E+07	7.00E+07
20	Pasture	1.70E+09	1.90E+09	2.70E+09	2.80E+09	2.80E+09	2.80E+09	2.90E+09	2.90E+09	3.10E+09	2.20E+09	2.20E+09	1.70E+09
20	LDR	2.00E+09	2.00E+09	2.00E+09	2.00E+09	2.00E+09	2.00E+09	2.00E+09	2.00E+09	2.00E+09	2.00E+09	2.00E+09	2.00E+09
20	HDR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
20	Forest	3.10E+07	3.10E+07	3.10E+07	3.10E+07	3.10E+07	3.10E+07	3.10E+07	3.10E+07	3.10E+07	3.10E+07	3.10E+07	3.10E+07
21	Cropland	5.50E+08	3.70E+07	2.10E+09	5.20E+08	1.50E+08	9.00E+06	9.00E+06	9.00E+06	9.00E+06	9.30E+07	9.60E+07	8.40E+07
21	Pasture	1.70E+09	1.90E+09	2.70E+09	2.80E+09	2.80E+09	2.80E+09	2.90E+09	2.90E+09	3.00E+09	2.20E+09	2.20E+09	1.70E+09
21	LDR	5.40E+08	5.40E+08	5.40E+08	5.40E+08	5.40E+08	5.40E+08	5.40E+08	5.40E+08	5.40E+08	5.40E+08	5.40E+08	5.40E+08
21	HDR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
21	Forest	2.70E+07	2.70E+07	2.70E+07	2.70E+07	2.70E+07	2.70E+07	2.70E+07	2.70E+07	2.70E+07	2.70E+07	2.70E+07	2.70E+07
22	Cropland	1.40E+09	1.70E+08	5.70E+09	1.70E+09	4.40E+08	9.10E+06	9.10E+06	9.10E+06	9.10E+06	2.90E+08	3.70E+08	2.00E+08
22	Pasture	3.10E+09	3.30E+09	5.00E+09	5.20E+09	5.20E+09	5.20E+09	5.20E+09	5.30E+09	5.40E+09	4.60E+09	4.50E+09	3.10E+09
22	LDR	7.40E+08	7.40E+08	7.40E+08	7.40E+08	7.40E+08	7.40E+08	7.40E+08	7.40E+08	7.40E+08	7.40E+08	7.40E+08	7.40E+08
22	HDR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Sub	Land Use	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
22	Forest	1.50E+07	1.50E+07	1.50E+07	1.50E+07	1.50E+07	1.50E+07	1.50E+07	1.50E+07	1.50E+07	1.50E+07	1.50E+07	1.50E+07
23	Cropland	2.30E+09	1.90E+07	8.60E+09	1.80E+09	5.00E+08	5.00E+06	5.00E+06	5.00E+06	5.00E+06	2.20E+08	2.30E+08	3.30E+08
23	Pasture	1.10E+09	1.20E+09	1.80E+09	1.80E+09	1.90E+09	1.90E+09	1.90E+09	2.00E+09	2.00E+09	1.40E+09	1.40E+09	1.00E+09
23	LDR	1.20E+09	1.20E+09	1.20E+09	1.20E+09	1.20E+09	1.20E+09	1.20E+09	1.20E+09	1.20E+09	1.20E+09	1.20E+09	1.20E+09
23	HDR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
23	Forest	7.80E+06	7.80E+06	7.80E+06	7.80E+06	7.80E+06	7.80E+06	7.80E+06	7.80E+06	7.80E+06	7.80E+06	7.80E+06	7.80E+06
24	Cropland	1.50E+09	6.50E+07	5.80E+09	1.40E+09	3.80E+08	5.10E+06	5.10E+06	5.10E+06	5.10E+06	2.20E+08	2.30E+08	2.20E+08
24	Pasture	1.00E+09	1.20E+09	1.80E+09	1.80E+09	1.90E+09	1.90E+09	1.90E+09	2.00E+09	2.00E+09	1.40E+09	1.40E+09	1.00E+09
24	LDR	1.20E+09	1.20E+09	1.20E+09	1.20E+09	1.20E+09	1.20E+09	1.20E+09	1.20E+09	1.20E+09	1.20E+09	1.20E+09	1.20E+09
24	HDR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
24	Forest	1.60E+07	1.60E+07	1.60E+07	1.60E+07	1.60E+07	1.60E+07	1.60E+07	1.60E+07	1.60E+07	1.60E+07	1.60E+07	1.60E+07
25	Cropland	1.00E+09	2.00E+07	3.80E+09	8.40E+08	2.30E+08	5.20E+06	5.20E+06	5.20E+06	5.20E+06	1.10E+08	1.20E+08	1.50E+08
25	Pasture	1.00E+09	1.20E+09	1.80E+09	1.80E+09	1.90E+09	1.90E+09	1.90E+09	1.90E+09	2.00E+09	1.40E+09	1.40E+09	1.00E+09
25	LDR	5.30E+08	5.30E+08	5.30E+08	5.30E+08	5.30E+08	5.30E+08	5.30E+08	5.30E+08	5.30E+08	5.30E+08	5.30E+08	5.30E+08
25	HDR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
25	Forest	1.30E+07	1.30E+07	1.30E+07	1.30E+07	1.30E+07	1.30E+07	1.30E+07	1.30E+07	1.30E+07	1.30E+07	1.30E+07	1.30E+07
26	Cropland	4.00E+09	5.40E+06	1.50E+10	3.10E+09	8.50E+08	5.40E+06	5.40E+06	5.40E+06	5.40E+06	3.50E+08	3.60E+08	5.70E+08
26	Pasture	1.30E+09	1.10E+09	3.40E+09	2.10E+09	1.90E+09	1.00E+10	1.80E+09	2.50E+09	2.00E+09	1.40E+09	1.40E+09	9.90E+08
26	LDR	5.40E+08	5.40E+08	5.40E+08	5.40E+08	5.40E+08	5.40E+08	5.40E+08	5.40E+08	5.40E+08	5.40E+08	5.40E+08	5.40E+08
26	HDR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
26	Forest	9.40E+06	9.40E+06	9.40E+06	9.40E+06	9.40E+06	9.40E+06	9.40E+06	9.40E+06	9.40E+06	9.40E+06	9.40E+06	9.40E+06
27	Cropland	4.00E+09	5.30E+06	1.50E+10	3.10E+09	8.50E+08	5.30E+06	5.30E+06	5.30E+06	5.30E+06	3.50E+08	3.60E+08	5.70E+08
27	Pasture	1.20E+09	1.20E+09	2.30E+09	2.00E+09	1.90E+09	4.20E+09	1.90E+09	2.20E+09	2.10E+09	1.40E+09	1.50E+09	1.10E+09
27	LDR	7.20E+08	7.20E+08	7.20E+08	7.20E+08	7.20E+08	7.20E+08	7.20E+08	7.20E+08	7.20E+08	7.20E+08	7.20E+08	7.20E+08
27	HDR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
27	Forest	1.10E+07	1.10E+07	1.10E+07	1.10E+07	1.10E+07	1.10E+07	1.10E+07	1.10E+07	1.10E+07	1.10E+07	1.10E+07	1.10E+07
28	Cropland	4.00E+09	5.30E+06	1.50E+10	3.10E+09	8.50E+08	5.30E+06	5.30E+06	5.30E+06	5.30E+06	3.50E+08	3.60E+08	5.70E+08
28	Pasture	1.10E+09	1.20E+09	2.00E+09	1.90E+09	1.90E+09	2.80E+09	1.90E+09	2.00E+09	2.00E+09	1.40E+09	1.40E+09	1.00E+09
28	LDR	7.10E+08	7.10E+08	7.10E+08	7.10E+08	7.10E+08	7.10E+08	7.10E+08	7.10E+08	7.10E+08	7.10E+08	7.10E+08	7.10E+08
28	HDR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
28	Forest	8.50E+06	8.50E+06	8.50E+06	8.50E+06	8.50E+06	8.50E+06	8.50E+06	8.50E+06	8.50E+06	8.50E+06	8.50E+06	8.50E+06
29	Cropland	1.70E+09	4.20E+07	6.50E+09	1.50E+09	4.00E+08	4.90E+06	4.90E+06	4.90E+06	4.90E+06	2.00E+08	2.10E+08	2.50E+08
29	Pasture	1.10E+09	1.20E+09	1.80E+09	1.80E+09	1.90E+09	1.90E+09	1.90E+09	2.00E+09	2.00E+09	1.40E+09	1.40E+09	1.10E+09
29	LDR	2.80E+08	2.80E+08	2.80E+08	2.80E+08	2.80E+08	2.80E+08	2.80E+08	2.80E+08	2.80E+08	2.80E+08	2.80E+08	2.80E+08
29	HDR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
29	Forest	8.20E+06	8.20E+06	8.20E+06	8.20E+06	8.20E+06	8.20E+06	8.20E+06	8.20E+06	8.20E+06	8.20E+06	8.20E+06	8.20E+06

Sub	Land Use	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
30	Cropland	4.00E+09	4.90E+06	1.50E+10	3.10E+09	8.50E+08	4.90E+06	4.90E+06	4.90E+06	4.90E+06	3.50E+08	3.60E+08	5.70E+08
30	Pasture	1.30E+09	1.40E+09	1.90E+09	1.90E+09	1.90E+09	2.10E+09	2.00E+09	2.00E+09	2.00E+09	1.50E+09	1.60E+09	1.30E+09
30	LDR	6.70E+08	6.70E+08	6.70E+08	6.70E+08	6.70E+08	6.70E+08	6.70E+08	6.70E+08	6.70E+08	6.70E+08	6.70E+08	6.70E+08
30	HDR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
30	Forest	5.50E+06	5.50E+06	5.50E+06	5.50E+06	5.50E+06	5.50E+06	5.50E+06	5.50E+06	5.50E+06	5.50E+06	5.50E+06	5.50E+06
31	Cropland	3.60E+09	4.90E+07	1.40E+10	3.00E+09	8.10E+08	5.30E+06	5.30E+06	5.30E+06	5.30E+06	3.80E+08	3.90E+08	5.10E+08
31	Pasture	1.30E+09	1.40E+09	1.80E+09	1.90E+09	1.90E+09	1.90E+09	1.90E+09	2.00E+09	2.00E+09	1.50E+09	1.60E+09	1.30E+09
31	LDR	1.60E+09	1.60E+09	1.60E+09	1.60E+09	1.60E+09	1.60E+09	1.60E+09	1.60E+09	1.60E+09	1.60E+09	1.60E+09	1.60E+09
31	HDR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
31	Forest	1.30E+07	1.30E+07	1.30E+07	1.30E+07	1.30E+07	1.30E+07	1.30E+07	1.30E+07	1.30E+07	1.30E+07	1.30E+07	1.30E+07
32	Cropland	1.80E+09	4.70E+07	6.90E+09	1.60E+09	4.30E+08	5.20E+06	5.20E+06	5.20E+06	5.20E+06	2.20E+08	2.30E+08	2.60E+08
32	Pasture	1.30E+09	1.40E+09	1.90E+09	1.90E+09	1.90E+09	1.90E+09	2.00E+09	2.00E+09	2.10E+09	1.60E+09	1.60E+09	1.30E+09
32	LDR	7.10E+08	7.10E+08	7.10E+08	7.10E+08	7.10E+08	7.10E+08	7.10E+08	7.10E+08	7.10E+08	7.10E+08	7.10E+08	7.10E+08
32	HDR	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
32	Forest	6.50E+06	6.50E+06	6.50E+06	6.50E+06	6.50E+06	6.50E+06	6.50E+06	6.50E+06	6.50E+06	6.50E+06	6.50E+06	6.50E+06

Table F. 5. MON-SQOLIM (monthly limit on surface accumulation) table - values in cfu/day for fecal coliform.

Sub	Land Use	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	Cropland	9.00E+09	1.70E+08	3.30E+10	7.20E+09	2.00E+09	9.50E+07	9.50E+07	9.50E+07	9.50E+07	9.70E+08	1.00E+09	1.30E+09
1	Pasture	1.30E+10	1.50E+10	2.50E+10	2.50E+10	2.60E+10	2.60E+10	2.70E+10	2.70E+10	2.80E+10	1.80E+10	1.90E+10	1.30E+10
1	LDR	1.10E+10	1.10E+10	1.10E+10	1.10E+10	1.10E+10	1.10E+10	1.10E+10	1.10E+10	1.10E+10	1.10E+10	1.10E+10	1.10E+10
1	HDR	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
1	Forest	3.00E+08	3.00E+08	3.00E+08	3.00E+08	3.00E+08	3.00E+08	3.00E+08	3.00E+08	3.00E+08	3.00E+08	3.00E+08	3.00E+08
2	Cropland	3.10E+10	9.50E+07	1.20E+11	2.40E+10	6.70E+09	9.50E+07	9.50E+07	9.50E+07	9.50E+07	2.80E+09	2.90E+09	4.50E+09
2	Pasture	1.50E+10	1.70E+10	2.90E+10	2.80E+10	2.80E+10	4.10E+10	2.80E+10	3.00E+10	3.00E+10	2.00E+10	2.10E+10	1.40E+10
2	LDR	9.90E+09	9.90E+09	9.90E+09	9.90E+09	9.90E+09	9.90E+09	9.90E+09	9.90E+09	9.90E+09	9.90E+09	9.90E+09	9.90E+09
2	HDR	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
2	Forest	2.30E+08	2.30E+08	2.30E+08	2.30E+08	2.30E+08	2.30E+08	2.30E+08	2.30E+08	2.30E+08	2.30E+08	2.30E+08	2.30E+08
3	Cropland	8.80E+09	4.80E+08	3.40E+10	8.20E+09	2.30E+09	9.10E+07	9.10E+07	9.10E+07	9.10E+07	1.40E+09	1.40E+09	1.30E+09
3	Pasture	1.50E+10	1.70E+10	2.60E+10	2.70E+10	2.70E+10	2.70E+10	2.80E+10	2.90E+10	3.00E+10	2.00E+10	2.10E+10	1.40E+10
3	LDR	1.50E+10	1.50E+10	1.50E+10	1.50E+10	1.50E+10	1.50E+10	1.50E+10	1.50E+10	1.50E+10	1.50E+10	1.50E+10	1.50E+10
3	HDR	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
3	Forest	3.30E+08	3.30E+08	3.30E+08	3.30E+08	3.30E+08	3.30E+08	3.30E+08	3.30E+08	3.30E+08	3.30E+08	3.30E+08	3.30E+08
4	Cropland	5.60E+09	6.50E+08	2.30E+10	6.40E+09	1.80E+09	9.00E+07	9.00E+07	9.00E+07	9.00E+07	1.30E+09	1.40E+09	8.60E+08
4	Pasture	1.40E+10	1.60E+10	2.60E+10	2.70E+10	2.70E+10	2.70E+10	2.80E+10	2.90E+10	3.00E+10	1.90E+10	2.00E+10	1.40E+10
4	LDR	7.40E+09	7.40E+09	7.40E+09	7.40E+09	7.40E+09	7.40E+09	7.40E+09	7.40E+09	7.40E+09	7.40E+09	7.40E+09	7.40E+09
4	HDR	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
4	Forest	6.30E+08	6.30E+08	6.30E+08	6.30E+08	6.30E+08	6.30E+08	6.30E+08	6.30E+08	6.30E+08	6.30E+08	6.30E+08	6.30E+08
5	Cropland	9.30E+09	5.40E+08	3.60E+10	8.90E+09	2.40E+09	8.10E+07	8.10E+07	8.10E+07	8.10E+07	1.50E+09	1.60E+09	1.40E+09
5	Pasture	1.40E+10	1.60E+10	2.60E+10	2.70E+10	2.70E+10	2.70E+10	2.80E+10	2.90E+10	3.00E+10	2.00E+10	2.00E+10	1.40E+10
5	LDR	1.20E+10	1.20E+10	1.20E+10	1.20E+10	1.20E+10	1.20E+10	1.20E+10	1.20E+10	1.20E+10	1.20E+10	1.20E+10	1.20E+10
5	HDR	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
5	Forest	4.10E+08	4.10E+08	4.10E+08	4.10E+08	4.10E+08	4.10E+08	4.10E+08	4.10E+08	4.10E+08	4.10E+08	4.10E+08	4.10E+08
6	Cropland	3.20E+09	1.10E+09	1.60E+10	6.30E+09	1.70E+09	8.10E+07	8.10E+07	8.10E+07	8.10E+07	1.30E+09	1.80E+09	5.20E+08
6	Pasture	2.60E+10	2.80E+10	5.50E+10	5.90E+10	5.90E+10	5.90E+10	5.90E+10	6.00E+10	6.20E+10	5.20E+10	4.90E+10	2.50E+10
6	LDR	8.60E+09	8.60E+09	8.60E+09	8.60E+09	8.60E+09	8.60E+09	8.60E+09	8.60E+09	8.60E+09	8.60E+09	8.60E+09	8.60E+09
6	HDR	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
6	Forest	2.50E+08	2.50E+08	2.50E+08	2.50E+08	2.50E+08	2.50E+08	2.50E+08	2.50E+08	2.50E+08	2.50E+08	2.50E+08	2.50E+08
7	Cropland	1.30E+10	2.30E+08	4.90E+10	1.10E+10	2.90E+09	8.00E+07	8.00E+07	8.00E+07	8.00E+07	1.40E+09	1.40E+09	1.90E+09
7	Pasture	7.10E+10	7.30E+10	8.20E+10	8.30E+10	8.30E+10	8.30E+10	8.40E+10	8.50E+10	8.60E+10	7.60E+10	7.60E+10	7.00E+10
7	LDR	2.90E+10	2.90E+10	2.90E+10	2.90E+10	2.90E+10	2.90E+10	2.90E+10	2.90E+10	2.90E+10	2.90E+10	2.90E+10	2.90E+10
7	HDR	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01

Sub	Land Use	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
7	Forest	3.30E+08	3.30E+08	3.30E+08	3.30E+08	3.30E+08	3.30E+08	3.30E+08	3.30E+08	3.30E+08	3.30E+08	3.30E+08	3.30E+08
8	Cropland	1.00E+10	7.60E+08	4.10E+10	1.10E+10	2.90E+09	7.90E+07	7.90E+07	7.90E+07	7.90E+07	1.90E+09	2.00E+09	1.50E+09
8	Pasture	1.40E+10	1.60E+10	2.60E+10	2.70E+10	2.70E+10	2.70E+10	2.80E+10	2.80E+10	3.00E+10	1.90E+10	2.00E+10	1.40E+10
8	LDR	9.00E+09	9.00E+09	9.00E+09	9.00E+09	9.00E+09	9.00E+09	9.00E+09	9.00E+09	9.00E+09	9.00E+09	9.00E+09	9.00E+09
8	HDR	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
8	Forest	2.20E+08	2.20E+08	2.20E+08	2.20E+08	2.20E+08	2.20E+08	2.20E+08	2.20E+08	2.20E+08	2.20E+08	2.20E+08	2.20E+08
9	Cropland	3.30E+10	4.70E+08	1.20E+11	2.70E+10	7.30E+09	7.80E+07	7.80E+07	7.80E+07	7.80E+07	3.40E+09	3.50E+09	4.70E+09
9	Pasture	4.50E+10	4.70E+10	5.70E+10	5.70E+10	5.80E+10	5.80E+10	5.80E+10	5.90E+10	6.00E+10	5.00E+10	5.10E+10	4.40E+10
9	LDR	1.30E+10	1.30E+10	1.30E+10	1.30E+10	1.30E+10	1.30E+10	1.30E+10	1.30E+10	1.30E+10	1.30E+10	1.30E+10	1.30E+10
9	HDR	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
9	Forest	4.10E+08	4.10E+08	4.10E+08	4.10E+08	4.10E+08	4.10E+08	4.10E+08	4.10E+08	4.10E+08	4.10E+08	4.10E+08	4.10E+08
10	Cropland	3.60E+10	4.50E+07	1.30E+11	2.80E+10	7.70E+09	4.50E+07	4.50E+07	4.50E+07	4.50E+07	3.20E+09	3.30E+09	5.10E+09
10	Pasture	1.00E+10	1.10E+10	1.80E+10	1.60E+10	1.60E+10	3.10E+10	1.60E+10	1.80E+10	1.70E+10	1.20E+10	1.30E+10	9.30E+09
10	LDR	1.00E+10	1.00E+10	1.00E+10	1.00E+10	1.00E+10	1.00E+10	1.00E+10	1.00E+10	1.00E+10	1.00E+10	1.00E+10	1.00E+10
10	HDR	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
10	Forest	1.10E+09	1.10E+09	1.10E+09	1.10E+09	1.10E+09	1.10E+09	1.10E+09	1.10E+09	1.10E+09	1.10E+09	1.10E+09	1.10E+09
11	Cropland	1.70E+10	7.10E+08	6.50E+10	1.50E+10	4.20E+09	4.60E+07	4.60E+07	4.60E+07	4.60E+07	2.40E+09	2.50E+09	2.40E+09
11	Pasture	1.30E+10	1.40E+10	1.80E+10	1.80E+10	1.80E+10	1.90E+10	1.90E+10	1.90E+10	1.90E+10	1.50E+10	1.60E+10	1.30E+10
11	LDR	1.30E+10	1.30E+10	1.30E+10	1.30E+10	1.30E+10	1.30E+10	1.30E+10	1.30E+10	1.30E+10	1.30E+10	1.30E+10	1.30E+10
11	HDR	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
11	Forest	2.40E+08	2.40E+08	2.40E+08	2.40E+08	2.40E+08	2.40E+08	2.40E+08	2.40E+08	2.40E+08	2.40E+08	2.40E+08	2.40E+08
12	Cropland	5.90E+09	1.20E+08	2.20E+10	4.80E+09	1.30E+09	4.60E+07	4.60E+07	4.60E+07	4.60E+07	6.50E+08	6.70E+08	8.70E+08
12	Pasture	1.10E+10	1.20E+10	1.50E+10	1.60E+10	1.60E+10	1.60E+10	1.60E+10	1.60E+10	1.70E+10	1.30E+10	1.30E+10	1.10E+10
12	LDR	1.40E+10	1.40E+10	1.40E+10	1.40E+10	1.40E+10	1.40E+10	1.40E+10	1.40E+10	1.40E+10	1.40E+10	1.40E+10	1.40E+10
12	HDR	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
12	Forest	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08
13	Cropland	3.30E+09	7.30E+07	1.20E+10	2.60E+09	7.50E+08	4.60E+07	4.60E+07	4.60E+07	4.60E+07	3.60E+08	3.70E+08	5.00E+08
13	Pasture	1.10E+10	1.20E+10	1.60E+10	1.60E+10	1.60E+10	1.60E+10	1.60E+10	1.70E+10	1.70E+10	1.30E+10	1.40E+10	1.10E+10
13	LDR	7.40E+09	7.40E+09	7.40E+09	7.40E+09	7.40E+09	7.40E+09	7.40E+09	7.40E+09	7.40E+09	7.40E+09	7.40E+09	7.40E+09
13	HDR	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
13	Forest	6.30E+07	6.30E+07	6.30E+07	6.30E+07	6.30E+07	6.30E+07	6.30E+07	6.30E+07	6.30E+07	6.30E+07	6.30E+07	6.30E+07
14	Cropland	3.60E+10	8.20E+07	1.30E+11	2.80E+10	7.70E+09	8.20E+07	8.20E+07	8.20E+07	8.20E+07	3.20E+09	3.30E+09	5.20E+09
14	Forest	8.70E+07	8.70E+07	8.70E+07	8.70E+07	8.70E+07	8.70E+07	8.70E+07	8.70E+07	8.70E+07	8.70E+07	8.70E+07	8.70E+07
15	Cropland	2.50E+10	4.30E+08	9.40E+10	2.10E+10	5.70E+09	4.70E+07	4.70E+07	4.70E+07	4.70E+07	2.70E+09	2.80E+09	3.60E+09
15	Pasture	9.10E+09	1.00E+10	1.50E+10	1.50E+10	1.60E+10	1.60E+10	1.60E+10	1.60E+10	1.70E+10	1.20E+10	1.20E+10	8.80E+09
15	LDR	2.10E+10	2.10E+10	2.10E+10	2.10E+10	2.10E+10	2.10E+10	2.10E+10	2.10E+10	2.10E+10	2.10E+10	2.10E+10	2.10E+10

Sub	Land Use	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
15	HDR	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
15	Forest	3.80E+08	3.80E+08	3.80E+08	3.80E+08	3.80E+08	3.80E+08	3.80E+08	3.80E+08	3.80E+08	3.80E+08	3.80E+08	3.80E+08
16	Cropland	3.60E+10	6.20E+07	1.30E+11	2.80E+10	7.70E+09	6.20E+07	6.20E+07	6.20E+07	6.20E+07	3.20E+09	3.30E+09	5.10E+09
16	Pasture	1.30E+10	6.10E+09	4.80E+10	1.80E+10	1.30E+10	2.10E+11	1.10E+10	2.60E+10	1.20E+10	8.60E+09	9.00E+09	6.10E+09
16	LDR	2.10E+09	2.10E+09	2.10E+09	2.10E+09	2.10E+09	2.10E+09	2.10E+09	2.10E+09	2.10E+09	2.10E+09	2.10E+09	2.10E+09
16	HDR	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
16	Forest	7.40E+08	7.40E+08	7.40E+08	7.40E+08	7.40E+08	7.40E+08	7.40E+08	7.40E+08	7.40E+08	7.40E+08	7.40E+08	7.40E+08
17	Cropland	4.00E+09	1.90E+08	1.50E+10	3.60E+09	1.00E+09	4.50E+07	4.50E+07	4.50E+07	4.50E+07	5.80E+08	6.00E+08	6.00E+08
17	Pasture	1.00E+10	1.10E+10	1.50E+10	1.50E+10	1.60E+10	1.60E+10	1.60E+10	1.60E+10	1.70E+10	1.20E+10	1.30E+10	9.90E+09
17	LDR	1.60E+10	1.60E+10	1.60E+10	1.60E+10	1.60E+10	1.60E+10	1.60E+10	1.60E+10	1.60E+10	1.60E+10	1.60E+10	1.60E+10
17	HDR	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
17	Forest	2.50E+08	2.50E+08	2.50E+08	2.50E+08	2.50E+08	2.50E+08	2.50E+08	2.50E+08	2.50E+08	2.50E+08	2.50E+08	2.50E+08
18	Cropland	8.70E+09	2.40E+08	3.30E+10	7.40E+09	2.00E+09	4.50E+07	4.50E+07	4.50E+07	4.50E+07	1.10E+09	1.10E+09	1.30E+09
18	Pasture	1.10E+10	1.20E+10	1.60E+10	1.60E+10	1.60E+10	1.60E+10	1.60E+10	1.70E+10	1.70E+10	1.30E+10	1.30E+10	1.10E+10
18	LDR	1.90E+10	1.90E+10	1.90E+10	1.90E+10	1.90E+10	1.90E+10	1.90E+10	1.90E+10	1.90E+10	1.90E+10	1.90E+10	1.90E+10
18	HDR	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
18	Forest	3.30E+08	3.30E+08	3.30E+08	3.30E+08	3.30E+08	3.30E+08	3.30E+08	3.30E+08	3.30E+08	3.30E+08	3.30E+08	3.30E+08
19	Cropland	6.40E+09	5.90E+08	2.60E+10	6.90E+09	1.90E+09	8.00E+07	8.00E+07	8.00E+07	8.00E+07	1.30E+09	1.40E+09	9.70E+08
19	Pasture	1.40E+10	1.60E+10	2.60E+10	2.70E+10	2.70E+10	2.70E+10	2.80E+10	2.80E+10	3.00E+10	1.90E+10	2.00E+10	1.40E+10
19	LDR	1.00E+10	1.00E+10	1.00E+10	1.00E+10	1.00E+10	1.00E+10	1.00E+10	1.00E+10	1.00E+10	1.00E+10	1.00E+10	1.00E+10
19	HDR	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
19	Forest	5.30E+08	5.30E+08	5.30E+08	5.30E+08	5.30E+08	5.30E+08	5.30E+08	5.30E+08	5.30E+08	5.30E+08	5.30E+08	5.30E+08
20	Cropland	4.00E+09	3.00E+08	1.50E+10	3.90E+09	1.10E+09	8.10E+07	8.10E+07	8.10E+07	8.10E+07	7.20E+08	7.40E+08	6.30E+08
20	Pasture	1.50E+10	1.70E+10	2.50E+10	2.50E+10	2.50E+10	2.50E+10	2.60E+10	2.60E+10	2.70E+10	1.90E+10	2.00E+10	1.50E+10
20	LDR	1.80E+10	1.80E+10	1.80E+10	1.80E+10	1.80E+10	1.80E+10	1.80E+10	1.80E+10	1.80E+10	1.80E+10	1.80E+10	1.80E+10
20	HDR	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
20	Forest	2.80E+08	2.80E+08	2.80E+08	2.80E+08	2.80E+08	2.80E+08	2.80E+08	2.80E+08	2.80E+08	2.80E+08	2.80E+08	2.80E+08
21	Cropland	4.90E+09	3.30E+08	1.90E+10	4.70E+09	1.30E+09	8.10E+07	8.10E+07	8.10E+07	8.10E+07	8.40E+08	8.70E+08	7.60E+08
21	Pasture	1.60E+10	1.70E+10	2.40E+10	2.50E+10	2.50E+10	2.50E+10	2.60E+10	2.60E+10	2.70E+10	1.90E+10	2.00E+10	1.50E+10
21	LDR	4.80E+09	4.80E+09	4.80E+09	4.80E+09	4.80E+09	4.80E+09	4.80E+09	4.80E+09	4.80E+09	4.80E+09	4.80E+09	4.80E+09
21	HDR	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
21	Forest	2.40E+08	2.40E+08	2.40E+08	2.40E+08	2.40E+08	2.40E+08	2.40E+08	2.40E+08	2.40E+08	2.40E+08	2.40E+08	2.40E+08
22	Cropland	1.20E+10	1.60E+09	5.20E+10	1.50E+10	4.00E+09	8.20E+07	8.20E+07	8.20E+07	8.20E+07	2.60E+09	3.30E+09	1.80E+09
22	Pasture	2.80E+10	2.90E+10	4.50E+10	4.70E+10	4.70E+10	4.60E+10	4.70E+10	4.70E+10	4.90E+10	4.10E+10	4.00E+10	2.70E+10
22	LDR	6.70E+09	6.70E+09	6.70E+09	6.70E+09	6.70E+09	6.70E+09	6.70E+09	6.70E+09	6.70E+09	6.70E+09	6.70E+09	6.70E+09
22	HDR	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01

Sub	Land Use	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
22	Forest	1.30E+08	1.30E+08	1.30E+08	1.30E+08	1.30E+08	1.30E+08	1.30E+08	1.30E+08	1.30E+08	1.30E+08	1.30E+08	1.30E+08
23	Cropland	2.10E+10	1.70E+08	7.70E+10	1.60E+10	4.50E+09	4.50E+07	4.50E+07	4.50E+07	4.50E+07	2.00E+09	2.10E+09	2.90E+09
23	Pasture	9.60E+09	1.10E+10	1.60E+10	1.70E+10	1.70E+10	1.70E+10	1.70E+10	1.80E+10	1.80E+10	1.30E+10	1.30E+10	9.40E+09
23	LDR	1.00E+10	1.00E+10	1.00E+10	1.00E+10	1.00E+10	1.00E+10	1.00E+10	1.00E+10	1.00E+10	1.00E+10	1.00E+10	1.00E+10
23	HDR	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
23	Forest	7.00E+07	7.00E+07	7.00E+07	7.00E+07	7.00E+07	7.00E+07	7.00E+07	7.00E+07	7.00E+07	7.00E+07	7.00E+07	7.00E+07
24	Cropland	1.40E+10	5.80E+08	5.30E+10	1.30E+10	3.40E+09	4.60E+07	4.60E+07	4.60E+07	4.60E+07	2.00E+09	2.00E+09	2.00E+09
24	Pasture	9.40E+09	1.10E+10	1.60E+10	1.60E+10	1.70E+10	1.70E+10	1.70E+10	1.80E+10	1.80E+10	1.20E+10	1.30E+10	9.20E+09
24	LDR	1.10E+10	1.10E+10	1.10E+10	1.10E+10	1.10E+10	1.10E+10	1.10E+10	1.10E+10	1.10E+10	1.10E+10	1.10E+10	1.10E+10
24	HDR	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
24	Forest	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08
25	Cropland	9.10E+09	1.80E+08	3.40E+10	7.50E+09	2.10E+09	4.70E+07	4.70E+07	4.70E+07	4.70E+07	1.00E+09	1.00E+09	1.30E+09
25	Pasture	9.40E+09	1.10E+10	1.60E+10	1.60E+10	1.70E+10	1.70E+10	1.70E+10	1.80E+10	1.80E+10	1.20E+10	1.30E+10	9.10E+09
25	LDR	4.80E+09	4.80E+09	4.80E+09	4.80E+09	4.80E+09	4.80E+09	4.80E+09	4.80E+09	4.80E+09	4.80E+09	4.80E+09	4.80E+09
25	HDR	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
25	Forest	1.20E+08	1.20E+08	1.20E+08	1.20E+08	1.20E+08	1.20E+08	1.20E+08	1.20E+08	1.20E+08	1.20E+08	1.20E+08	1.20E+08
26	Cropland	3.60E+10	4.90E+07	1.30E+11	2.80E+10	7.70E+09	4.90E+07	4.90E+07	4.90E+07	4.90E+07	3.20E+09	3.30E+09	5.10E+09
26	Pasture	1.20E+10	9.90E+09	3.00E+10	1.90E+10	1.70E+10	9.20E+10	1.70E+10	2.20E+10	1.80E+10	1.20E+10	1.30E+10	8.90E+09
26	LDR	4.90E+09	4.90E+09	4.90E+09	4.90E+09	4.90E+09	4.90E+09	4.90E+09	4.90E+09	4.90E+09	4.90E+09	4.90E+09	4.90E+09
26	HDR	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
26	Forest	8.40E+07	8.40E+07	8.40E+07	8.40E+07	8.40E+07	8.40E+07	8.40E+07	8.40E+07	8.40E+07	8.40E+07	8.40E+07	8.40E+07
27	Cropland	3.60E+10	4.80E+07	1.30E+11	2.80E+10	7.70E+09	4.80E+07	4.80E+07	4.80E+07	4.80E+07	3.20E+09	3.30E+09	5.10E+09
27	Pasture	1.10E+10	1.10E+10	2.00E+10	1.80E+10	1.70E+10	3.70E+10	1.80E+10	1.90E+10	1.90E+10	1.30E+10	1.30E+10	9.50E+09
27	LDR	6.50E+09	6.50E+09	6.50E+09	6.50E+09	6.50E+09	6.50E+09	6.50E+09	6.50E+09	6.50E+09	6.50E+09	6.50E+09	6.50E+09
27	HDR	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
27	Forest	9.60E+07	9.60E+07	9.60E+07	9.60E+07	9.60E+07	9.60E+07	9.60E+07	9.60E+07	9.60E+07	9.60E+07	9.60E+07	9.60E+07
28	Cropland	3.60E+10	4.80E+07	1.30E+11	2.80E+10	7.70E+09	4.80E+07	4.80E+07	4.80E+07	4.80E+07	3.20E+09	3.30E+09	5.10E+09
28	Pasture	9.70E+09	1.10E+10	1.80E+10	1.70E+10	1.70E+10	2.50E+10	1.70E+10	1.80E+10	1.80E+10	1.20E+10	1.30E+10	9.10E+09
28	LDR	6.40E+09	6.40E+09	6.40E+09	6.40E+09	6.40E+09	6.40E+09	6.40E+09	6.40E+09	6.40E+09	6.40E+09	6.40E+09	6.40E+09
28	HDR	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
28	Forest	7.60E+07	7.60E+07	7.60E+07	7.60E+07	7.60E+07	7.60E+07	7.60E+07	7.60E+07	7.60E+07	7.60E+07	7.60E+07	7.60E+07
29	Cropland	1.60E+10	3.70E+08	5.90E+10	1.30E+10	3.60E+09	4.40E+07	4.40E+07	4.40E+07	4.40E+07	1.80E+09	1.90E+09	2.20E+09
29	Pasture	9.70E+09	1.10E+10	1.60E+10	1.60E+10	1.70E+10	1.70E+10	1.70E+10	1.80E+10	1.80E+10	1.30E+10	1.30E+10	9.50E+09
29	LDR	2.50E+09	2.50E+09	2.50E+09	2.50E+09	2.50E+09	2.50E+09	2.50E+09	2.50E+09	2.50E+09	2.50E+09	2.50E+09	2.50E+09
29	HDR	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
29	Forest	7.40E+07	7.40E+07	7.40E+07	7.40E+07	7.40E+07	7.40E+07	7.40E+07	7.40E+07	7.40E+07	7.40E+07	7.40E+07	7.40E+07

Sub	Land Use	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
30	Cropland	3.60E+10	4.50E+07	1.30E+11	2.80E+10	7.70E+09	4.50E+07	4.50E+07	4.50E+07	4.50E+07	3.20E+09	3.30E+09	5.10E+09
30	Pasture	1.20E+10	1.30E+10	1.70E+10	1.70E+10	1.70E+10	1.90E+10	1.80E+10	1.80E+10	1.80E+10	1.40E+10	1.40E+10	1.10E+10
30	LDR	6.10E+09	6.10E+09	6.10E+09	6.10E+09	6.10E+09	6.10E+09	6.10E+09	6.10E+09	6.10E+09	6.10E+09	6.10E+09	6.10E+09
30	HDR	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
30	Forest	5.00E+07	5.00E+07	5.00E+07	5.00E+07	5.00E+07	5.00E+07	5.00E+07	5.00E+07	5.00E+07	5.00E+07	5.00E+07	5.00E+07
31	Cropland	3.30E+10	4.40E+08	1.20E+11	2.70E+10	7.30E+09	4.80E+07	4.80E+07	4.80E+07	4.80E+07	3.40E+09	3.50E+09	4.60E+09
31	Pasture	1.10E+10	1.20E+10	1.70E+10	1.70E+10	1.70E+10	1.70E+10	1.70E+10	1.80E+10	1.80E+10	1.40E+10	1.40E+10	1.10E+10
31	LDR	1.40E+10	1.40E+10	1.40E+10	1.40E+10	1.40E+10	1.40E+10	1.40E+10	1.40E+10	1.40E+10	1.40E+10	1.40E+10	1.40E+10
31	HDR	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
31	Forest	1.10E+08	1.10E+08	1.10E+08	1.10E+08	1.10E+08	1.10E+08	1.10E+08	1.10E+08	1.10E+08	1.10E+08	1.10E+08	1.10E+08
32	Cropland	1.60E+10	4.20E+08	6.20E+10	1.40E+10	3.80E+09	4.60E+07	4.60E+07	4.60E+07	4.60E+07	2.00E+09	2.00E+09	2.30E+09
32	Pasture	1.20E+10	1.30E+10	1.70E+10	1.70E+10	1.70E+10	1.70E+10	1.80E+10	1.80E+10	1.80E+10	1.40E+10	1.40E+10	1.20E+10
32	LDR	6.40E+09	6.40E+09	6.40E+09	6.40E+09	6.40E+09	6.40E+09	6.40E+09	6.40E+09	6.40E+09	6.40E+09	6.40E+09	6.40E+09
32	HDR	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
32	Forest	5.90E+07	5.90E+07	5.90E+07	5.90E+07	5.90E+07	5.90E+07	5.90E+07	5.90E+07	5.90E+07	5.90E+07	5.90E+07	5.90E+07

Appendix G: Simulated Stream Flow Chart for TMDL Allocation Period

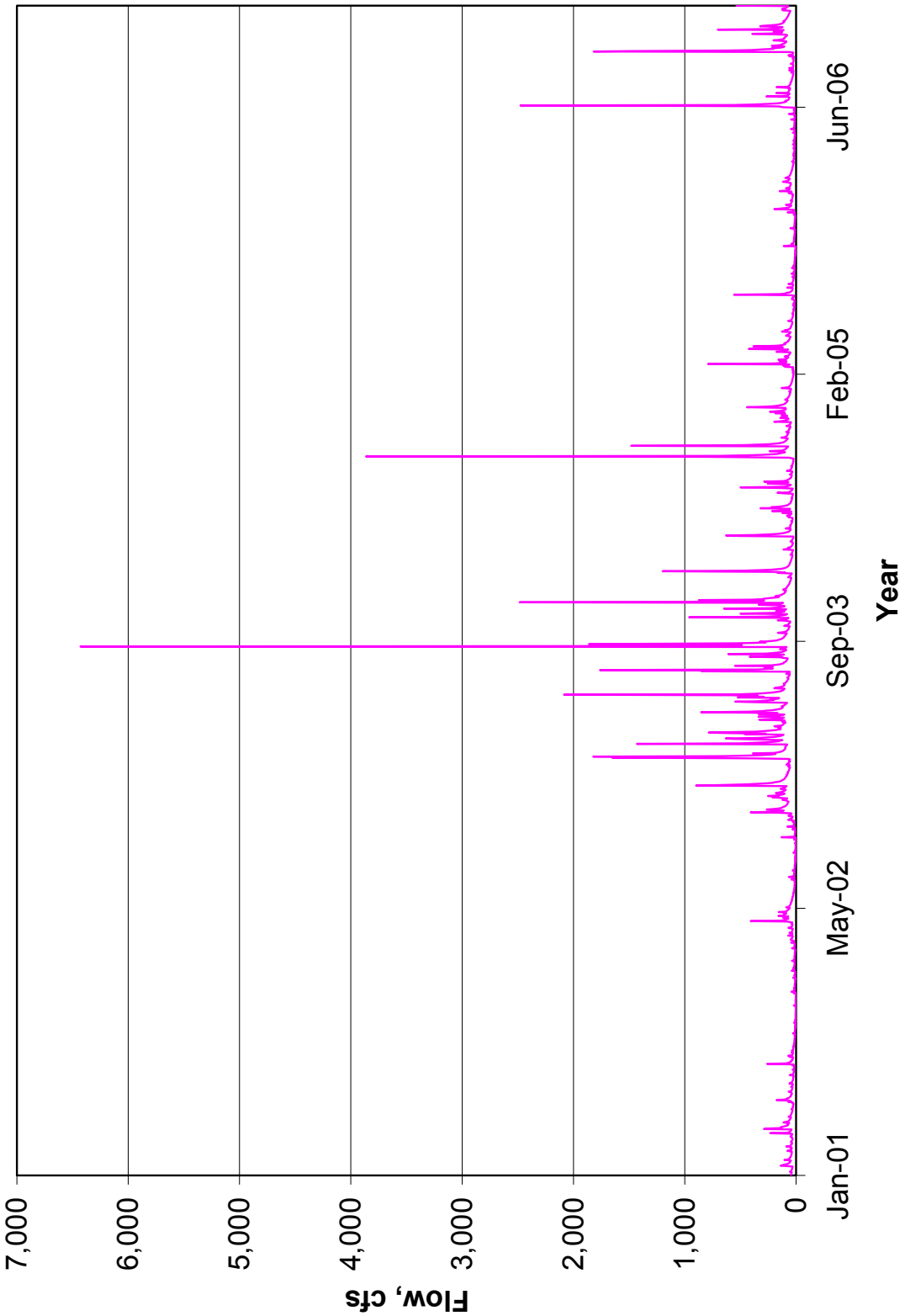

Figure G.1. Simulated stream flow at the outlet of Hays Creek for the allocation period.

Appendix H: Required Reductions in Fecal Coliform Loads by Sub-watershed – Allocation Scenario

Table H-1a. Required annual reductions in nonpoint sources in sub-watershed HYS-1.

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	346,528	19%	17,326	95%
Pasture	1,378,936	76%	68,947	95%
Forest	48,637	3%	48,637	0%
Residential	32,982	2%	32,982	0%
Total	1,807,083	100%	167,892	91%

Table H-1b. Required annual reductions in direct nonpoint sources in sub-watershed HYS-1.

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	26,285	70%	2,628	90%
Wildlife in Streams	11,163	30%	1,116	90%
Total	37,447	100%	3,745	90%

Table H-2a. Required annual reductions in nonpoint sources in sub-watershed HYS-2.

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	110,547	3%	5,527	95%
Pasture	4,038,390	95%	201,920	95%
Forest	104,286	2%	104,286	0%
Residential	12,842	0.3%	12,842	0%
Total	4,266,065	100%	324,575	92%

Table H-2b. Required annual reductions in direct nonpoint sources in sub-watershed HYS-2.

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	63,908	75%	6,391	90%
Wildlife in Streams	21,111	25%	2,111	90%
Total	85,019	100%	8,502	90%

Table H-3a. Required annual reductions in nonpoint sources in sub-watershed HYS-3.

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	596,344	5%	29,817	95%
Pasture	11,765,680	94%	588,284	95%
Forest	133,786	1%	133,786	0%
Residential	33,903	0.3%	33,903	0%
Total	12,529,713	100%	785,790	94%

Table H-3b. Required annual reductions in direct nonpoint sources in sub-watershed HYS-3.

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	210,277	87%	21,028	90%
Wildlife in Streams	32,648	13%	3,265	90%
Total	242,925	100%	24,292	90%

Table H-4a. Required annual reductions in nonpoint sources in sub-watershed HYS-4.

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	431,528	2%	21,576	95%
Pasture	17,190,666	97%	859,534	95%
Forest	100,224	0.6%	100,224	0%
Residential	53,736	0.3%	53,736	0%
Total	17,776,154	100%	1,035,069	94%

Table H-4b. Required annual reductions in direct nonpoint sources in sub-watershed HYS-4.

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	310,003	91%	31,000	90%
Wildlife in Streams	29,617	9%	2,962	90%
Total	339,620	100%	33,962	90%

Table H-5a. Required annual reductions in nonpoint sources in sub-watershed HYS-5.

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	370,301	4%	18,515	95%
Pasture	7,922,164	94%	396,108	95%
Forest	62,968	0.7%	62,968	0%
Residential	74,182	0.9%	74,182	0%
Total	8,429,615	100%	551,773	93%

Table H-5b. Required annual reductions in direct nonpoint sources in sub-watershed HYS-5.

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	142,246	89%	14,225	90%
Wildlife in Streams	17,101	11%	1,710	90%
Straight Pipes	1,337	0.8%	0	100%
Total	160,684	100%	15,935	90%

Table H-6a. Required annual reductions in nonpoint sources in sub-watershed HYS-6.

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	644,358	3%	32,218	95%
Pasture	21,462,215	96%	1,073,111	95%
Forest	51,495	0.2%	51,495	0%
Residential	113,427	0.5%	113,427	0%
Total	22,271,495	100%	1,270,251	94%

Table H-6b. Required annual reductions in direct nonpoint sources in sub-watershed HYS-6.

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	413,658	97%	41,366	90%
Wildlife in Streams	11,966	3%	1,197	90%
Total	425,624	100%	42,562	90%

Table H-7a. Required annual reductions in nonpoint sources in sub-watershed HYS-7.

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	336,509	5%	16,825	95%
Pasture	6,197,275	94%	309,864	95%
Forest	22,334	0.3%	22,334	0%
Residential	7,911	0.1%	7,911	0%
Total	6,564,029	100%	356,934	95%

Table H-7b. Required annual reductions in direct nonpoint sources in sub-watershed HYS-7.

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	32,469	85%	3,247	90%
Wildlife in Streams	5,719	15%	572	90%
Total	38,188	100%	3,819	90%

Table H-8a. Required annual reductions in nonpoint sources in sub-watershed HYS-8.

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	377,370	3%	18,869	95%
Pasture	10,421,105	96%	521,055	95%
Forest	48,266	0.4%	48,266	0%
Residential	53,062	0.5%	53,062	0%
Total	10,899,803	100%	641,252	94%

Table H-8b. Required annual reductions in direct nonpoint sources in sub-watershed HYS-8.

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	189,404	95%	18,940	90%
Wildlife in Streams	10,471	5%	1,047	90%
Total	199,874	100%	19,987	90%

Table H-9a. Required annual reductions in nonpoint sources in sub-watershed HYS-9.

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	324,109	4%	16,205	95%
Pasture	7,574,967	95%	378,748	95%
Forest	20,756	0.3%	20,756	0%
Residential	14,179	0.2%	14,179	0%
Total	7,934,011	100%	429,889	95%

Table H-9b. Required annual reductions in direct nonpoint sources in sub-watershed HYS-9.

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	58,754	91%	5,875	90%
Wildlife in Streams	5,679	9%	568	90%
Total	64,433	100%	6,443	90%

Table H-10a. Required annual reductions in nonpoint sources in sub-watershed HYS-10.

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	282,903	47%	14,145	95%
Pasture	316,388	52%	15,819	95%
Forest	6,048	1.0%	6,048	0%
Residential	1,644	0.3%	1,644	0%
Total	606,983	100%	37,656	94%

Table H-10b. Required annual reductions in direct nonpoint sources in sub-watershed HYS-10.

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	3,479	80%	1,218	65%
Wildlife in Streams	866	20%	390	55%
Total	4,345	100%	1,607	63%

Table H-11a. Required annual reductions in nonpoint sources in sub-watershed HYS-11.

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	348,258	3%	17,413	95%
Pasture	11,266,797	96%	563,340	95%
Forest	78,915	0.7%	78,915	0%
Residential	52,822	0.4%	52,822	0%
Total	11,746,792	100%	712,490	94%

Table H-11b. Required annual reductions in direct nonpoint sources in sub-watershed HYS-11.

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	46,385	81%	16,235	65%
Wildlife in Streams	9,814	17%	4,416	55%
Straight Pipes	1,407	2%	0	100%
Total	57,606	100%	20,651	64%

Table H-12a. Required annual reductions in nonpoint sources in sub-watershed HYS-12.

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	361,898	9%	18,095	95%
Pasture	3,432,832	89%	171,642	95%
Forest	26,150	0.7%	26,150	0%
Residential	53,611	1%	53,611	0%
Total	3,874,491	100%	269,498	93%

Table H-12b. Required annual reductions in direct nonpoint sources in sub-watershed HYS-12.

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	28,411	92%	9,944	65%
Wildlife in Streams	2,389	8%	1,075	55%
Total	30,800	100%	11,019	64%

Table H-13a. Required annual reductions in nonpoint sources in sub-watershed HYS-13.

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	404,890	13%	20,245	95%
Pasture	2,602,035	85%	130,102	95%
Forest	14,483	0.5%	14,483	0%
Residential	36,735	1%	36,735	0%
Total	3,058,144	100%	201,564	93%

Table H-13b. Required annual reductions in direct nonpoint sources in sub-watershed HYS-13.

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	21,163	96%	7,407	65%
Wildlife in Streams	825	4%	371	55%
Total	21,988	100%	7,778	65%

Table H-14a. Required annual reductions in nonpoint sources in sub-watershed HYS-14.

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	2,984	90%	149	95%
Forest	321	10%	321	0%
Total	3,305	100%	470	86%

Table H-14b. Required annual reductions in direct nonpoint sources in sub-watershed HYS-14.

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
Wildlife in Streams	5	100%	2	55%
Total	5	100%	2	55%

Table H-15a. Required annual reductions in nonpoint sources in sub-watershed HYS-15.

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	327,636	11%	16,382	95%
Pasture	2,709,849	88%	135,492	95%
Forest	28,966	0.9%	28,966	0%
Residential	25,394	0.8%	25,394	0%
Total	3,091,845	100%	206,234	93%

Table H-15b. Required annual reductions in direct nonpoint sources in sub-watershed HYS-15.

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	31,310	89%	10,958	65%
Wildlife in Streams	3,823	11%	1,720	55%
Total	35,132	100%	12,679	64%

Table H-16a. Required annual reductions in nonpoint sources in sub-watershed HYS-16.

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	1,490	2%	75	95%
Pasture	57,313	90%	2,866	95%
Forest	3,504	5%	3,504	0%
Residential	1,644	3%	1,644	0%
Total	63,951	100%	8,088	87%

Table H-16b. Required annual reductions in direct nonpoint sources in sub-watershed HYS-16.

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	870	65%	304	65%
Wildlife in Streams	477	35%	215	55%
Total	1,347	100%	519	61%

Table H-17a. Required annual reductions in nonpoint sources in sub-watershed HYS-17.

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	404,750	4%	20,238	95%
Pasture	9,064,277	94%	453,214	95%
Forest	54,609	0.6%	54,609	0%
Residential	99,652	1%	99,652	0%
Total	9,623,287	100%	627,712	93%

Table H-17b. Required annual reductions in direct nonpoint sources in sub-watershed HYS-17.

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	71,993	88%	25,197	65%
Wildlife in Streams	6,988	9%	3,145	55%
Straight Pipes	2,837	3%	0	100%
Total	81,818	100%	28,342	65%

Table H-18a. Required annual reductions in nonpoint sources in sub-watershed HYS-18.

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	352,162	6%	17,608	95%
Pasture	5,539,613	92%	276,981	95%
Forest	35,342	0.6%	35,342	0%
Residential	71,215	1%	71,215	0%
Total	5,998,333	100%	401,147	93%

Table H-18b. Required annual reductions in direct nonpoint sources in sub-watershed HYS-18.

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	51,410	89%	17,993	65%
Wildlife in Streams	4,691	8%	2,111	55%
Straight Pipes	1,423	2%	0	100%
Total	57,524	100%	20,104	65%

Table H-19a. Required annual reductions in nonpoint sources in sub-watershed HYS-19.

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	407,541	3%	20,377	95%
Pasture	13,580,930	96%	679,047	95%
Forest	99,344	0.7%	99,344	0%
Residential	44,487	0.3%	44,487	0%
Total	14,132,303	100%	843,255	94%

Table H-19b. Required annual reductions in direct nonpoint sources in sub-watershed HYS-19.

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	241,973	89%	24,197	90%
Wildlife in Streams	28,698	11%	2,870	90%
Total	270,670	100%	27,067	90%

Table H-20a. Required annual reductions in nonpoint sources in sub-watershed HYS-20.

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	427,557	3%	21,378	95%
Pasture	12,392,060	95%	619,603	95%
Forest	108,912	0.8%	108,912	0%
Residential	106,918	0.8%	106,918	0%
Total	13,035,446	100%	856,811	93%

Table H-20b. Required annual reductions in direct nonpoint sources in sub-watershed HYS-20.

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	201,859	87%	20,186	90%
Wildlife in Streams	26,145	11%	2,615	90%
Straight Pipes	2,860	1%	0	100%
Total	230,864	100%	22,800	90%

Table H-21a. Required annual reductions in nonpoint sources in sub-watershed HYS-21.

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	405,096	3%	20,255	95%
Pasture	11,160,893	96%	558,045	95%
Forest	46,812	0.4%	46,812	0%
Residential	28,731	0.2%	28,731	0%
Total	11,641,532	100%	653,842	94%

Table H-21b. Required annual reductions in direct nonpoint sources in sub-watershed HYS-21.

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	176,948	94%	17,695	90%
Wildlife in Streams	10,720	6%	1,072	90%
Total	187,669	100%	18,767	90%

Table H-22a. Required annual reductions in nonpoint sources in sub-watershed HYS-22.

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	407,628	3%	20,381	95%
Pasture	12,168,214	96%	608,411	95%
Forest	24,807	0.2%	24,807	0%
Residential	65,893	0.5%	65,893	0%
Total	12,666,542	100%	719,492	94%

Table H-22b. Required annual reductions in direct nonpoint sources in sub-watershed HYS-22.

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	179,244	98%	17,924	90%
Wildlife in Streams	3,256	2%	326	90%
Total	182,500	100%	18,250	90%

Table H-23a. Required annual reductions in nonpoint sources in sub-watershed HYS-23.

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	324,055	23%	16,203	95%
Pasture	1,056,438	75%	10,564	99%
Forest	15,986	1%	15,986	0%
Residential	9,555	0.7%	9,555	0%
Total	1,406,033	100%	52,308	96%

Table H-23b. Required annual reductions in direct nonpoint sources in sub-watershed HYS-23.

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	12,720	93%	0	100%
Wildlife in Streams	976	7%	683	30%
Total	13,695	100%	683	95%

Table H-24a. Required annual reductions in nonpoint sources in sub-watershed HYS-24.

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	351,796	5%	17,590	95%
Pasture	6,868,611	94%	68,686	99%
Forest	49,365	0.7%	49,365	0%
Residential	51,062	0.7%	51,062	0%
Total	7,320,834	100%	186,703	97%

Table H-24b. Required annual reductions in direct nonpoint sources in sub-watershed HYS-24.

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	83,818	94%	0	100%
Wildlife in Streams	5,305	6%	3,714	30%
Total	89,124	100%	3,714	96%

Table H-25a. Required annual reductions in nonpoint sources in sub-watershed HYS-25.

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	345,805	12%	17,290	95%
Pasture	2,583,285	86%	25,833	99%
Forest	46,198	2%	46,198	0%
Residential	28,051	0.9%	28,051	0%
Total	3,003,340	100%	117,373	96%

Table H-25b. Required annual reductions in direct nonpoint sources in sub-watershed HYS-25.

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	31,636	88%	0	100%
Wildlife in Streams	4,350	12%	3,045	30%
Total	35,986	100%	3,045	92%

Table H-26a. Required annual reductions in nonpoint sources in sub-watershed HYS-26.

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	14,893	2%	745	95%
Pasture	582,247	84%	5,822	99%
Forest	70,462	10%	70,462	0%
Residential	22,090	3%	22,090	0%
Total	689,692	100%	99,120	86%

Table H-26b. Required annual reductions in direct nonpoint sources in sub-watershed HYS-26.

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	7,501	61%	0	100%
Wildlife in Streams	4,848	39%	3,394	30%
Total	12,350	100%	3,394	73%

Table H-27a. Required annual reductions in nonpoint sources in sub-watershed HYS-27.

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	5,212	0.2%	261	95%
Pasture	2,389,093	96%	23,891	99%
Forest	56,933	2%	56,933	0%
Residential	33,596	1%	33,596	0%
Total	2,484,834	100%	114,681	95%

Table H-27b. Required annual reductions in direct nonpoint sources in sub-watershed HYS-27.

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	28,700	86%	0	100%
Wildlife in Streams	4,515	14%	3,161	30%
Total	33,216	100%	3,161	90%

Table H-28a. Required annual reductions in nonpoint sources in sub-watershed HYS-28.

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	157,111	5%	7,856	95%
Pasture	2,798,855	91%	27,989	99%
Forest	70,949	2%	70,949	0%
Residential	44,231	1%	44,231	0%
Total	3,071,147	100%	151,025	95%

Table H-28b. Required annual reductions in direct nonpoint sources in sub-watershed HYS-28.

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	34,245	89%	0	100%
Wildlife in Streams	4,365	11%	3,056	30%
Total	38,610	100%	3,056	92%

Table H-29a. Required annual reductions in nonpoint sources in sub-watershed HYS-29.

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	337,842	8%	16,892	95%
Pasture	3,859,505	92%	38,595	99%
Forest	2,262	0.1%	2,262	0%
Residential	10,892	0.3%	10,892	0%
Total	4,210,501	100%	68,641	98%

Table H-29b. Required annual reductions in direct nonpoint sources in sub-watershed HYS-29.

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	45,007	99%	0	100%
Wildlife in Streams	277	0.6%	194	30%
Total	45,284	100%	194	100%

Table H-30a. Required annual reductions in nonpoint sources in sub-watershed HYS-30.

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	268,012	5%	13,401	95%
Pasture	5,001,468	94%	50,015	99%
Forest	5,277	0.1%	5,277	0%
Residential	24,434	0.5%	24,434	0%
Total	5,299,191	100%	93,126	98%

Table H-30b. Required annual reductions in direct nonpoint sources in sub-watershed HYS-30.

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	48,196	97%	0	100%
Wildlife in Streams	272	0.5%	190	30%
Straight Pipes	1,423	3%	0	100%
Total	49,892	100%	190	100%

Table H-31a. Required annual reductions in nonpoint sources in sub-watershed HYS-31.

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	323,532	10%	16,177	95%
Pasture	2,879,826	87%	28,798	99%
Forest	69,470	2%	69,470	0%
Residential	36,949	1%	36,949	0%
Total	3,309,777	100%	151,394	95%

Table H-31b. Required annual reductions in direct nonpoint sources in sub-watershed HYS-31.

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	28,266	76%	0	100%
Wildlife in Streams	6,227	17%	4,359	30%
Straight Pipes	2,860	8%	0	100%
Total	37,352	100%	4,359	88%

Table H-32a. Required annual reductions in nonpoint sources in sub-watershed HYS-32.

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	338,092	6%	16,905	95%
Pasture	5,653,192	93%	56,532	99%
Forest	25,403	0.4%	25,403	0%
Residential	56,459	0.9%	56,459	0%
Total	6,073,146	100%	155,298	97%

Table H-32b. Required annual reductions in direct nonpoint sources in sub-watershed HYS-32.

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	53,995	98%	0	100%
Wildlife in Streams	1,083	2%	758	30%
Total	55,078	100%	758	99%