Bacteria Total Maximum Daily Load Development for Mill Creek, Cove Creek, Miller Creek, Stony Fork, Tate Run, South Fork Reed Creek and Reed Creek in Wythe County, Virginia

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Executive Summary

Background

The Reed Creek (N10R, N11R, N12R) watershed is located in Wythe County. The watershed is approximately 173,828 acres and is part of the New River Basin. Reed Creek flows into the New River (USGS Hydrologic Unit Code 05050002) which flows north into the Kanawha River. The Kanawha is a tributary of the Ohio River, which flows into the Mississippi River, with the Mississippi discharging into the Gulf of Mexico.

A segment of Reed Creek (VAS-N10R_RDC01A00) was first listed as impaired on Virginia's 2002 Section 303(d) Report on Impaired Waters due to water quality violations of the fecal coliform standard. Another segment of Reed Creek (VAS-N11R_RDC03B04) was listed as impaired on Virginia's 2004 Section 303(d) Total Maximum Daily Load Priority List and Report due to water quality violations of the E. coli standard. Additional segments of Reed Creek (VAS-11NR_RDC01B00, VAS-N11R_RDC02B02, VAS-N10R_RDC01A02, and VAS-N10R_RDC01B00) were listed on Virginia's 2006 305(b)/303(d) Water Quality Assessment Integrated Report due to water quality violations of the bacteria standard. South Fork Reed Creek (VAS-N10R_RSF01A00), Mill Creek (VAS-10R_MCE01A02), Stony Fork (VAS-N10R_SFK01A02), Tate Run (VAS-N10R_TAT01A06), Cove Creek (VAS-N12R_CVR01A00), and Miller Creek (VAS-N11R_MER01A06) all tributaries in the Reed Creek watershed were also listed on Virginia's 2006 305(b)/303(d) Water Quality Assessment Integrated Report due to water quality violations of the E. coli standard.

This document describes the Total Maximum Daily Loads (TMDL) for bacteria that were developed for the South Fork Reed Creek, Mill Creek, Stony Fork, Tate Run, Cove Creek, Miller Creek and Reed Creek watersheds in order to remedy the bacteria water quality impairments. The TMDLs were developed for the water quality standard for bacteria, which states that the calendar-month geometric mean concentration of *E. coli* shall not exceed 126 cfu/100 mL. A glossary of terms used in the development of this TMDL is listed in Appendix A.

Sources of Bacteria

There are eleven large and three small point sources with permits to discharge bacteria into the Reed Creek watershed. However, the majority of the bacteria load originates from nonpoint sources. The nonpoint sources of bacteria originate from livestock, wildlife, pets, and humans. Significant bacteria loads come from livestock 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. Straight pipes discharging household sewage directly into streams, and failing septic systems and household pets in residential areas contribute a small amount of bacteria to the streams. 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 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 Table ES. 2 reflect the contributions from each source to the bacteria **surviving** in-stream at the outlet of Reed Creek. These surviving bacteria are quantified through modeling (see next section) that takes into account the varied fate and transport processes and represents the fraction of in-stream bacteria attributable to each source for each impaired stream segment. Because the bacteria deposited directly to the stream are subject to less die-off than land deposited sources and do not require a rainfall event to be transferred to the stream, the directly deposited sources compose a higher percentage of surviving bacteria than they do of the overall number of bacteria produced in the watershed.

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

Source	Fecal coliform loading ($x10^{12}$ cfu/yr)	Percent of total loading
Direct loading to streams		
Livestock in stream	298	0.9%
Wildlife in stream	64	0.2%
Straight pipes	13	<0.1%
Point Sources	12	<0.1%
Loading to land surfaces		
Cropland	6	<0.1%
Pasture	33,782	96.3%
Residential	641	1.8%
Forest	201	0.6%
Total	**35,017**	

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

Source	Mean Daily *E. coli* Concentration by Source, cfu/100 mL	Relative Contribution by Source
Nonpoint source loadings from pervious land segments	56	28%
Direct nonpoint source loadings to the stream from wildlife	22	11%
Direct nonpoint source loadings to the stream from livestock	103	53%
Interflow and groundwater contribution	3	1%
Straight-pipe discharges to stream	5	3%
Nonpoint source loadings from impervious land segments	<1	<1%
Permitted point source loadings	7	4%
All Sources	196	

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 Reed 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 the Virginia Department of Environmental Quality (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 Reed Creek watershed was divided into 69 sub-watersheds based on homogeneity of land use, stream network connectivity, and monitoring station locations.

The hydrology component of HSPF was calibrated using flow data from January 1, 1991 to December 31, 1998; it was validated using data from January 1, 2001 to December 31, 2005. Initial estimates of hydrologic parameters were generated according to the guidance in BASINS Technical Note 6 (USEPA, 2000a). These parameters were refined during calibration. The program Expert System for the Calibration of HSPF (HSPEXP) was used to aid in calibration, and after the successful calibration the default calibration criteria in HSPEXP were met for both the calibration and validation periods.

The water quality component of the HSPF model was calibrated and validated for Reed Creek and its tributaries at 15 monitoring stations. The bacteria model was calibrated to data from one station (9-RDC009.00 was the only monitoring station with enough data for calibration) for the period of January 1, 2000 to June 30, 2003. The bacteria model was validated to data from all 15 stations for the period of July 1, 2003 to June 15, 2005, and additional validation from monitoring station 9-RDC009.00 from January 1, 1990 to December 31, 1997. Inputs to the model included fecal coliform loadings on land and in the stream. A comparison of simulated and observed bacteria loadings in the stream indicated that the model adequately simulated the fate and transport of fecal bacteria.

Existing Conditions

Contributions from various sources in the Reed 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 1992, 2001, and 2003-2006 to represent the appropriate range of conditions. Results from the calibrated HSPF model showed routine high signatures from livestock direct deposit, with some additional contributions from wildlife direct deposit, and overland flow. In the Mill Creek, Stony Fork, and Tate Run watersheds, contributions from wildlife direct deposit alone (without any other source of bacteria) violated the geometric mean criterion.

Allocation Scenarios

Different source reduction scenarios were evaluated to identify implementable scenarios that meet the calendar-month geometric mean *E. coli* criterion (126 cfu/100 mL) with zero violations. These scenarios were conducted using the same meteorological data used to establish existing conditions. The bacteria loadings used in modeling correspond to anticipated and permitted future conditions for the South Fork Reed Creek, Mill Creek, Stony Fork, Tate Run, Cove Creek, Miller Creek and Reed Creek watersheds. These future conditions differed from existing conditions in that permitted point source dischargers were represented in the model at their maximum permitted limits, with an allocation for potential future permits of five times this permitted amount. The reductions required for each impaired segment to meet the applicable water quality criterion are presented in Table ES. 3. In several segments reductions in wildlife contributions are required; note that in these cases, these are the minimum wildlife reductions needed to attain the criteria under the critical conditions, even if all other bacteria sources were completely eliminated. The critical conditions for most of these watersheds are times of very low flow. Eleven large and three small point sources currently discharge at or below their permit requirements; therefore, the proposed scenarios require load reductions only for nonpoint sources of *E. coli*. Details on the loads to be reduced from each source are given in Table ES. 4 through Table ES. 27.

Table ES. 3. Required *E. coli* loading reductions (%) to meet the *E. coli* standard.

Impaired Segment	Cattle Direct Deposit	Loads from Cropland	Loads from Pasture	Wildlife Direct Deposit	Straight Pipes and Failing Septics	Residential*
Mill Creek	100	0	85	20	100	0
Cove Creek	100	0	0	0	100	0
Miller Creek	100	0	0	0	100	0
Stony Fork	100	0	90	15	100	0
Tate Run	100	0	95	10	100	0
S Frk Reed Crk	100	0	55	0	100	0
Reed Creek N10R_RDC01B00	90	0	0	0	100	0
Reed Creek N10R_RDC01A02	65	0	0	0	100	0
Reed Creek N10R_RDC01A00	15	0	0	0	100	0
Reed Creek N11R_RDC01B00	15	0	0	0	100	0
Reed Creek N11R_RDC02B02	15	0	0	0	100	0
Reed Creek N11R_RDC03B04	15	0	0	0	100	0

* does not include failing septic systems

Table ES. 4. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for The TMDL allocation scenario for Mill 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	6	<1	6	0
Pasture	2,027	97	304	85
Residential	33	2	14	58
Forest	9	<1	9	0
Total	2,075		333	84

Table ES. 5. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for The TMDL allocation scenario for Cove 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	16	<1	16	0
Pasture	4,688	98	4,688	0
Residential	38	<1	20	46
Forest	26	<1	26	0
Total	4,768		4,750	<1

Table ES. 6. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for The TMDL allocation scenario for Miller 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	5	<1	5	0
Pasture	1,952	97	1,952	0
Residential	32	2	11	65
Forest	14	<1	14	0
Total	2,003		1,982	1

Table ES. 7. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for The TMDL allocation scenario for Stony Fork.

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	9	<1	9	0
Pasture	1,921	96	192	90
Residential	25	1	10	60
Forest	38	2	38	0
Total	1,993		249	88

Table ES. 8. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for The TMDL allocation scenario for Tate Run.

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	12	<1	12	0
Pasture	3,355	98	168	95
Residential	47	1	16	66
Forest	9	<1	9	0
Total	3,423		205	94

Table ES. 9. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for The TMDL allocation scenario for South Fork Reed 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	29	<1	29	0
Pasture	4,871	97	2,192	55
Residential	86	2	42	51
Forest	8	<1	8	0
Total	4,994		2,271	55

Table ES. 10. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for The TMDL allocation scenario for Reed Creek watershed (N10R_RDC01B00, sub-watershed 55).

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	5	<1	5	0
Pasture	1,707	96	1,707	0
Residential	15	<1	6	62
Forest	47	3	47	0
Total	1,774		1,765	<1

Table ES. 11. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for The TMDL allocation scenario for Reed Creek watershed (N10R_RDC01A02, sub-watershed 43).

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	22	<1	22	0
Pasture	3,054	97	3,054	0
Residential	61	2	32	48
Forest	6	<1	6	0
Total	3,143		3,114	<1

Table ES. 12. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for The TMDL allocation scenario for Reed Creek watershed (N10R_RDC01A00, sub-watershed 37).

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	0	0	0	0
Pasture	155	98	155	0
Residential	2	1	2	0
Forest	<1	<1	<1	0
Total	158		158	0

Table ES. 13. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for The TMDL allocation scenario for Reed Creek watershed (N11R_RDC01B00, sub-watershed 17).

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	22	<1	22	0
Pasture	4,805	95	4,805	0
Residential	188	4	131	30
Forest	24	<1	24	0
Total	5,039		4,982	1

Table ES. 14. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for The TMDL allocation scenario for Reed Creek watershed (N11R_RDC02B02, sub-watershed 7).

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	5	<1	5	0
Pasture	1,561	96	1,561	0
Residential	51	3	18	65
Forest	9	<1	9	0
Total	1,626		1,593	2

Table ES. 15. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for The TMDL allocation scenario for Reed Creek watershed (N11R_RDC03B04, sub-watershed 1).

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	14	<1	14	0
Pasture	3,735	98	3,735	0
Residential	63	2	23	63
Forest	11	<1	11	0
Total	3,823		3,783	1

Table ES. 16. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for The TMDL allocation scenario for Mill 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	23	84	0	100
Wildlife in Streams	4	14	3	20
Straight Pipes	<1	2	0	100
Total	28		3	89

Table ES. 17. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for The TMDL allocation scenario for Cove 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	65	89	0	100
Wildlife in Streams	7	10	7	0
Straight Pipes	<1	<1	0	100
Total	73		7	90

Table ES. 18. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for The TMDL allocation scenario for Miller 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	31	89	0	100
Wildlife in Streams	3	8	3	0
Straight Pipes	<1	3	0	100
Total	35		3	91

Table ES. 19. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for The TMDL allocation scenario for Stony Fork.

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	30	84	0	100
Wildlife in Streams	6	15	5	15
Straight Pipes	<1	<1	0	100
Total	36		5	86

Table ES. 20. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for The TMDL allocation scenario for Tate Run.

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	53	90	0	100
Wildlife in Streams	4	8	3.6	10
Straight Pipes	1	2	0	100
Total	58		3.6	93

Table ES. 21. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for The TMDL allocation scenario for South Fork Reed 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	57	84	0	100
Wildlife in Streams	8	13	8	0
Straight Pipes	2	3	0	100
Total	67		8	82

Table ES. 22. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for The TMDL allocation scenario for Reed Creek watershed (N10R_RDC01B00, sub-watershed 55).

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	5	33	1	90
Wildlife in Streams	10	67	10	0
Straight Pipes	0	0	0	100
Total	15		11	27

Table ES. 23. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for The TMDL allocation scenario for Reed Creek watershed (N10R_RDC01A02, sub-watershed 43).

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	7	58	2	65
Wildlife in Streams	4	31	4	0
Straight Pipes	1	11	0	100
Total	12		6	50

Table ES. 24. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for The TMDL allocation scenario for Reed Creek watershed (N10R_RDC01A00, sub-watershed 37).

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	0.4	50	0.3	15
Wildlife in Streams	0.4	50	0.4	0
Straight Pipes	0	0	0	100
Total	0.8		0.7	12

Table ES. 25. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for The TMDL allocation scenario for Reed Creek watershed (N11R_RDC01B00, sub-watershed 17).

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	14	54	12	15
Wildlife in Streams	9	36	9	0
Straight Pipes	3	10	0	100
Total	26		21	19

Table ES. 26. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for The TMDL allocation scenario for Reed Creek watershed (N11R_RDC02B02, sub-watershed 7).

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	4	42	3	15
Wildlife in Streams	3	40	3	0
Straight Pipes	1	18	0	100
Total	8		6	25

Table ES. 27. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for The TMDL allocation scenario for Reed Creek watershed (N11R_RDC03B04, sub-watershed 1).

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	9	61	8	15
Wildlife in Streams	4	31	4	0
Straight Pipes	1	8	0	100
Total	14		12	14

Equation ES.1 was used to calculate the TMDL allocations shown in Table ES. 28.

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

where:

WLA = wasteload allocation (point source contributions);

LA = load allocation (nonpoint source contributions); and

MOS = margin of safety.

Table ES. 28. Annual *E. coli* loadings (cfu/yr) for the TMDLs.

Impaired Segment	ΣWLA	ΣLA	MOS*	TMDL
Mill Creek	6.79×10^{10}	672.27×10^{10}	--	679.06×10^{10}
Cove Creek	7.40×10^{11}	733.46×10^{11}	--	740.86×10^{11}
Miller Creek	2.63×10^{11}	261.72×10^{11}	--	263.35×10^{11}
Stony Fork	9.00×10^{10}	890.63×10^{10}	--	899.63×10^{10}
Tate Run	7.99×10^{10}	773.76×10^{10}	--	781.75×10^{10}
S Frk Reed Crk	2.18×10^{12}	38.78×10^{12}	--	40.96×10^{12}
Reed Creek N10R_RDC01B00	4.32×10^{11}	427.61×10^{11}	--	431.93×10^{11}
Reed Creek N10R_RDC01A02	8.71×10^{11}	862.61×10^{11}	--	871.32×10^{11}
Reed Creek N10R_RDC01A00	2.18×10^{12}	134.01×10^{12}	--	136.19×10^{12}
Reed Creek N11R_RDC01B00	3.80×10^{13}	32.06×10^{13}	--	35.86×10^{13}
Reed Creek N11R_RDC02B02	5.54×10^{13}	36.54×10^{13}	--	42.08×10^{13}
Reed Creek N11R_RDC03B04	6.03×10^{13}	39.32×10^{13}	--	45.35×10^{13}

*Implicit MOS

The TMDL was determined as the average annual *E. coli* load at the watershed outlets for the chosen allocation scenarios. The WLAs for Mill Creek, Miller Creek, Stony Fork, Reed Creek (N10R_RDC01B00, sub-watershed 55), and Reed Creek (N10R_RDC01A02, sub-watershed 43) were determined as approximately 1% of the total TMDL load to allow for future growth in permitted facilities. The WLAs for Cove Creek, Tate Run, South Fork Reed Creek, Reed Creek (N10R_RDC01A00, sub-watershed 37), Reed Creek (N11R_RDC01B00, sub-watershed 17), Reed Creek (N11R_RDC02B02, sub-watershed 7), and Reed Creek (N11R_RDC03B04, sub-watershed 1) were obtained by first taking the product of the permitted point sources' *E. coli* discharge concentrations and allowable annual discharges, and adding a load five times this amount as an allocation for potential future permits. The LAs were then determined as the TMDL - WLA. The margin of safety for all of these TMDLs was implicit and achieved through conservative assumptions of bacteria loading and management practices as detailed throughout this report.

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. 29 for each impaired segment.

Table ES. 29. Allocation scenarios for Stage 1 TMDL implementation for the Reed Creek watersheds.

Impaired Segment	Cattle Direct Deposit	Loads from Cropland	Loads from Pasture	Wildlife Direct Deposit	Straight Pipes and Failing Septics	Residential*
Mill Creek	95	0	0	0	100	0
Cove Creek	85	0	0	0	100	0
Miller Creek	95	0	0	0	100	0
Stony Fork	95	0	0	0	100	0
Tate Run	100	0	0	0	100	0
S Frk Reed Crk	90	0	0	0	100	0
Reed Creek N10R_RDC01B00	0	0	0	0	100	0
Reed Creek N10R_RDC01A02	0	0	0	0	100	0
Reed Creek N10R_RDC01A00	0	0	0	0	100	0
Reed Creek N11R_RDC01B00	0	0	0	0	100	0
Reed Creek N11R_RDC02B02	0	0	0	0	100	0
Reed Creek N11R_RDC03B04	0	0	0	0	100	0

* does not include failing septic systems

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 South Fork Reed Creek, Mill

Creek, Stony Fork, Tate Run, Cove Creek, Miller Creek, and six segments of Reed 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 September 2011, members of the Center for Watershed Studies at Virginia Tech traveled to Wythe County for a day trip around the impaired watersheds to become acquainted with them. Throughout the process, personnel from Virginia Tech contacted stakeholders and local agency personnel via telephone, email, 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 November 15, 2011 and April 19, 2012 at the Wythe Bland Conference Room at the Wythe Bland Community Hospital in Wytheville, Virginia. A Local Steering Committee meeting was also held on November 15, 2011 prior to the first public meeting. This meeting 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

A segment of Reed Creek (VAS-N10R_RDC01A00) was first listed as impaired on Virginia's 2002 Section 303(d) Report on Impaired Waters due to water quality violations of the fecal coliform standard. Another segment of Reed Creek (VAS-N11R_RDC03B04) was listed as impaired on Virginia's 2004 Section 303(d) Total Maximum Daily Load Priority List and Report due to water quality violations of the E. coli standard. Additional segments of Reed Creek (VAS-11NR_RDC01B00, VAS-N11R_RDC02B02, VAS-N10R_RDC01A02, and VAS-N10R_RDC01B00) were listed on Virginia's 2006 305(b)/303(d) Water Quality Assessment Integrated Report due to water quality violations of the bacteria standard. South Fork Reed Creek (VAS-N10R_RSF01A00), Mill Creek (VAS-10R_MCE01A02), Stony Fork (VAS-N10R_SFK01A02), Tate Run (VAS-N10R_TAT01A06), Cove Creek (VAS-N12R_CVR01A00), and Miller Creek (VAS-N11R_MER01A06) all tributaries in the Reed Creek watershed were also listed on Virginia's 2006 305(b)/303(d) Water Quality Assessment Integrated Report due to water quality violations of the E. coli standard.

The Virginia Department of Environmental Quality (VADEQ) has described the impaired segments as presented in Figure 1.1 and Table 1.1.

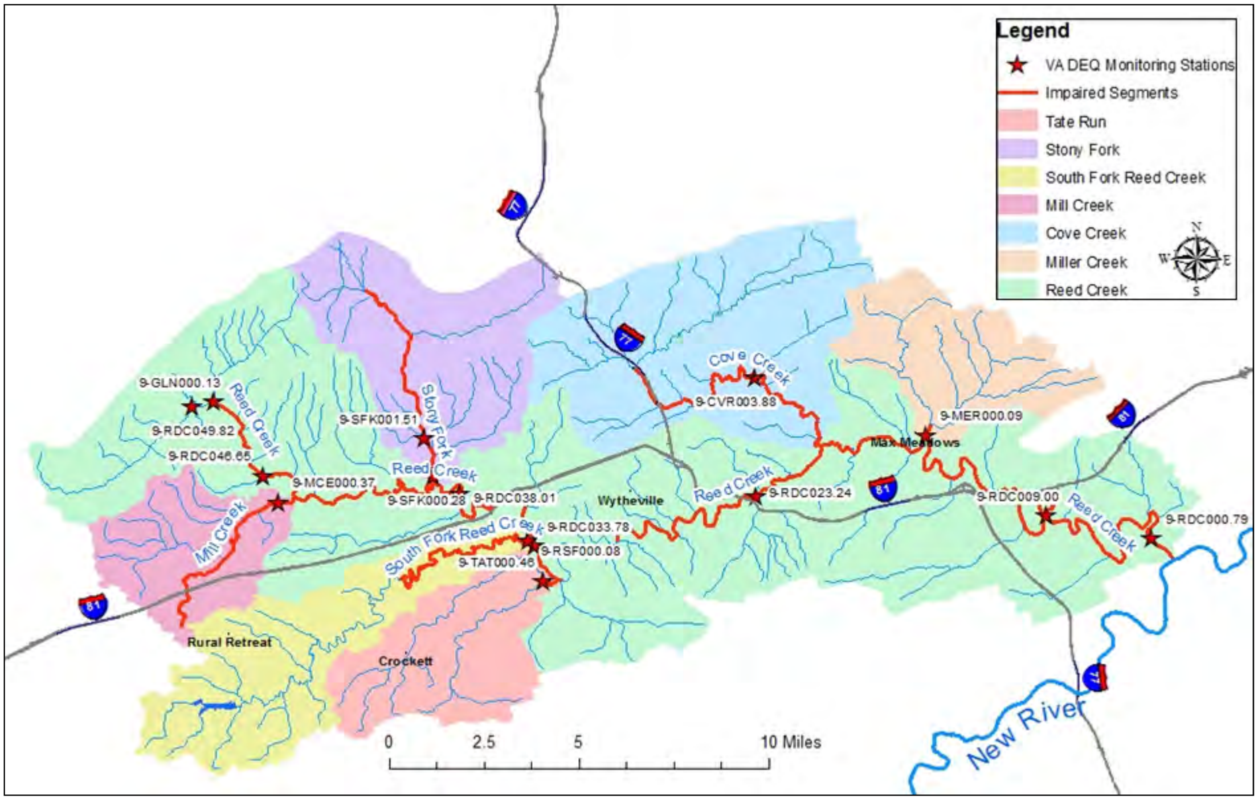

Figure 1.1. Impaired segments in the Reed Creek watershed.

Table 1.1. Impaired Segments Addressed in this TMDL report.

Impaired Segment	Size	Initial Listing Year	Description
Miller Creek (VAS-N11R_MER01A06)	0.42 miles	2006	extending from the Beaverdam confluence at Max Meadows to the Reed Creek confluence
Cove Creek (VAS-N12R_CVR01A00)	9.10 miles	2006	extending from the confluence with St. Lukes Fork to the confluence with Reed Creek
Mill Creek (VAS-N10R_MCE01A02)	6.18 miles	2006	extending from the mainstem to the confluence with Reed Creek
South Fork Reed Creek (VAS-N10R_RSF01A00)	6.72 miles	2006	extending from mainstem from river mile 6.8 to the confluence with Reed Creek
Stony Fork (VAS-N10R_SFK01A02)	6.66 miles	2006	extending from the headwaters to the Reed Creek confluence
Tate Run (VAS-N10R_TAT01A06)	0.52 miles	2006	extending from the Stuffle Run confluence to the Reed Creek confluence
Reed Creek (VAS-N10R_RDC01A00)	1.46 miles	2002	extending from the Pine Run confluence to the Venrick Run confluence
Reed Creek (VAS-N10R_RDC01A02)	5.18 miles	2006	extending from the Stony Fork confluence to the South Fork Reed Creek confluence
Reed Creek (VAS-N10R_RDC01B00)	9.75 miles	2006	extending from the Stony Fork confluence upstream to the Guillion Fork confluence
Reed Creek (VAS-N11R_RDC01B00)	5.71 miles	2006	extending from the Muskrat Branch confluence to the Miller Creek confluence
Reed Creek (VAS-N11R_RDC02B02)	6.01 miles	2006	extending from Beaverdam Creek to Glade Creek
Reed Creek (VAS-N11R_RDC03B04)	9.75 miles	2004	extending from the Glade Creek confluence to the confluence with the New River

1.1.3. Watershed Location and Description

The Reed Creek watershed is located in Wythe County (Figure 1.2). The watershed is approximately 173,828 acres and is part of the New River Basin. The predominant land use in the Reed Creek watershed is forest (52%), with additional significant areas in pasture and hay land (38%); less significant land uses are residential (8%) and cropland (2%). Reed Creek flows into the New River which flows north into the Kanawha River. The Kanawha is a tributary of the Ohio River, which flows into the Mississippi River, with the Mississippi discharging into the Gulf of Mexico.

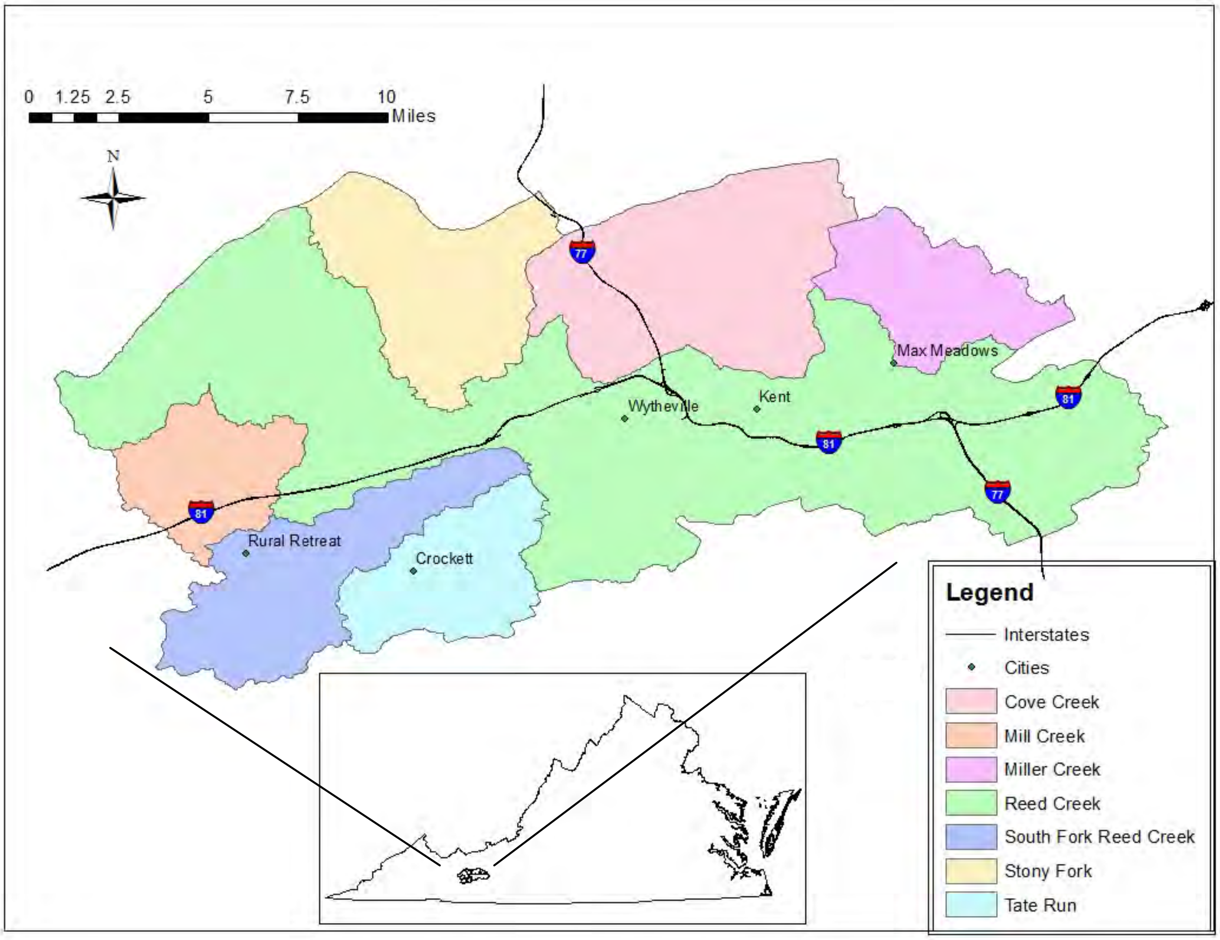

Figure 1.2. Reed Creek watershed location.

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, 2011.

Mill Creek, Cove Creek, Miller Creek, Stony Fork, Tate Run, South Fork Reed Creek and Reed 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 strong correlation between the concentration of these organisms (*E. coli* and enterococci) and the incidence of gastrointestinal illness. *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.

For a non-shellfish water body to be in compliance with Virginia's revised bacteria standards the following criterion shall apply to protect primary contact recreational uses (SWCB, 2011):

***Escherichia coli* Standard:**

E. coli bacteria concentrations for freshwater shall not exceed a monthly geometric mean of 126 colony forming units (cfu) per 100 mL.

During any assessment period, if more than 10.5% of a station's samples exceed 235 *E. coli* cfu/100mL, 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 fifteen ambient monitoring stations in the impaired Reed Creek watershed: seven on Reed Creek, two on Stony Fork, and one each on Mill Creek, Cove Creek, Miller Creek, Gullion Fork, Tate Run and South Fork Reed Creek. For the most recent assessment period, January 2003 through December 2008, all of the stations except the one on Gullion Fork and one of the Reed Creek stations (9-RDC049.82) have a violation rate greater than 10.5% of the instantaneous target concentration of 235 cfu/100ml, leading to the impaired classification for the Reed Creek, South Fork Reed Creek, Mill Creek, Stony Fork, Cove Creek, Miller Creek, and Tate Run segments.

The bacteria TMDL for the impaired segments will be developed to meet the *E. coli* standard of a monthly geometric mean not exceeding 126 *E. coli* cfu/100mL. 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 Reed Creek watershed was subdivided into 69 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 also shown in Figure 2.1

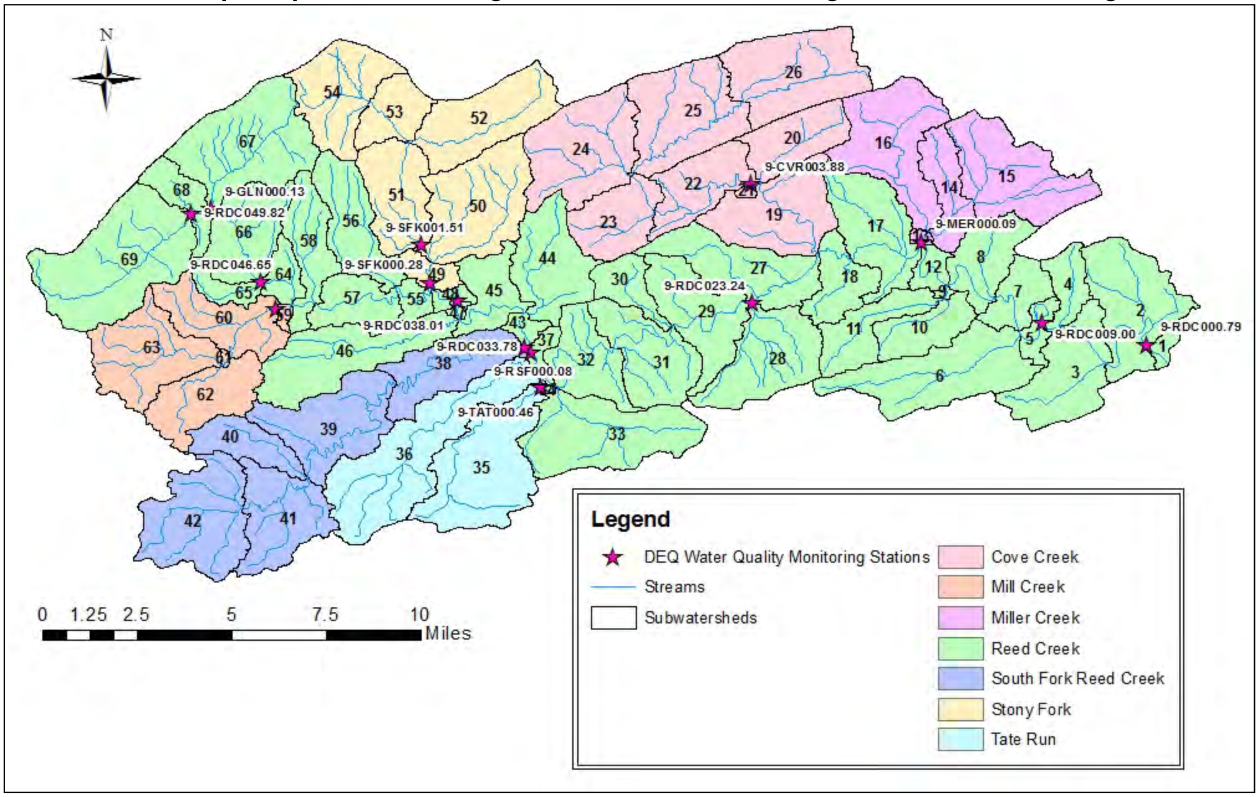

Figure 2.1.

Table 2.1. Impaired streams and corresponding sub-watersheds.

Stream Name	Corresponding Sub-watersheds
Reed Creek	1 – 12, 17 – 18, 27 – 33, 37, 43 – 48, 55 – 58, 64 – 69
Mill Creek	59 – 63
Cove Creek	19 – 26
Miller Creek	13 – 16
Stony Fork	49 – 54
Tate Run	34 – 36

South Fork Reed Creek	38 – 42

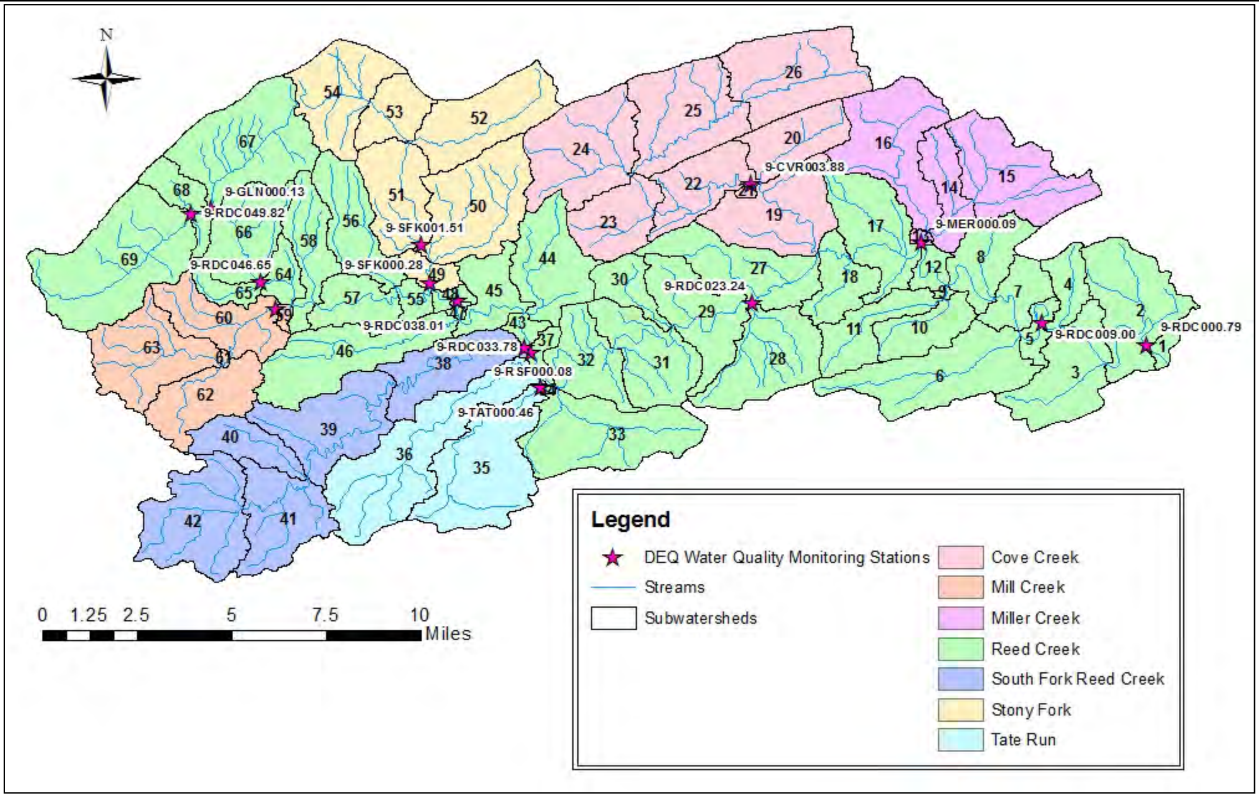

Figure 2.1. Sub-watersheds for the Reed Creek watershed.

2.2. Ecoregion and Geology

Ecoregions in this section are classified at two levels: level III ecoregions and their subgroup, level IV ecoregions. The study area lies in five level III/IV ecoregions. The majority of the Reed Creek watershed lies in the Ridge and Valley Level III Ecoregion, Southern Limestone/Dolomite Valleys and Low Rolling Hills Level IV Ecoregion. This level IV ecoregion “is a lowland characterized by broad, undulating, fertile valleys” (Woods et al., 1999). The drainage density is low due to the underlying limestone/dolomite (Woods et al., 1999). The northern part of the Reed Creek watershed, having the highest elevations, is located in the Ridge and Valley Level III Ecoregion, Southern Sandstone Ridges Level IV Ecoregion. The northeastern portion of the watershed has areas that lie in the Ridge and Valley Level III Ecoregion, Southern Sandstone Dissected Ridges and Knobs Level IV Ecoregion. Scattered areas in the southern portion of the watershed are located in the Ridge and Valley Level III Ecoregion, Southern Shale Valleys Level IV Ecoregion. The far southern part of the watershed lies in the Blue Ridge Level III Ecoregion and Southern Sedimentary Ridges Level IV Ecoregion.

2.3. Soils

Although the finer resolution Soil Survey Geographic (SSURGO) soils were used for modeling purposes, the coarser resolution State Soil Geographic (STATSGO) soils are presented here to simplify the overall watershed soil characterization discussion. There are five STATSGO soil groups represented in the study area (Table 2.2, Figure 2.2). The dominant soil group, Frederick-Carbo-Timberville, comprises 44% of the watershed area. The soil groups Berks-Weikert-Laidig and Groseclose-Litz-Shotower comprise 27% and 20% of the watershed area, respectively. The other two soil groups cover the remaining 9% of the watershed area.

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 Reed Creek watershed.

STATSGO Soil Group	% of Watershed	Soil Name	% of Soil Group	Texture†	Hydrologic Group	%Slope, Range	%Slope, Mean
VA001 BERKS-WEIKERT-LAIDIG	27	WEIKERT	25	CN-SIL	B/D	7 – 60	25
		BERKS	51	CN-SIL	C	2 – 70	24
		CALVIN	5	CN-SIL	C	25 – 65	40
		LILY	4	L	B	2 –12	7
		LAIDIG	6	CN-L	C	8 – 25	16
		ORRVILLE	1	SIL	C	0 – 3	2
		DEKALB	3	STV-SL	A	35 – 70	53
		JEFFERSON	1	FSL	B	2 – 7	5
		SHELOCTA	2	SIL	B	7 – 25	16
		DERROC	1	CB-SL	B	0 – 5	3
		IRONGATE	1	SIL	B	0 – 3	2
VA003 FREDERICK-CARBO-TIMBERVILLE	44	FREDERICK	66	SIL	B	2 – 60	25
		POYNOR	6	CR-SIL	B	2 – 60	24
		CARBO	13	SIC	C	2 – 35	16
		TIMBERVILLE	9	SIL	B	2 – 15	8
		LAIDIG	1	STV-L	C	7 – 25	16
		CHILHOWIE	4	GR-SICL	C	0 – 60	23
		SINDION	1	SIL	B	0 – 3	2
VA005 WALLEN-DEKALB-DRYPOND	8	LILY	12	GR-L	B	6 – 20	13
		DEKALB	22	CN-L	C	25 – 65	45
		WALLEN	34	STV-SL	B	7 – 65	31
		DRYPOND	13	CN-SL	D	15 – 65	33
		LAIDIG	5	GR-FSL	C	2 – 25	13
		JEFFERSON VARIANT	9	STV-SL	B	10 – 25	16
		JEFFERSON	1	GR-FSL	B	7 – 15	11
		DERROC	2	CB-SL	B	0 – 5	3
		OPEQUON	1	SICL	C	15 – 25	20
		PURDY	1	SIL	D	0 – 5	3
VA016 SHOTTOWER-LAIDIG-WEIKERT	1	LAIDIG	26	STV-FSL	C	2 – 25	13
		SHOTTOWER	48	L	B	2 – 30	18
		ALONZVILLE	5	FSL	B	2 – 15	8
		WEIKERT	8	CN-SIL	B\D	7 – 65	31
		BERKS	3	CN-SIL	C	7 – 25	16
		POPE	3	FSL	B	0 – 2	1
		DERROC	5	CB-SL	B	0 – 5	3
		PURDY	1	SIL	D	0 – 5	3
		ZOAR	1	SIL	C	0 – 7	4
VA017 GROSECLOSE-LITZ-SHOTTOWER	20	LITZ	40	SIL	C	2 – 60	24
		GROSECLOSE	54	SIL	C	2 – 65	23
		SHOTTOWER	5	FSL	B	2 – 25	12
		TIMBERVILLE	1	SIL	B	0 – 7	4

† FSL = Fine Sandy Loam; SIL = Silt Loam; L = Loam; SCL = Sandy Clay Loam; SIC = Silty Clay; SICL = Silty Clay Loam; SL – Sandy Loam; CB = Cobbly (as prefix); CR = Cherty (as prefix); ST = Stony (as prefix); V = Very (as prefix); MK = Mucky (as prefix); GR = Gravelly (as prefix); CN = Channery* (as prefix)

* Channery: coarse, flat fragments

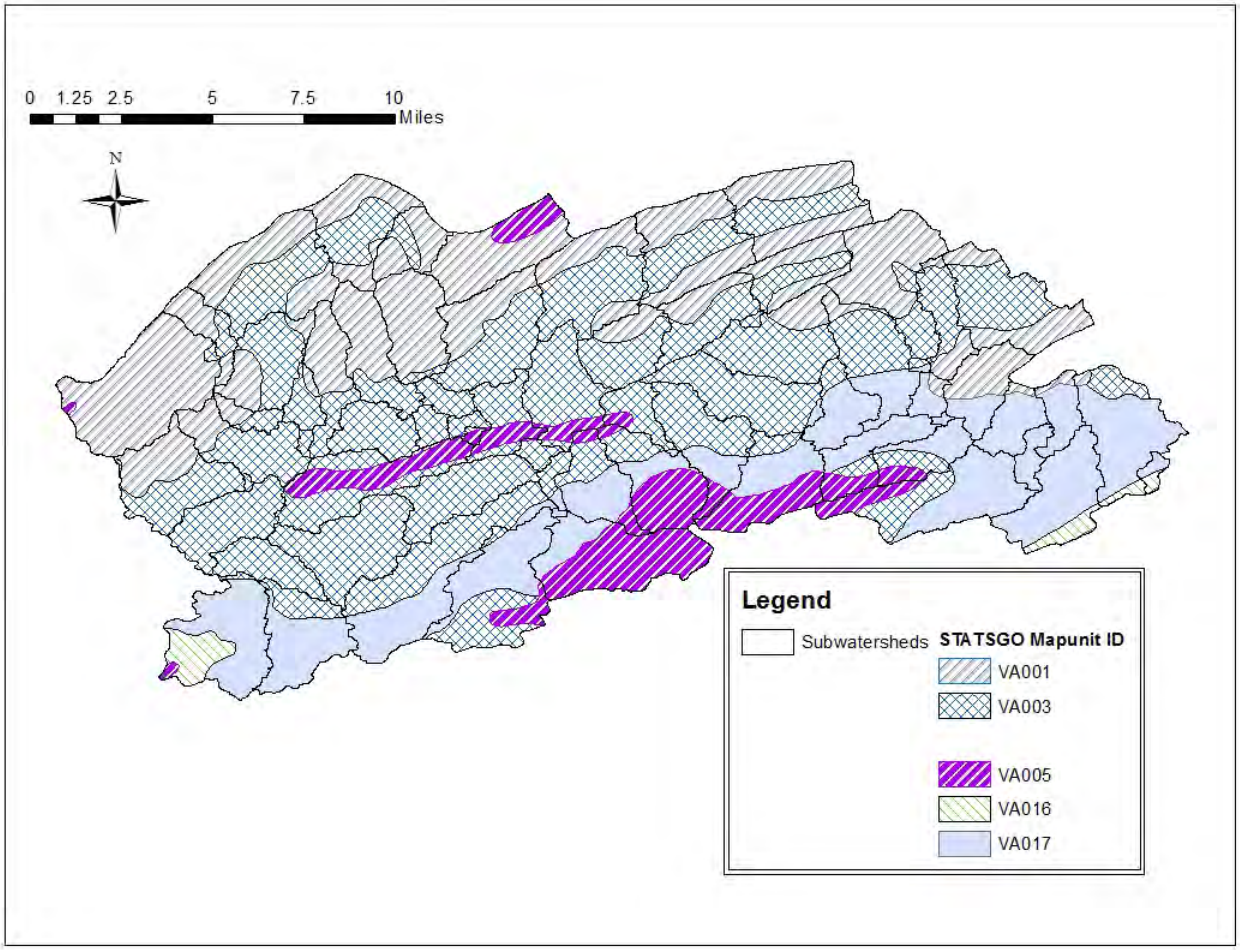

Figure 2.2. STATSGO soil groups in the Reed Creek watershed.

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, 2011). Meteorological data were obtained primarily from the National Weather Service COOP station at Wytheville (COOP ID 449301). The Wytheville station is located approximately 15 miles due west of the watershed outlet. Data from the following stations were used to address missing data in the Wytheville record: Pulaski, Bland, and Lynchburg Regional Airport. The long-term record summary (1/1/1893-12/31/2011) at the Wytheville station (COOP ID 449301) shows an average annual precipitation of 37.42 inches, with 55% of the precipitation occurring during the cropping season (May-October). Average annual snowfall at the Wytheville station is 19.6 inches. Average annual daily temperature is 52.7°F, with the highest average daily temperature of 71.6°F occurring in July, and the lowest average daily temperature of 33.2°F occurring in January (SERCC, 2012).

2.5. Land Use

The National Agricultural Statistics Service (NASS) 2009 cropland data layer (CDL) land use map for Virginia was used to obtain the land use estimates. This layer uses satellite imagery from sources such as the Indian Remote Sensing RESOURCESAT-1, Landsat 5 TM, and Landsat 7 ETM+, supplemented by the USGS National Elevation Dataset, USGS National Land Cover Dataset 2001, and NASA Moderate Resolution Imaging Spetroradiometer data. The dataset was verified using the Farm Service Agency’s Common Land Unit program and NLCD 2001 data (USDA-NASS, 2009). The land cover categories in the Reed Creek watershed were grouped into six major categories based on similarities in hydrologic features and waste application/production practices (Table 2.4). The land use categories were assigned pervious and impervious percentages for use in the watershed model. Land uses for the Reed Creek watershed are presented graphically in Figure 2.3 and tabulated in Table 2.5.

Table 2.4. NASS and land use aggregation.

TMDL Land Use Categories	Pervious/Impervious (Percentage)	NASS Land Use Categories (Class No.)
Cropland	Pervious (100%)	Corn (1) Sorghum (4) Soybeans (5) Tobacco (11) Winter Wheat (24) Rye (27) Oats (28) Alfalfa (36) Dbl. Crop Barley/Corn (237) Cabbage (243)
Hayland	Pervious (100%)	Other Hays (37)
Pasture	Pervious (100%)	Grass/Pasture (62) NLCD - Grassland Herbaceous (171)
Residential	Pervious (90%); Impervious (10%) Pervious (65%); Impervious (35%) Pervious (35%); Impervious (65%) Pervious (10%); Impervious (90%) Pervious (100%)	NLCD - Developed/Open Space (121) NLCD - Developed/Low Intensity (122) NLCD - Developed/Medium Intensity (123) NLCD - Developed/High Intensity (124) NLCD – Barren (131)
Forest	Pervious (100%)	Christmas Trees (70) NLCD - Deciduous Forest (141) NLCD - Evergreen Forest (142) NLCD - Mixed Forest (143) NLCD – Shrubland (152)
Water	Pervious (100%)	NLCD - Open Water (111)

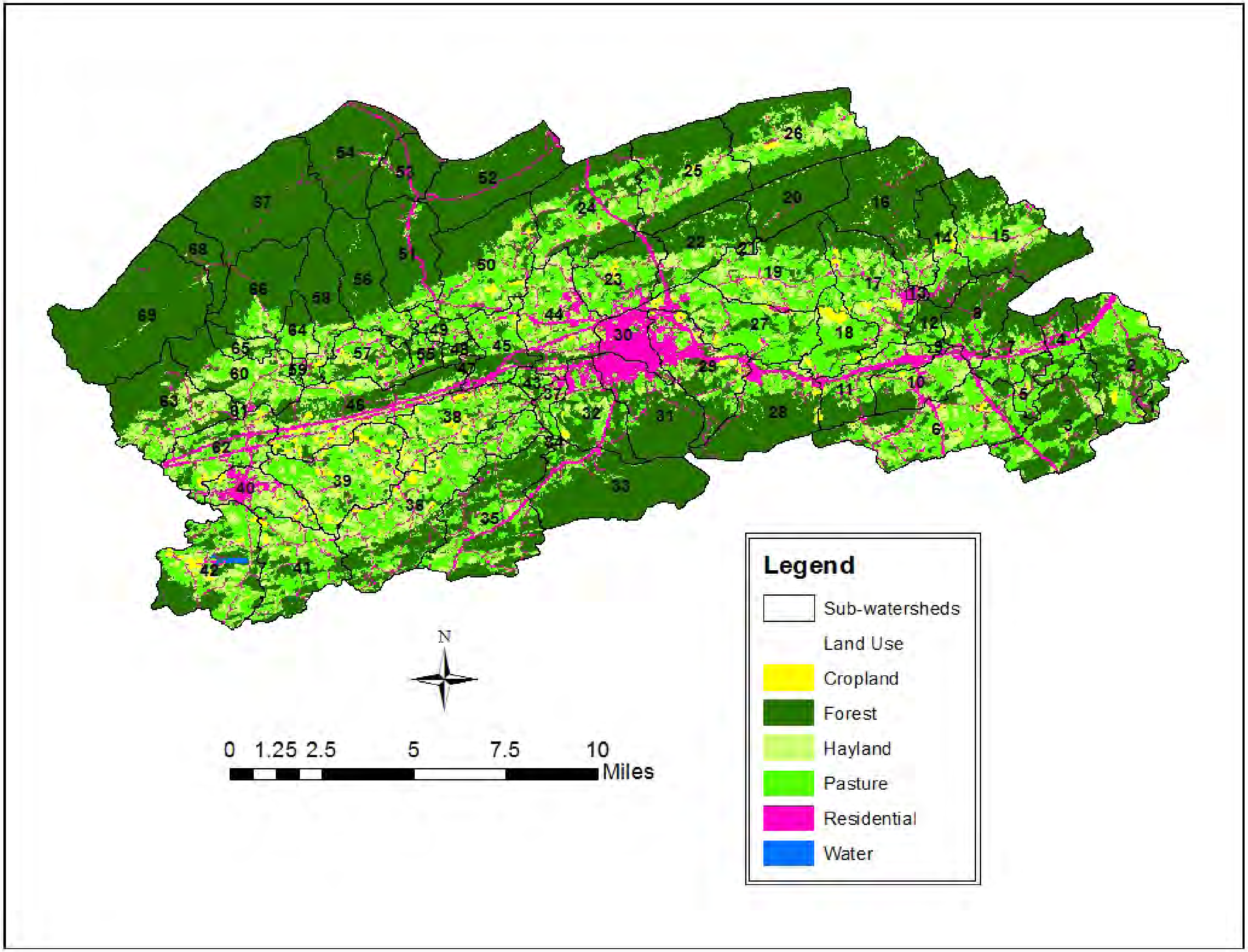

Figure 2.3 Land use in the Reed Creek watershed.

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

Sub-watershed	Cropland	Forest	Hayland	Pasture	Residential	Water	Total
1	2	183	42	77	29	-	332
2	57	1,633	480	1,507	343	-	4,020
3	9	1,941	320	1,055	173	-	3,498
4	1	558	80	350	177	-	1,165
5	15	206	104	292	55	1	674
6	77	1,275	1,001	1,888	493	-	4,734
7	2	617	180	459	188	-	1,446
8	8	1,506	152	315	200	-	2,181
9	-	21	6	40	13	-	80
10	36	469	383	604	287	-	1,779
11	43	716	319	563	466	-	2,106
12	2	375	58	176	13	-	624
13	-	22	5	26	80	-	134
14	57	1,148	170	364	81	-	1,821
15	33	2,626	620	932	126	1	4,337
16	10	3,720	248	353	110	-	4,441
17	128	934	788	1,269	268	-	3,387
18	160	208	241	1,138	45	3	1,795
19	74	1,005	859	1,601	187	-	3,726
20	-	2,207	39	28	20	-	2,294
21	-	19	32	53	7	-	111
22	5	1,593	356	457	71	-	2,482
23	60	619	437	1,013	309	-	2,437
24	12	2,269	620	1,370	293	-	4,564
25	20	2,891	630	782	100	-	4,422
26	51	2,637	873	865	49	5	4,479
27	127	535	645	1,944	281	2	3,533
28	47	2,448	255	475	350	-	3,575
29	130	1,001	477	642	974	2	3,227
30	20	55	56	49	1,081	1	1,262
31	3	2,083	152	280	686	-	3,204
32	35	1,150	323	524	414	2	2,447
33	-	4,130	118	278	202	-	4,727
34	-	9	17	23	6	-	54
35	4	2,720	597	1,302	394	-	5,017
36	164	1,581	1,448	2,489	372	1	6,054
37	0	80	105	214	78	-	476
38	220	313	954	1,191	237	-	2,913
39	354	307	1,306	1,784	191	4	3,945
40	105	41	646	378	533	-	1,703
41	74	950	799	1,246	172	-	3,241
42	176	1,502	959	1,508	260	64	4,468
43	-	135	66	160	48	-	409
44	85	282	995	1,145	712	2	3,221

Sub-watershed	Cropland	Forest	Hayland	Pasture	Residential	Water	Total
45	20	541	283	699	265	-	1,808
46	254	1,365	950	897	636	1	4,103
47	-	101	12	18	7	-	138
48	-	176	67	75	3	-	321
49	9	99	146	388	48	-	690
50	105	2,036	626	1,420	207	-	4,394
51	-	2,474	116	189	165	-	2,944
52	1	3,511	25	8	183	-	3,727
53	0	1,531	22	15	113	-	1,681
54	-	3,193	28	26	130	-	3,377
55	-	250	86	165	32	-	534
56	5	2,221	182	366	25	-	2,799
57	48	486	407	785	107	-	1,832
58	29	1,631	213	247	41	-	2,161
59	-	19	32	92	11	-	154
60	8	1,033	738	899	117	-	2,794
61	-	9	12	33	4	-	59
62	102	517	728	892	499	1	2,738
63	14	2,178	882	554	156	-	3,784
64	2	352	193	277	13	-	837
65	1	331	158	179	5	-	674
66	3	2,409	190	316	39	-	2,956
67	-	5,101	2	1	47	1	5,152
68	-	1,257	9	5	21	-	1,292
69	-	6,258	42	15	21	-	6,336
Total	3,004	89,791	2,5107	41,770	14,069	88	173,828

2.6. Stream Flow Data

USGS monitors average daily flow rates on the Reed Creek at station 03167000, near Grahams Forge, VA, at the outlet of sub-watershed 5. The drainage area contributing to the station is 258 mi². The consistent period of record at station 03167000 extends from April 1927 to present (March 2012 at time of writing), with an average flow rate of 263 cfs (USGS, 2012).

There are two major springs in the Reed Creek watershed: Wyrick Spring and Harkrader (Boiling) Spring. The approximate flow rates (Helfrich, et al., 1990) from these springs are shown in Table 2.6

Table 2.6 Discharge rates of springs in Reed Creek.

Spring	Approximate discharge rate (cfs)
Wyrick Spring	0.13 – 0.38
Harkrader (Boiling) Spring	5.01 – 5.90

2.7. Water Quality Data

VADEQ monitors water quality within the impaired Reed Creek watersheds at 17 stations. The locations of these stations were shown previously (Figure 2.1

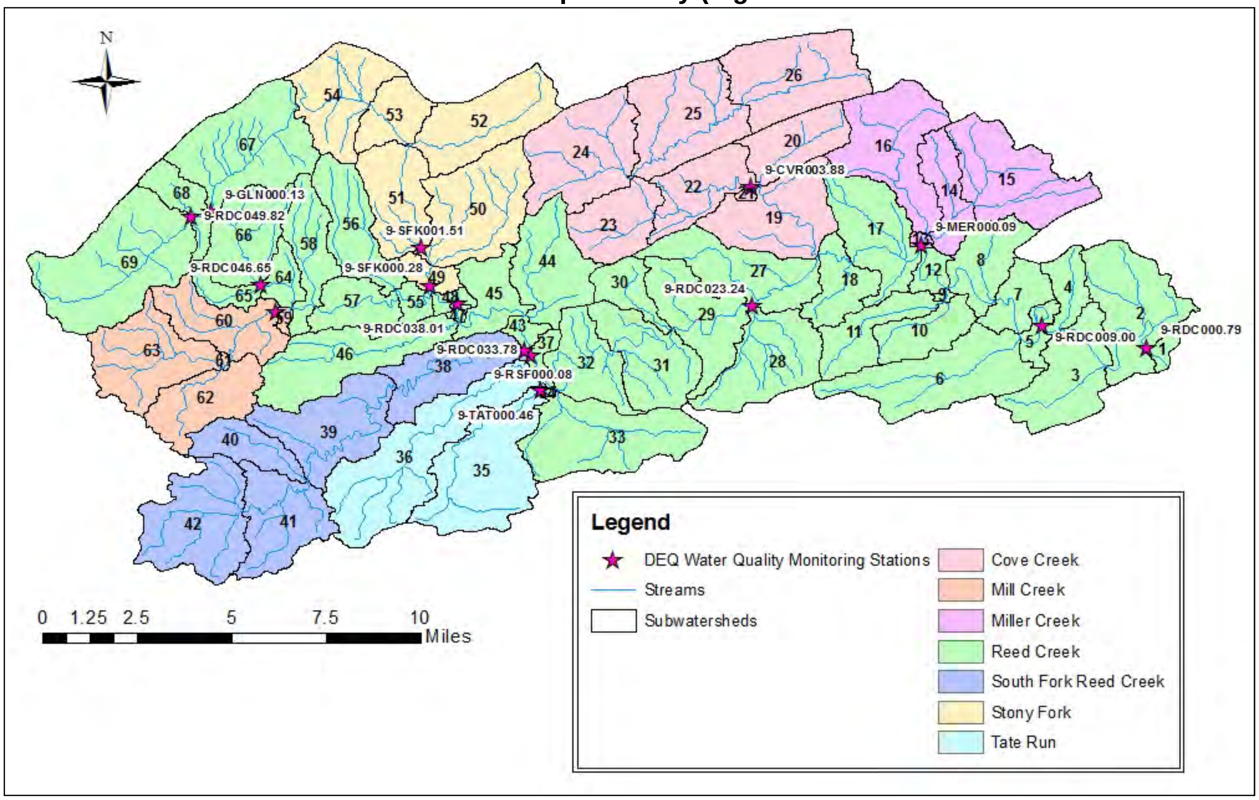

Figure 2.1); a summary of the bacteria data, including violation rates of the appropriate single-sample standards, is presented in Table 2.7. Of these stations, stations 9-MER000.85 and 9-MGV000.37 include less than three years of sampling data and therefore will not be included in the water quality calibration or validation.

Table 2.7 VADEQ monitoring stations within the Reed Creek watershed.

Station ID	Stream Name	Station Description	Indicator Organism Measured	Number of Samples	Violation Rate	Period of Record
9-CVR003.88	Cove Creek	Bridge on Rt. 647 off Rt. 610	*E. coli*	23	52%	2003 - 2010
9-MER000.09	Miller Creek	Bridge on Rt. 614 off Rt. 121	*E. coli*	23	61%	2003 - 2010

Station ID	Stream Name	Station Description	Indicator Organism Measured	Number of Samples	Violation Rate	Period of Record
9-MER000.85	Miller Creek	Rt. 610 bridge #6010 at Max Meadows	*E. coli*	10	20%	2009 - 2010
9-MGV000.37	McGavak Run	Route 618 culvert at private drive	*E. coli*	11	18%	2009 - 2010
9-RDC000.79	Reed Creek	Swinging Bridge on Rt. 618 off 81 exit 86	*E. coli*	23	8%	2003 - 2010
9-RDC009.00	Reed Creek	Rt. 619 at Gaging Station	Fecal Coliform	257	24%	1970 - 2011
			E. coli	46	6%	2002 - 2011
9-RDC023.24	Reed Creek	Bridge on Rt. 649 at transfer station	*E. coli*	23	30%	2003 - 2010
9-GLN000.13	Gullion Fork	Bridge on Rt. 625	*E. coli*	24	12%	2003 - 2010
9-MCE000.37	Mill Creek	Bridge on Rt. 830 off Rt. 680	*E. coli*	24	58%	2003 - 2010
9-RDC033.78	Reed Creek	Pull off on Rt. 655 off Rt. 684	*E. coli*	15	60%	2003 - 2009
9-RDC038.01	Reed Creek	Rt. 663 off Rt. 11	*E. coli*	24	33%	2003 - 2010
9-RDC046.65	Reed Creek	Bridge on Rt. 625 off Rt. 680	*E. coli*	24	29%	2003 - 2010
9-RDC049.82	Reed Creek	FS road off Rt. 625	*E. coli*	24	17%	2003 - 2010
9-RSF000.08	Reed Creek, South Fork	Off Rt. 667 on Avery Lane	*E. coli*	24	67%	2003 - 2010
9-SFK000.28	Stony Fork	Bridge on Rt. 664 off Rt. 666	*E. coli*	23	52%	2003 - 2010
9-SFK001.51	Stony Fork	Off US 21/52	*E. coli*	24	38%	2003 - 2010
9-TAT000.46	Tate Run	Bridge on Rt. 655 off Rt. 684	*E. coli*	24	54%	2003 - 2010

Seasonality of fecal coliform concentrations in the streams was evaluated by plotting the mean monthly fecal coliform concentrations observed at station 9-RDC009.00, 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; there were between 15 and 27 samples available for every month. The observed bacteria record shows little seasonality, except perhaps to show that bacteria concentrations in August and November are generally low and do not violate the water quality standard.

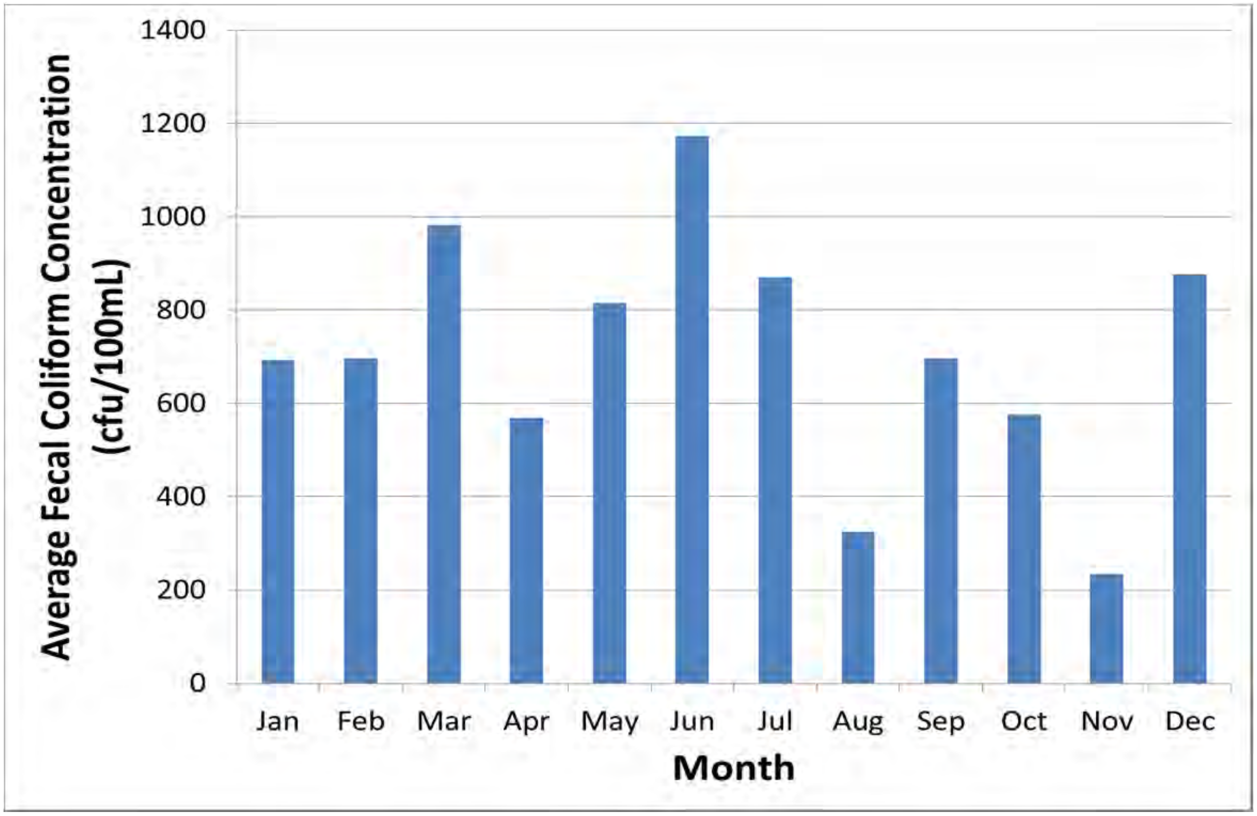

Figure 2.4. Average fecal coliform concentrations by month for station 9-RDC009.00.

Chapter 3: Source Assessment of Fecal Coliform

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

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

Potential Source	Population	Fecal coliform produced (x 10^6 cfu/head/day)
Humans (permanent)	20,660	360[a]
Beef Cattle	10,988	6,000[a]
Dairy Cattle	2,572	4,550[b]
Goats	285	5,110[d]
Sheep	839	2,180[d]
Horses	725	80[d]
Pets	9,974	450[c]
Deer	7,463	64
Raccoons	2,482	9
Muskrats	952	.05[e]
Beavers	511	0.2
Ducks	1079[f]	150
Geese	1353[f]	440
Wild Turkeys	1496	17

[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

Point sources of fecal coliform bacteria in the Reed Creek watershed include eleven sewage treatment plants and three single family domestic sewage discharges (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, load for each permitted point source was calculated as the allowable point source discharge concentration of 126 cfu/100 mL at their facility's maximum design flow rate.

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

Permit Number	Facility Name	Sub-watershed	Design Flow (mgd*)	Permitted *E. coli* Conc. (cfu/100 mL)	*E. coli* Load (cfu/year)
VA0021326	Rural Retreat STP	40	0.25	126	4.35×10^{11}
VA0059137	DGIF - Wytheville Fish Cultural Station	6	0.54	126	9.41×10^{11}
VA0068144	DGIF - Wytheville Fish Cultural Station	6	0.002	126	3.48×10^{9}
VA0090549	Flying J 754 - Wytheville	11	0.001	126	1.74×10^{9}
VA0092398	Flying J 750 - Max Meadows	11	0.0003	126	5.23×10^{8}
VA0074161	Fort Chiswell WWTP	9	2	126	3.48×10^{12}
VA0090956	Loves Travel Stops and Country Stores 239	7	0.001	126	1.74×10^{9}
VA0020281	Wytheville WWTP	29	4	126	6.97×10^{12}
VA0024490	Edgemont Center Incorporated STP	29	0.0271	126	4.72E+10
VA0065706	I-81 Travel Plaza - Max Meadows	2	0.015	126	2.61×10^{10}
VA0091847	SVC Manufacturing Inc. - QTG Blue Ridge Facility	19	0.085	126	1.48×10^{11}
VAG400652	Single Family Home	27	0.001	126	1.74×10^{9}
VAG400843	Single Family Home	5	0.001	126	1.74×10^{9}
VAG400883	Single Family Home	35	0.001	126	1.74×10^{9}

*million gallons per day

3.1. Humans and Pets

The Reed Creek watershed has an estimated permanent population of 20,660 (9,974 households with an average of 2.07 people per household; actual people per household varies by sub-watershed). The number of households and the number of people per household for the watershed was determined from the 2010 Census of Population and Housing for Virginia. Fecal coliform from humans can be transported to streams from failing septic systems, via straight pipes discharging directly into streams, sewage spills, or through leaky sewer lines. 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. Professional judgment was used to specify one pet per household for the Reed Creek watershed.

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 U.S. Census (2010) provides an estimate of house ages in its summary file 3. An estimate was made for each Census block group of the fraction of houses in old (pre-1970), middle (1970-1989), and new (post-1989) age categories. This fraction was applied to the total number of houses in each block group to obtain an estimate of the number of houses in each age group in each sub-watershed. 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 1.3 to 2.8 persons per household (Census Bureau, 2010)) by the per capita fecal coliform production rate of $3.6x10^8$ 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 $3.6x10^8$ 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 in Table 3.3.

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

Sub-watershed	Sewered Houses	People per Unsewered House	Straight Pipes	Houses with Septic Systems in each age category			Failing Septic Systems*	Pet Population
				Old	Mid-age	New		
1	1	2	0	1	2	2	0	6
2	0	2.3	1	45	59	64	31	169
3	0	2.1	0	18	24	28	12	70
4	0	2.3	1	26	29	30	17	86
5	0	2.1	0	4	6	6	2	16
6	0	2.2	2	98	139	98	69	337
7	0	2.6	1	18	20	21	11	60
8	0	2.3	1	38	35	31	23	105
9	0	2	0	1	0	0	0	1
10	0	2.2	1	45	59	44	31	149
11	0	2.3	2	57	74	47	39	180
12	0	2.5	0	7	6	6	4	19
13	0	2.2	0	17	15	16	10	48
14	0	2.4	1	18	17	19	11	55
15	0	2.4	1	42	39	43	25	125
16	0	2.1	1	36	35	46	22	118
17	0	2.3	2	68	51	64	39	185
18	0	2.4	0	17	11	12	9	40
19	91	2.4	0	11	8	11	6	121
20	0	1.8	0	1	1	2	0	4
21	2	1.5	0	1	1	0	0	4
22	8	1.4	0	2	1	2	1	13
23	214	2.2	1	19	24	15	12	273
24	0	2.2	1	40	44	39	25	124
25	0	1.9	0	17	16	22	10	55
26	0	1.9	0	8	7	10	4	25
27	100	2.2	0	16	11	12	8	139
28	0	2.2	2	54	56	44	34	156
29	557	2.8	1	42	24	17	22	641
30	1528	1.9	0	15	7	3	7	1553
31	893	2.2	1	30	11	9	14	944
32	252	2.2	1	25	36	19	17	333
33	0	2	2	66	61	45	39	174
34	0	1.7	0	2	3	1	1	6
35	0	2.1	3	116	75	61	63	255
36	0	2.1	2	84	65	54	48	205
37	64	1.3	0	1	2	0	0	67
38	0	2.1	2	73	62	73	43	210
39	44	2.2	1	40	31	16	22	132
40	579	2	0	18	14	7	10	618
41	0	2.3	2	54	35	40	29	131

Sub-watershed	Sewered Houses	People per Unsewered House	Straight Pipes	Houses with Septic Systems in each age category			Failing Septic Systems*	Pet Population
				Old	Mid-age	New		
42	20	2.3	2	80	60	55	45	217
43	20	1.6	0	7	7	7	4	41
44	449	1.9	2	55	51	29	33	586
45	0	2.1	1	35	35	24	21	95
46	28	2.1	2	83	76	46	49	235
47	0	1.7	0	1	1	1	0	3
48	0	1.7	0	3	3	1	1	7
49	0	2	0	13	13	8	8	34
50	0	2	1	27	30	19	17	77
51	0	1.9	0	18	20	12	11	50
52	0	1.9	0	8	10	6	5	24
53	0	1.5	0	18	19	12	11	49
54	0	1.5	0	9	10	6	5	25
55	0	1.9	0	6	6	4	3	16
56	0	1.8	0	9	9	5	5	23
57	0	2.3	0	12	12	8	7	32
58	0	1.9	0	6	6	3	3	15
59	0	1	0	1	1	0	0	2
60	0	1.9	0	14	14	9	8	37
61	0	1	0	1	0	0	0	1
62	161	2.2	1	47	41	26	27	276
63	0	2.6	1	39	39	24	24	103
64	0	1.6	0	3	3	1	1	7
65	0	2.3	0	1	1	1	0	3
66	0	1.7	0	9	9	5	5	23
67	0	1.6	0	5	5	3	3	13
68	0	1.7	0	1	1	1	0	3
69	0	2.2	0	10	9	6	5	25
Total	**5,011**	**2.07**[†]	**43**	**1,812**	**1,707**	**1,401**	**1071**	**9,974**

* 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

3.1.2. 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, 1% were estimated to have straight pipes. Based on this criterion, it was estimated that 43 houses with straight pipes exist in the Reed 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 3.6×10^8 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 3.6×10^8 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).

3.1.3. Sewage Spills

Sewage spills can occur at many places along the collection system. Leaks in lines or overflows at pumping stations are two examples. There were reported sewage spills in the Reed Creek watershed in the Wytheville WWTP and Fort Chiswell WWTP service areas over the past eighteen years (1994-2011). The spills were modeled as unique events occurring on the report date.

3.1.4. 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 2011-2012 survey: 39% of American households owned an average of 1.7 dogs, and 33% of American households owned an average of 2.2 cats (HSUS, 2012). Assuming that a unit pet is one dog or two cats, this yields (0.39*1.7 + (0.33*2.2)/2) = 1.026 unit pets per household. Therefore, the pet population in the Reed Creek watershed was calculated at a rate of one unit pet per permanent household. Given this assumption, there are an estimated 9974 pets in the Reed 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.

3.2.1. Distribution of Dairy and Beef Cattle

There are currently 13 dairy farms in the Reed Creek watershed. The number of dairy farms was initially estimated from information from the Virginia Department of Agriculture and Consumer Services (VDACS) and was further refined according to information from the Big Walker SWCD and, when possible, dairy farmers were contacted individually to determine the number of cows on each farm.

The population of beef cattle in the Reed Creek watershed was initially estimated from the 2007 Agricultural Census. All beef farms were assumed to be cow-calf operations. 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.

Because there are not many dairy operations in this watershed, it is impossible to report the dairy cows on a sub-watershed basis without allowing the reader to tie the numbers to a specific farm. Therefore, to preserve the confidentiality of the dairy farmers personally contacted, the populations for all cattle are reported on the basis of the impaired watersheds. The number of beef and dairy cattle and the distribution of animals among the sub-watersheds are listed in Table 3.4 for the Reed Creek watershed.

Beef and dairy cattle spend varying amounts of time in confinement, streams, and pastures depending on the time of year. Accordingly, the proportion of fecal coliform deposited in any given land area varies throughout the year. The contacted dairy farmers were asked specifically about their confinement schedules and stream access. Stream access for all other cattle farms was estimated based on watershed visits and pasture proximity to the stream.

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

Sub-watershed	Cattle*	Sub-watershed	Cattle*	Sub-watershed	Cattle*
1	19	24	343	47	4
2	377	25	196	48	19
3	264	26	216	49	116
4	87	27	486	50	582
5	73	28	119	51	71
6	473	29	161	52	3
7	115	30	12	53	6
8	79	31	70	54	11
9	10	32	131	55	41
10	151	33	83	56	92
11	141	34	7	57	196
12	44	35	391	58	62
13	11	36	868	59	323
14	137	37	53	60	225
15	550	38	298	61	8
16	132	39	631	62	223
17	318	40	95	63	139
18	285	41	312	64	69
19	401	42	772	65	45
20	7	43	40	66	79
21	13	44	423	67	0
22	114	45	175	68	1
23	483	46	1075	69	4
Total					13,560

* Cow-calf pairs

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) Cows are confined according to the schedule given in Table 3.5. This table reflects the communications with farmers and agency personnel, and is area-weighted to reflect sub-watershed-level confinement.
b) When cattle are not confined, they are on pasture.
c) 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.
d) 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.

The resulting numbers of cattle in pastures and streams for all sub-watersheds are given in Table 3.6.

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

Month	Fraction of time spent in confinement			Time spent in the stream (hours/day)
	Milk Cows (range; typical)	Dry Cows and Heifers (range; typical)	Beef Cattle (range; typical)	
January	25%-100%; 75%	17%-40%; 40%	0%-40%; 20%	0.5
February	25%-100%; 75%	17%-40%; 40%	0%-40%; 20%	0.5
March	25%-100%; 40%	0%-15%; 0%	0%-0.7%; 0%	0.75
April	25%-100%; 30%	0%-15%; 0%	0%-0.7%; 0%	1
May	25%-100%; 30%	0%-15%; 0%	0%-0.7%; 0%	1.5
June	25%-100%; 30%	0%-15%; 0%	0%-0.7%; 0%	2.0
July	25%-100%; 30%	0%-15%; 0%	0%-0.7%; 0%	2.0
August	25%-100%; 30%	0%-15%; 0%	0%-0.7%; 0%	2.0
September	25%-100%; 30%	0%-15%; 0%	0%-0.7%; 0%	1.5
October	25%-100%; 30%	0%-15%; 0%	0%-0.7%; 0%	1
November	25%-100%; 40%	0%-15%; 0%	0%-0.7%; 0%	0.75
December	25%-100%; 75%	17%-40%; 40%	0%-40%; 20%	0.5

Table 3.6. Distribution of the cattle population among land use types and stream.

Month	Confinement	Pasture	Streams*
January	3,661	9,837	62
February	3,661	9,837	62
March	497	12,941	122
April	373	13,023	164
May	373	12,940	247
June	373	12,858	329
July	373	12,858	329
August	373	12,858	329
September	373	12,940	247
October	373	13,023	164
November	497	12,941	122
December	3,661	9,837	62

*Number of cow equivalent defecations in the stream

3.2.2. Direct Manure Deposition in Streams

Direct manure loading to streams is due to both 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 entire Reed Creek watershed, using the table above, is 3.2×10^6 lb. The associated average daily fecal coliform loading to the stream for Reed Creek is 8.2×10^{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

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 5,911 lb/ac for the Reed Creek watershed. The associated fecal coliform loading from cattle to pasture on a daily basis averaged over the year is 2.4×10^9 cfu/ac/day for the Reed 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 gal of liquid manure daily (ASAE, 1998). Based on the monthly confinement schedule (Table 3.5) and the number of lactating cows, annual liquid dairy manure production in the Reed Creek watershed is 3.3×10^6 gal. Based on the per capita fecal coliform production of lactating cows, the fecal coliform concentration in fresh liquid manure is 7.31×10^6 cfu/gal. Liquid dairy manure receives priority over other manure types (poultry litter and solid cattle manure) when applied to land. Liquid dairy manure application rates are 6,600 and 6,000 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 444 acres (15%) of cropland and 95 acres (0.1%) of hayland and pasture.

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

Table 3.7. Schedule of cattle manure application for Reed Creek.

Month	Solid cattle manure applied (%)*	Liquid dairy manure applied (%)*
January	0	0
February	5	5
March	25	25
April	20	20
May	5	5
June	5	10
July	5	0
August	5	5
September	10	15
October	10	5
November	10	10
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. The application of liquid and solid manure (which is discussed in Section 3.3) is given in Table 3.7. 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). The amount of solid manure produced in each sub-watershed was estimated based on the populations of beef cattle in the sub-watershed (Table 3.5) and their confinement schedules (Table 3.6).

Table 3.8. Estimated solid manure production characteristics.

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	340	1,400†	115‡	40§
Heifer	990	640††	40.7†	1123§
Beef*	10,988	1000†	60†	100§

†Source: ASAE (1998)
‡Source: MWPS (1993)
§Based on per capita fecal coliform production per day (Table 3.1) and manure production
††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 cropland and hay land, 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 hay land 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 1,001 acres (33%) of cropland and 304 acres (0.4%) of hayland and pasture in the Reed Creek watershed.

3.3. Sheep and Goats

The sheep and goat populations (Table 3.1) were estimated from population numbers in the 2007 Agricultural Census for Wythe County. The populations were area-weighted according to pasture areas in each sub-watershed of Reed Creek. 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 represented as being deposited directly on pasture.

Pasture in the Reed Creek watershed has average annual sheep and goat manure loadings of 31 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 1.2×10^8 cfu/ac-day.

3.4. Horses

Horse populations for the watershed were estimated from population numbers in the 2007 Agricultural Census for Wythe County. The populations were area-weighted according to pasture areas in each sub-watershed of Reed Creek. The distribution of horses among the sub-watersheds is given in Table 3.9. 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 1.3×10^6 cfu/ac-day for the Reed Creek watershed.

Table 3.9. Horse Population in the Reed Creek watershed.

Sub-watershed	Horse	Sub-watershed	Horse	Sub-watershed	Horse
1	1	24	24	47	0
2	26	25	14	48	1
3	18	26	15	49	7
4	6	27	35	50	25
5	5	28	8	51	3
6	33	29	11	52	0
7	8	30	1	53	0
8	5	31	5	54	0
9	1	32	9	55	3
10	10	33	5	56	6
11	10	34	0	57	14
12	3	35	23	58	4
13	0	36	43	59	2
14	6	37	4	60	16
15	16	38	21	61	1
16	6	39	31	62	15
17	22	40	7	63	10
18	20	41	22	64	5
19	28	42	26	65	3
20	0	43	3	66	5
21	1	44	20	67	0
22	8	45	12	68	0
23	18	46	16	69	0
Total					**725**

3.5. Wildlife

Wildlife fecal coliform contributions can come from excretion of waste on land and from excretion directly into streams. Information gleaned from the literature and 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.

Professional judgment was used in estimating the percent of each wildlife species depositing directly into streams, by considering each habitat area occupied (Table 3.10). 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 3.11 for the Reed Creek watershed.

Table 3.10. 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	30	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	300 ft buffer of main streams and impoundments on forest and pasture	10	50%
Geese	300 ft buffer around main streams and impoundments	50 – off season 70 – peak season	25%
Wood Duck	300 ft buffer around main streams and impoundments	40 – off season 60 – peak season	25%
Wild Turkey	Forest; based on kill rate per square mile of forest for Nelson county, assuming the killed birds are 10% of the total population	4	0%

Table 3.11. Wildlife populations in the Reed Creek watershed.

Sub-watershed	Deer	Raccoon	Muskrat	Beaver	Goose	Wood Duck	Wild Turkey
1	13	9	0	2	4	3	3
2	158	54	10	12	33	26	27
3	143	71	8	7	20	16	32
4	42	18	1	1	3	3	9
5	27	10	4	5	14	11	3
6	182	47	20	6	17	14	21
7	54	17	11	6	12	9	10
8	85	45	5	8	23	18	25
9	3	1	1	1	2	2	0
10	64	17	13	4	12	9	8
11	70	34	1	5	13	10	12
12	26	14	2	4	12	9	6
13	2	1	2	1	2	2	0
14	75	29	16	6	16	13	19
15	181	65	16	7	19	15	44
16	186	120	6	8	23	18	62
17	134	35	32	11	31	25	16
18	75	9	23	7	16	13	3
19	152	26	21	7	19	15	17
20	98	41	1	3	9	7	37
21	4	1	2	1	1	1	0
22	103	36	20	9	24	19	27
23	91	22	14	6	16	13	10
24	183	66	31	10	24	19	38
25	186	74	31	13	34	27	48
26	190	79	33	11	23	18	44
27	140	25	27	11	29	23	9
28	138	67	7	7	19	15	41
29	97	31	8	8	22	18	17
30	8	3	1	1	4	3	1
31	108	47	6	9	26	21	35
32	87	43	13	10	26	21	19
33	194	82	10	7	21	17	69
34	2	0	4	1	3	2	0
35	198	77	17	12	35	28	45
36	244	59	51	20	56	45	26
37	17	4	4	3	8	6	1
38	115	14	26	13	36	29	5
39	161	14	70	22	53	43	5
40	50	2	16	6	17	13	1
41	132	35	31	9	25	20	16
42	178	56	75	26	52	41	25
43	15	5	1	2	6	5	2
44	108	13	32	13	25	20	5
45	66	23	1	5	14	11	9
46	149	59	15	10	27	21	23
47	6	3	1	1	3	2	2
48	14	6	2	2	7	5	3
49	28	4	4	2	5	4	2
50	180	55	31	11	31	25	34

Sub-watershed	Deer	Raccoon	Muskrat	Beaver	Goose	Wood Duck	Wild Turkey
51	119	52	12	9	26	21	41
52	152	76	0	8	22	17	59
53	676	33	1	3	9	8	26
54	139	64	3	7	20	16	53
55	22	8	3	4	10	8	4
56	119	52	15	10	28	22	37
57	74	22	14	6	17	14	8
58	91	38	8	5	13	11	27
59	6	1	1	1	2	2	0
60	115	27	43	13	36	29	17
61	2	0	3	1	2	1	0
62	96	24	18	7	17	14	9
63	156	66	22	10	28	22	36
64	35	6	9	3	8	6	6
65	29	10	7	2	5	4	6
66	125	62	11	13	36	29	40
67	219	131	3	25	68	55	85
68	55	24	0	2	6	5	21
69	271	118	2	10	28	22	105
Total	**7,463**	**2,482**	**952**	**511**	**1,353**	**1,079**	**1,496**

3.6. 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 3.12. The estimated distribution of annual fecal coliform loading from nonpoint sources among the different land use categories is also given in Table 3.12.

From Table 3.12, 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 96%. 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 3.12. Estimated annual fecal coliform loadings to the stream and the various land use categories for the Reed Creek watershed.

Source	Fecal coliform loading ($x10^{12}$ cfu/yr)	Percent of total loading
Direct loading to streams		
Livestock in stream	298	0.9%
Wildlife in stream	64	0.2%
Straight pipes	13	<0.1%
Point Sources	12	<0.1%
Loading to land surfaces		
Cropland	6	<0.1%
Pasture	33,782	96.3%
Residential	641	1.8%
Forest	201	0.6%
Total	**35,017**	

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., 2005; Duda et al., 2001) was used to model fecal coliform transport and fate in the Reed Creek watershed. The ArcGIS 10 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 Reed Creek watershed are discussed below.

4.2.1. Climatological Data

Hourly precipitation data were obtained from NCDC's closest National Weather Service COOP station in Wytheville, located approximately 15 miles due west of the watershed outlet. Missing data were patched with data from the NCDC weather stations in Pulaski and Bland Counties. Because data for some parameters needed by HSPF were not available at Wytheville, data from the Lynchburg Regional Airport station was 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 B.

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., 2005). Initial estimates for required hydrology parameters were generated based on guidance in BASINS Technical Note 6 (USEPA, 2000); these parameters were refined during calibration. Each reach requires a function table (FTABLE) to describe the relationship between water depth, surface area, volume, and discharge (Bicknell et al., 2005). A visual assessment of stream characteristics for selected reaches within the Reed Creek watershed was completed in September 2011. Stream lengths and slopes were determined using GIS data. The procedures described in Staley et al. (2006) were used to characterize the reaches in the Reed Creek watershed using NRCS bankfull equations and digital elevation models. Information on the calculated stream geometry for each sub-watershed is presented in Table 4.1 for the bankfull conditions.

Table 4.1. Reach characteristics for Reed Creek.

Sub-watershed	Stream length (mile)	Average bankfull width (ft)	Average bankfull channel depth (ft)	Slope (ft/ft)
1	1.26	143	5.0	0.0003
2	5.82	143	5.0	0.0002
3	3.79	142	5.0	0.0004
4	0.91	141	5.0	0.0004
5	3.85	140	5.0	0.0004
6	6.55	30	1.8	0.0021
7	2.69	138	4.9	0.0003
8	3.60	138	4.9	0.0002
9	0.63	28	1.7	0.0032
10	4.49	19	1.3	0.0066
11	6.79	21	1.4	0.0079
12	3.39	135	4.8	0.0003
13	0.68	43	2.3	0.0009
14	3.03	33	1.9	0.0011
15	4.11	29	1.7	0.0028
16	8.71	29	1.7	0.0033
17	3.91	131	4.7	0.0002
18	2.07	129	4.7	0.0002
19	5.39	61	2.9	0.0008
20	5.47	22	1.4	0.0056
21	0.47	54	2.6	0.0008
22	6.96	54	2.6	0.0006
23	1.82	51	2.5	0.0012
24	5.72	29	1.8	0.0045
25	7.29	39	2.1	0.0017
26	6.30	29	1.8	0.0031
27	4.16	118	4.4	0.0002
28	5.36	26	1.6	0.0114
29	5.11	114	4.3	0.0002
30	4.22	17	1.2	0.0048
31	4.79	112	4.3	0.0003
32	5.90	111	4.2	0.0003
33	7.22	30	1.8	0.0070
34	0.85	43	2.3	0.0012
35	11.25	31	1.8	0.0031
36	13.93	33	1.9	0.0018
37	2.19	101	4.0	0.0005
38	10.84	51	2.5	0.0010
39	11.41	47	2.4	0.0005
40	4.68	19	1.3	0.0014
41	5.17	37	2.1	0.0005
42	5.99	29	1.8	0.0077
43	1.63	91	3.7	0.0004
44	6.99	25	1.6	0.0034

Sub-watershed	Stream length (mile)	Average bankfull width (ft)	Average bankfull channel depth (ft)	Slope (ft/ft)
45	4.01	88	3.7	0.0004
46	10.08	28	1.7	0.0023
47	0.83	84	3.5	0.0005
48	1.86	84	3.5	0.0004
49	1.56	52	2.6	0.0012
50	0.85	51	2.5	0.0016
51	5.20	44	2.3	0.0011
52	8.14	27	1.7	0.0066
53	2.65	31	1.8	0.0008
54	4.38	26	1.6	0.0094
55	3.08	70	3.1	0.0004
56	7.14	24	1.5	0.0067
57	5.06	67	3.1	0.0004
58	1.06	66	3.0	0.0004
59	0.77	40	2.2	0.0004
60	3.86	40	2.2	0.0012
61	0.58	34	2.0	0.0002
62	4.75	23	1.5	0.0024
63	6.75	27	1.7	0.0049
64	2.26	52	2.6	0.0003
65	3.64	13	1.0	0.0066
66	4.25	50	2.5	0.0006
67	7.39	31	1.8	0.0069
68	1.01	37	2.0	0.0005
69	9.61	34	1.9	0.0053

Required water quality parameters are also given in the HSPF User's Manual (Bicknell et al., 2005). Initial estimates for bacteria loading parameters in Reed 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 Spring Flows and Withdrawals

As previously mentioned (Section 2.6), Reed Creek has two significant springs that contribute to its flow even during times of drought. The spring inputs were modeled as constant values as shown in Table 4.2.

Table 4.2 Discharge rates of springs used for modeling Reed Creek.

Spring	Approximate discharge rate (cfs)	Discharge rate used for modeling (cfs)
Wyrick Spring	0.13 – 0.38	0.133
Harkrader (Boiling) Spring	5.01 – 5.90	5.009

The Town of Wytheville withdraws water from Reed Creek in reach 32 at the Wytheville Water Filtration Plant. The monitored total monthly withdrawals from 1990 to 2011 were evenly divided by the days in each month to get average daily withdrawals. These were put directly into the model as a time-dependent withdrawal from sub-watershed 32.

4.4. Accounting for Pollutant Sources

4.4.1. Overview

There are eleven VPDES facilities currently in operation that are permitted to discharge bacteria within the Reed Creek study area. There are four single family domestic sewage discharges. During calibration and validation, reported bacteria concentrations discharged by these facilities were used as input to the model. During future conditions, loads from the facilities were modeled at their design flows and bacteria concentrations at their permitted limits (126 cfu/100 mL) (Table 3.2).

Bacteria loads that are 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.

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.

4.4.2. Modeling fecal coliform die-off

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

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

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 Reed 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	Crane and Moore (1986)
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.

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.

4.4.3. 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. The sources of fecal coliform to different land use categories and how the model handled them are briefly discussed below.

1. Cropland and Hayland: Liquid and solid manure is applied to cropland and hayland 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 and hayland 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 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. 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 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. 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.

4.4.4. 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 and sewage spills. 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 8 cfu/100mL for interflow and 4 cfu/100mL for groundwater for most of the watershed.

4.5. 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.

4.5.1. Hydrology

The HSPEXP decision support system developed by USGS was used to calibrate the hydrologic portion of HSPF for Reed Creek. The default HSPEXP criteria for evaluating the accuracy of the flow simulation were used in the calibration for Reed Creek. These criteria are listed in Table 4.4. After calibration, all criteria listed in Table 4.4 were met.

Table 4.4. Default criteria for HSPEXP.

Variable	Percent Error Criteria
Total Volume	10%
50% Lowest Flows	10%
10% Highest Flows	15%
Storm Peaks	15%
Seasonal Volume Error	10%
Summer Storm Volume Error	15%

The hydrologic calibration period was January 1, 1991 to December 31, 1998. The hydrologic validation period was from January 1, 2001 to December 31, 2005. The output from the HSPF model for both calibration and validation was daily average flow in cubic feet per second (cfs). Calibration parameters were adjusted within the recommended range (USEPA, 2000).

The simulated flow for both the calibration and validation matched the observed flow well, as shown in Figure 1.1Figure 4.1 and Figure 4.2. The agreement with observed flows is further illustrated in Figure 4.3 and Figure 4.4 for a representative year and Figure 4.5 and Figure 4.6 for a representative storm. The agreement between the simulated and observed time series can be further seen through the comparison of their cumulative frequency curves (Figure 4.7 and Figure 4.8).

Selected diagnostic output from the HSPEXP program is listed in Table 4.5 and Table 4.6. The total winter runoff and total summer runoff errors are considered in the HSPEXP term 'seasonal volume error' (see Table 4.5). The errors for seasonal volume error were 5.0% for the calibration period and 6.9% for the validation period; both are within the required range of ±10%.

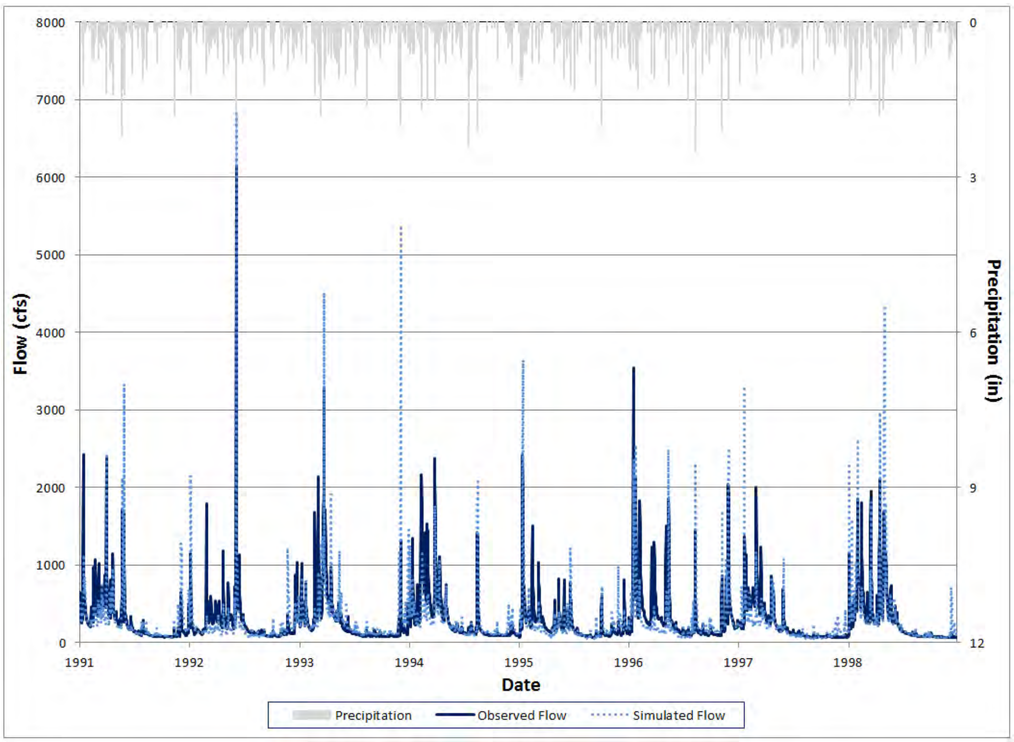

Figure 4.1. Observed and simulated flows and precipitation for Reed Creek for the calibration period.

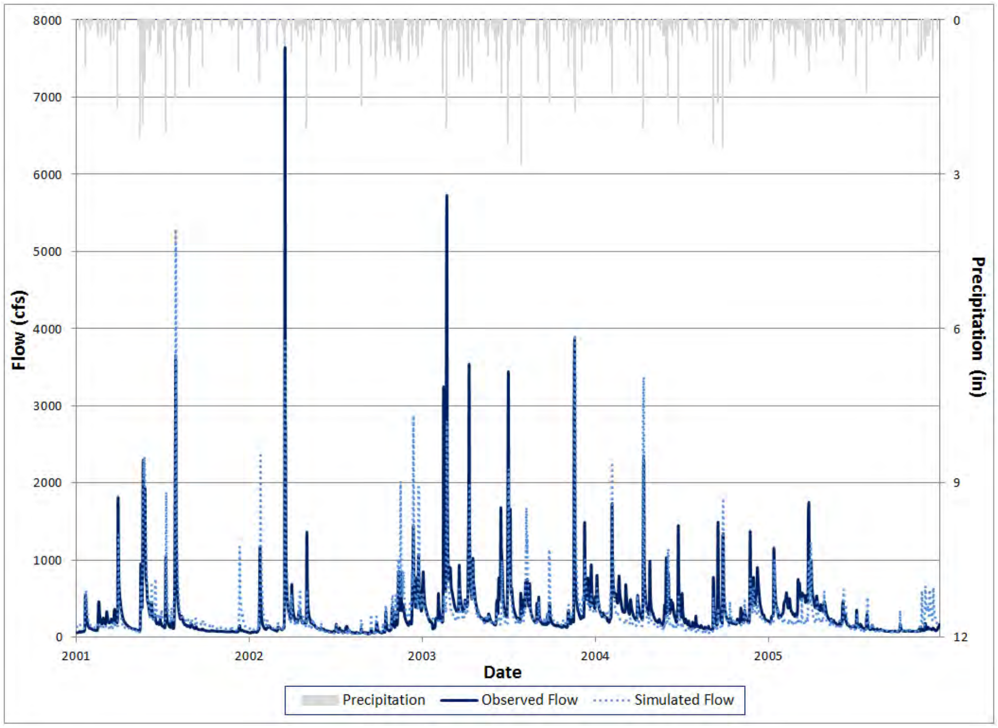

Figure 4.2. Observed and simulated flows and precipitation for Reed Creek during the validation period.

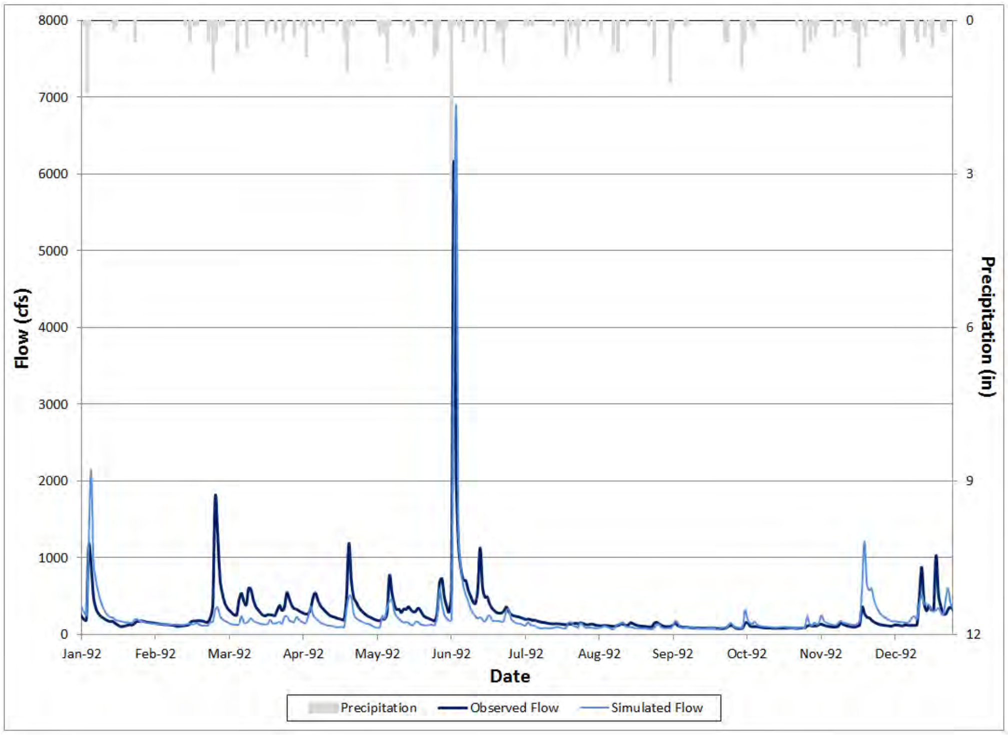

Figure 4.3. Observed and simulated flows and precipitation for a representative year in the calibration period for Reed Creek.

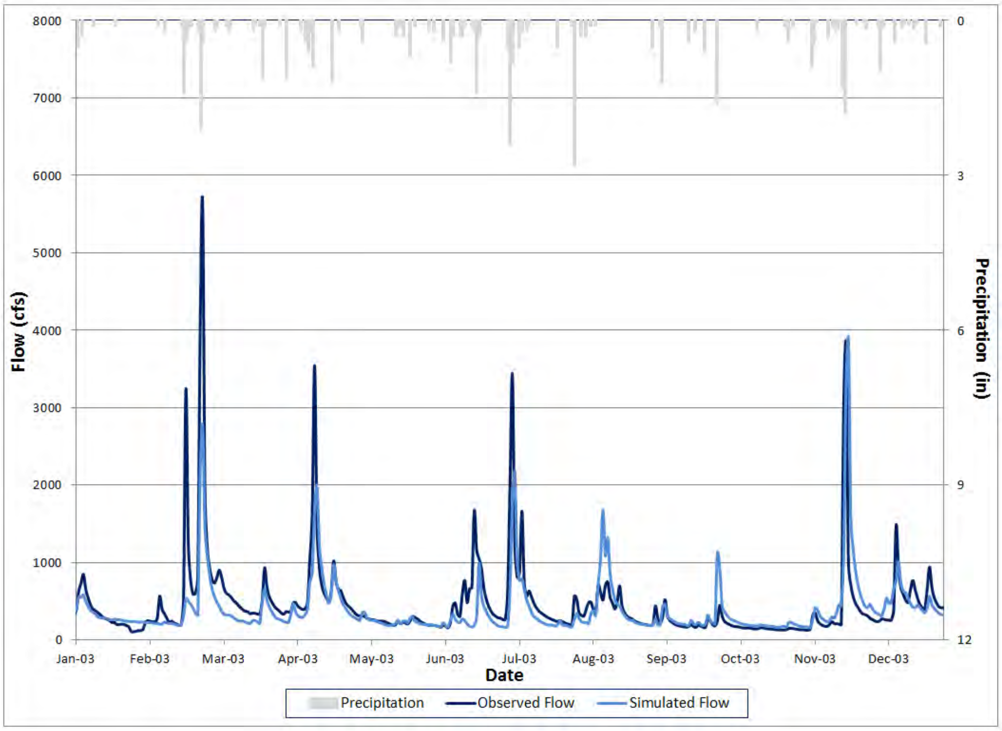

Figure 4.4. Observed and simulated flows and precipitation for Reed Creek during a representative year in the validation period.

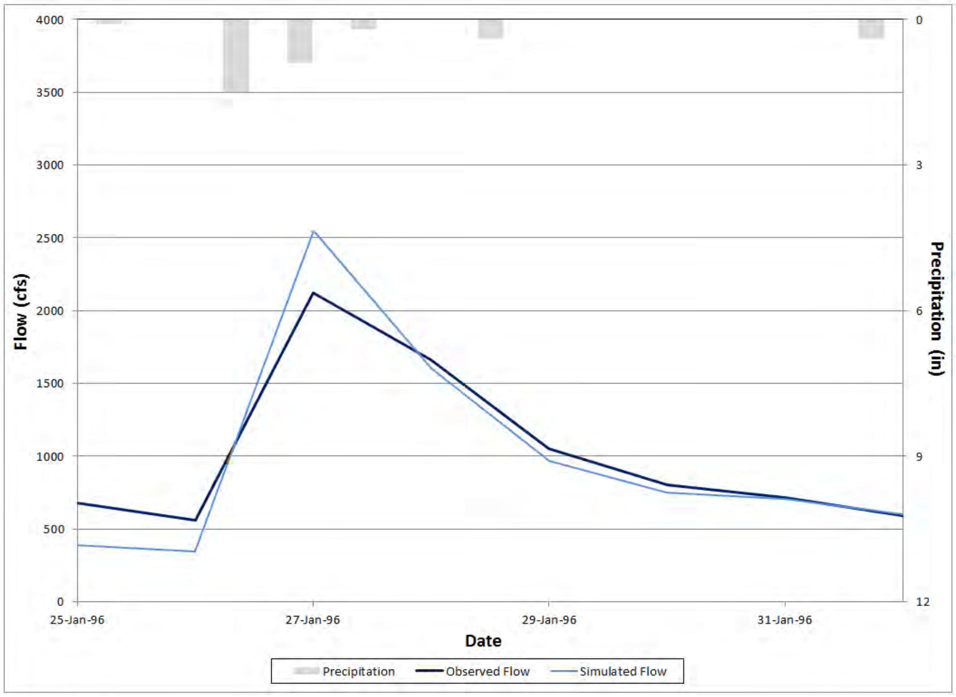

Figure 4.5. Observed and simulated flows and precipitation for Reed Creek for a representative storm in the calibration period.

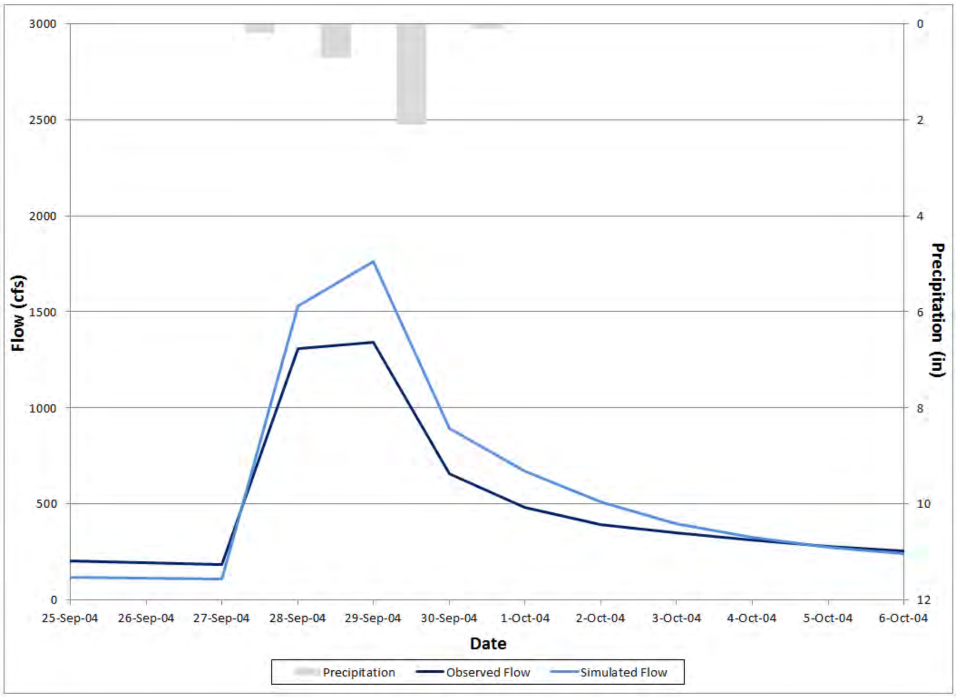

Figure 4.6. Observed and simulated flows and precipitation for Reed Creek for a representative storm in the validation period.

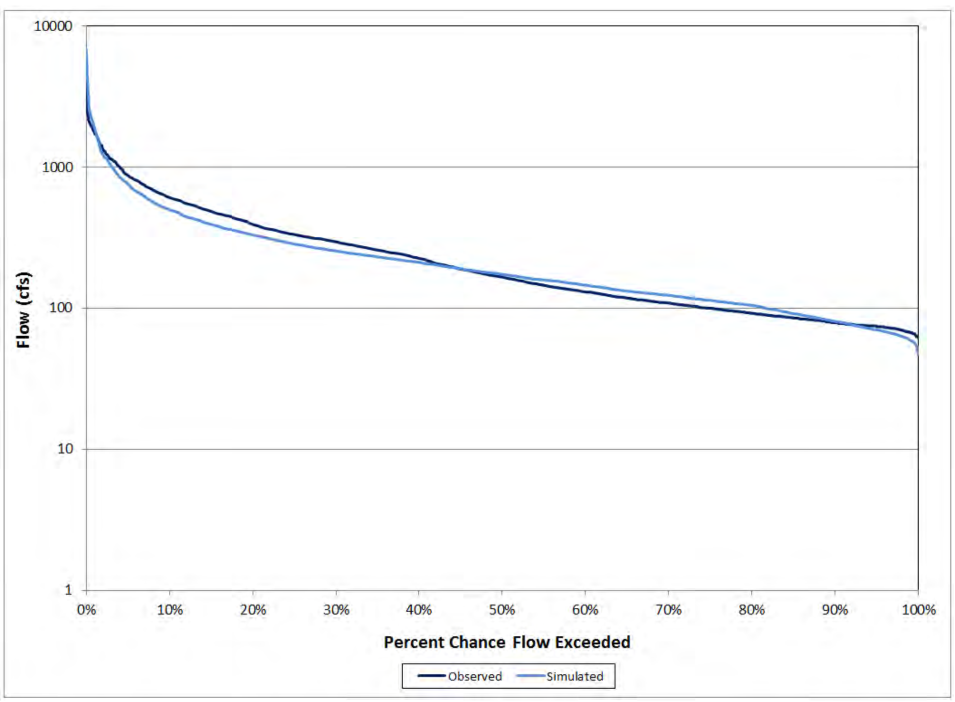

Figure 4.7 Cumulative frequency curves for the calibration period for Reed Creek.

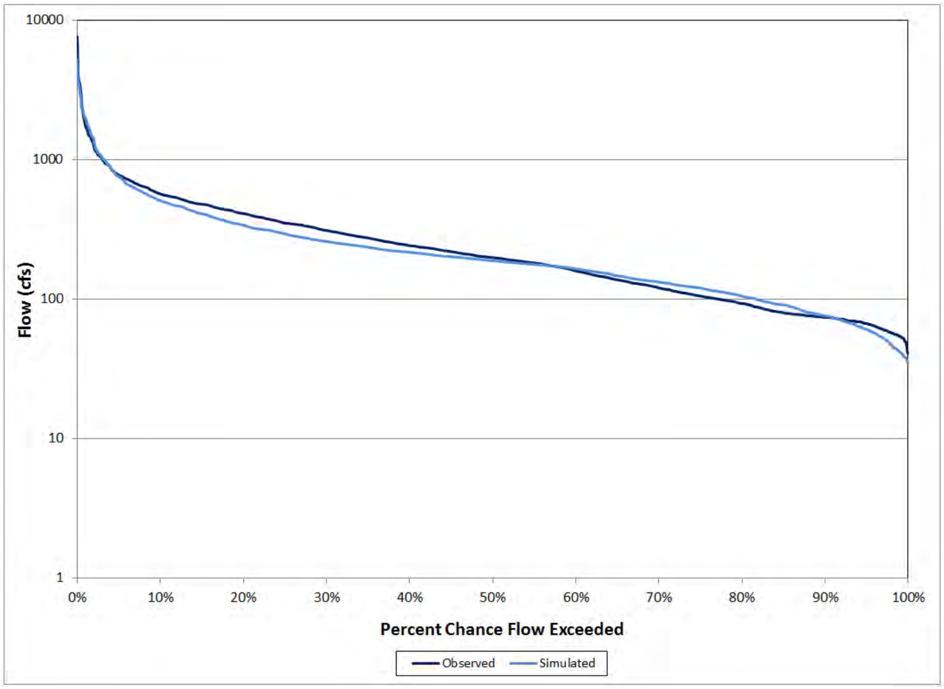

Figure 4.8. Cumulative frequency curves for the validation period for Reed Creek.

Table 4.5. Summary statistics for the calibration for Reed Creek.

	Simulated	Observed	Error (%)	Criterion
Total Runoff (in)	114.200	121.398	-5.9	10%
Average Annual Total Runoff (in)	14.275	15.175	-5.9	10%
Total of Highest 10% of flows (in)	43.250	45.073	-4.0	15%
Total of Lowest 50% of flows (in)	23.970	22.154	8.2	10%
Total Winter Runoff (in)	39.890	40.480	-1.5	na
Total Summer Runoff (in)	19.980	19.309	3.5	na
Coefficient of Determination, r^2	0.496			

na = not applicable; these are not criteria directly considered by HSPEXP

Table 4.6. Summary statistics for the validation period for Reed Creek.

	Simulated	Observed	Error (%)	Criterion
Total Runoff (in)	73.640	79.011	-6.8	10%
Average Annual Total Runoff (in)	14.728	15.802	-6.8	10%
Total of Highest 10% of flows (in)	27.620	28.609	-3.5	15%
Total of Lowest 50% of flows (in)	15.690	15.106	3.9	10%
Total Winter Runoff (in)	21.680	21.966	-1.3	na
Total Summer Runoff (in)	16.040	17.475	-8.2	na
Coefficient of Determination, r^2	0.545			

na = not applicable; these are not criteria directly considered by HSPEXP

Flow partitioning for the Reed Creek hydrologic model calibration and validation is shown in Table 4.7. When the observed flow data were evaluated using Baseflow Program (Arnold, 1999), the baseflow indices for the calibration and validation periods were 0.62 and

0.60, respectively. The baseflow indices for the simulated data are presented in Table 4.7. The simulated baseflow indices shown in Table 4.7 match the observed values well. The final calibrated hydrology parameters are shown in Table 4.8.

Table 4.7. Flow partitioning for the calibration and validation periods for Reed Creek.

Average Annual Flow	Calibration	Validation
Total Runoff (in)	14.28	14.73
Total Surface Runoff (in)	2.32 (16.25%)	2.28 (15.48%)
Total Interflow (in)	4.01 (28.08%)	4.17 (28.31%)
Total Baseflow (in)	7.95 (55.67%)	8.28 (56.21%)
Baseflow Index	0.62	0.60

Table 4.8. Hydrology parameters for Reed Creek.

Parameter	Definition	Units	FINAL CALIBRATION	FUNCTION OF…	Appendix C Table (if applicable)
PERLND					
PWAT-PARM2					
FOREST	Fraction forest cover	none	1.0	Forest cover	
LZSN	Lower zone nominal soil moisture storage	inches	7.0	Soil properties	
INFILT	Index to infiltration capacity	in/hr	0.020 – 0.138	Soil and cover conditions	
LSUR	Length of overland flow	feet	8 – 907.4	Topography	
SLSUR	Slope of overland flowplane	none	0.0240 – 0.4255	Topography	
KVARY	Groundwater recession variable	1/in	0.0	Calibrate	
AGWRC	Base groundwater recession	none	0.990 – 0.999	Calibrate	
PWAT-PARM3					
PETMAX	Temp below which ET is reduced	deg. F	40	Climate, vegetation	
PETMIN	Temp below which ET is set to zero	deg. F	35	Climate, vegetation	
INFEXP	Exponent in infiltration equation	none	2	Soil properties	
INFILD	Ratio of max/mean infiltration capacities	none	2	Soil properties	
DEEPFR	Fraction of GW inflow to deep recharge	none	0.01 – 0.05	Geology	
BASETP	Fraction of remaining ET from baseflow	none	0.05 – 0.2	Riparian vegetation	
AGWETP	Fraction of remaining ET from active GW	none	0.01 – 0.2	Marsh/wetlands ET	

Parameter	Definition	Units	FINAL CALIBRATION	FUNCTION OF…	Appendix C Table (if applicable)
PWAT-PARM4					
CEPSC	Interception storage capacity	inches	monthly[a]	Vegetation	1
UZSN	Upper zone nominal soil moisture storage	inches	monthly[a]	Soil properties	2
NSUR	Mannings' n (roughness)	none	0.15 forest; 0.35 residential; 0.20 pasture and cropland; 0.10 water	Land use, surface condition	
INTFW	Interflow/surface runoff partition parameter	none	2.0	Soils, topography, land use	
IRC	Interfiow recession parameter	none	0.70	Soils, topography, land use	
LZETP	Lower zone ET parameter	none	monthly[a]	Vegetation	3
IMPLND					
IWAT-PARM2					
LSUR	Length of overland flow	feet	150	Topography	
SLSUR	Slope of overland flowplane	none	0.140	Topography	
NSUR	Mannings' n (roughness)	none	0.3	Land use, surface condition	
RETSC	Retention/inter-ception storage capacity	inches	0.070	Land use, surface condition	
IWAT-PARM3					
PETMAX	Temp below which ET is reduced	deg. F	40	Climate, vegetation	
PETMIN	Temp below which ET is set to zero	deg. F	35	Climate, vegetation	
RCHRES					
HYDR-PARM2					
KS	Weighting factor for hydraulic routing		0.5		

[a]Varies by month and with land use

The calibration met all the acceptance criteria in both the calibration and the validation period. This indicates that the developed hydrologic model provides an acceptable prediction of Reed Creek flows.

4.5.2. Water Quality

The water quality calibration for the Reed 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 Figure 2.1 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. In order to separate the variability in the regression equation from the variability due to uncertainties in the HSPF model, *E. coli* data were not used during calibration, but were used for visual assessment as a method of 'validating' the model.

Using this method, we have more confidence in the final water quality parameters obtained as a result of the calibration. Thus, VADEQ monitoring station 9-RDC009.00 was the only station used for the calibration. Station 9-RDC009.00 had a large enough dataset that allowed for both calibration and validation using fecal coliform data. As a validation, the *E. coli* predictions from the model were visually compared with *E. coli* data collected at fourteen VADEQ stations of 9-CVR003.88, 9-MER000.09, 9-RDC000.79, 9-RDC023.24, 9-GLN000.13, 9-MCE000.37, 9-RDC033.78, 9-RDC038.01, 9-RDC046.65, 9-RDC049.82, 9-RSF000.08, 9-SFK000.28, 9-SFK001.51 and 9-TAT000.46 as well as the station 9-RDC009.00 for fecal coliform.

The period of January 1, 2000 to June 30, 2003 was selected for calibration of 9-RDC009.00. The validation period for fifteen stations for *E. coli* was July 1, 2003 to June 15, 2005 and 9-RDC009.00 for fecal coliform was January 1, 1990 to December 31, 1997. Output from the HSPF model was generated as an hourly time series and daily average time series of fecal coliform concentration at the sub-watershed outlets that correspond to the locations of stations 9-RDC009.00, 9-CVR003.88, 9-MER000.09, 9-RDC000.79, 9-RDC023.24, 9-GLN000.13, 9-MCE000.37, 9-RDC033.78, 9-RDC038.01, 9-RDC046.65, 9-RDC049.82, 9-RSF000.08, 9-SFK000.28, 9-SFK001.51 and 9-TAT000.46.

To represent the *E. coli* concentrations during validation and later during allocation, the VADEQ *E. coli* translator (Eqn. 4.2) was implemented using the GENER block in HSPF to calculate instream *E. coli* concentration. The geometric mean of *E. coli* concentrations was 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 Reed Creek watershed were typically collected through grab samples collected on a monthly or bimonthly 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

Initial model predictions of fecal coliform concentrations were high. Several input parameters were altered during the calibration process. These parameters included: the washoff factor (WSQOP); fecal coliform production rates for livestock, human, pets, and wildlife; and the first order decay rate (FSTDEC). 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 monitoring station are listed in Table 4.9. Based on the goodness-of-fit parameter values and the visual comparison (Figure 4.9), the water quality calibration was considered acceptable.

Table 4.9. Water quality calibration statistics for Reed Creek at station 9-RDC009.00

	Geometric Mean cfu/100ml	Average* cfu/100ml	Median* cfu/100ml	Single Sample Criterion Violation Rate (%)
Observed	85	351	100	15
Simulated	224	421	223	22

* 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.

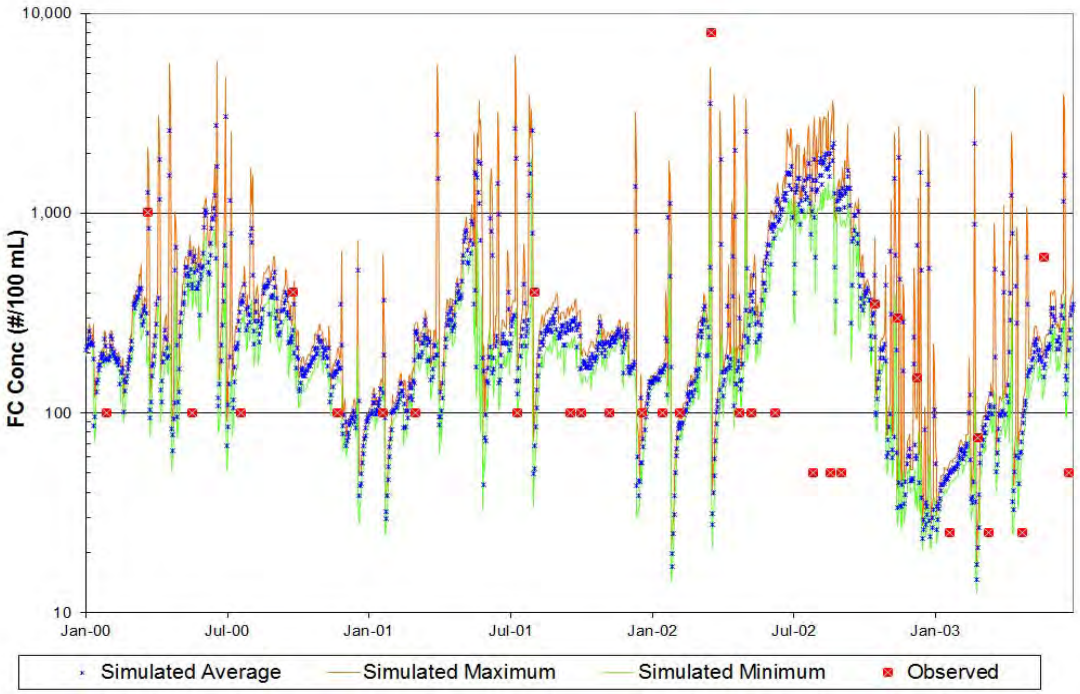

Figure 4.9. Observed fecal coliform data plotted with the daily maximum, minimum, and average simulated fecal coliform values for Reed Creek (9-RDC009.00) for the calibration period (January 1, 2000 to June 30, 2003).

Validation

After the calibration of Reed Creek at VADEQ monitoring station 9-RDC009.00, the model output was compared to fecal coliform data from station 9-RDC009.00 for a different period (January 1, 1990 to June 30, 1997) as a validation to ensure the calibrated input parameters were appropriate. The goodness-of-fit statistics for the validation run are listed in Table 4.10. Figure 4.10 shows the daily minimum, maximum, and average of the simulated fecal coliform 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 Reed Creek at monitoring station 9-RDC009.00 were considered acceptable.

Table 4.10. Summarized goodness-of-fit measures for simulated and observed fecal coliform concentrations for the validation period for Reed Creek at station 2-RFS001.00.

	Geometric Mean cfu/100ml	Average* cfu/100ml	Median* cfu/100ml	Single Sample Criterion Violation Rate (%)
Observed	173	786	100	24
Simulated	212	382	354	30

* 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.

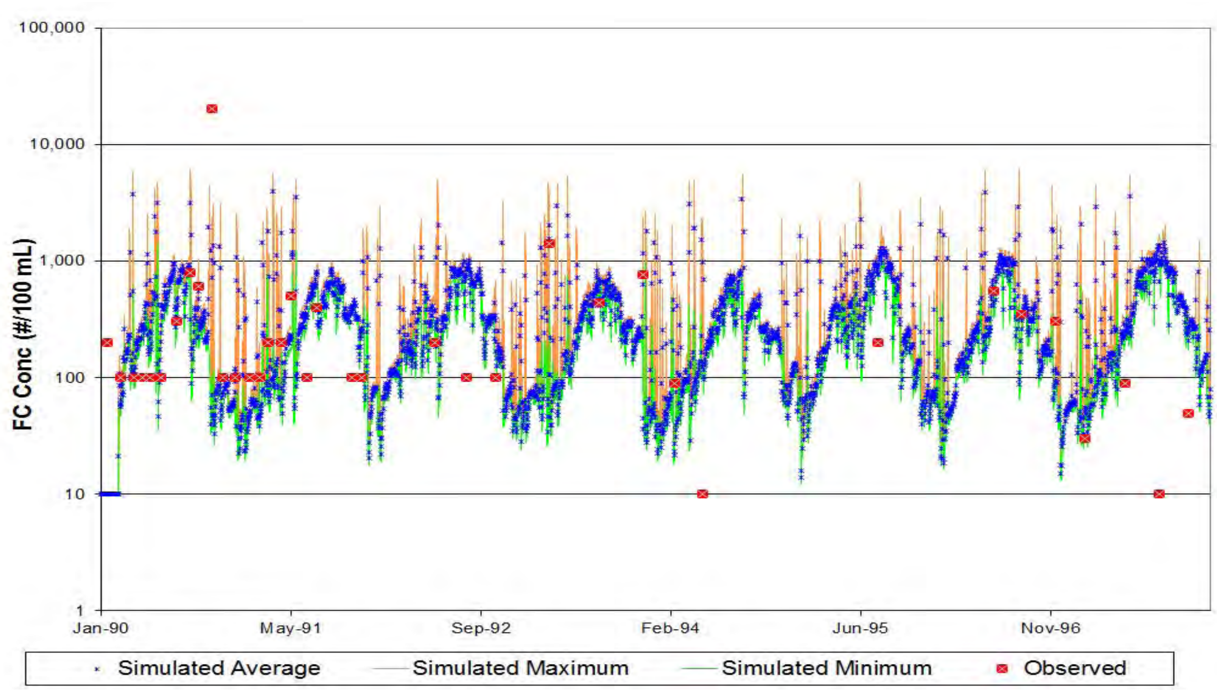

Figure 4.10. Observed fecal coliform data plotted with the daily maximum, minimum, and average simulated fecal coliform values for Reed Creek (9-RDC009.00) for the validation period (January 1, 1990 to June 30, 1997).

Additional 'validation' included visually comparing simulated *E. coli* concentrations with observed *E. coli* data from fourteen stations of 9-CVR003.88, 9-MER000.09, 9-RDC000.79, 9-RDC023.24, 9-GLN000.13, 9-MCE000.37, 9-RDC033.78, 9-RDC038.01, 9-RDC046.65, 9-RDC049.82, 9-RSF000.08, 9-SFK000.28, 9-SFK001.51 and 9-TAT000.46. The translated and observed *E. coli* data were plotted (Figure 4.11 – Figure 4.24)) to verify that the simulated *E. coli* concentrations approximated the observed values. The validation period was July 2003 through June 2005. The simulated data match well with the observed *E. coli* concentrations. The final calibrated water quality parameters are given in Table 4.11.

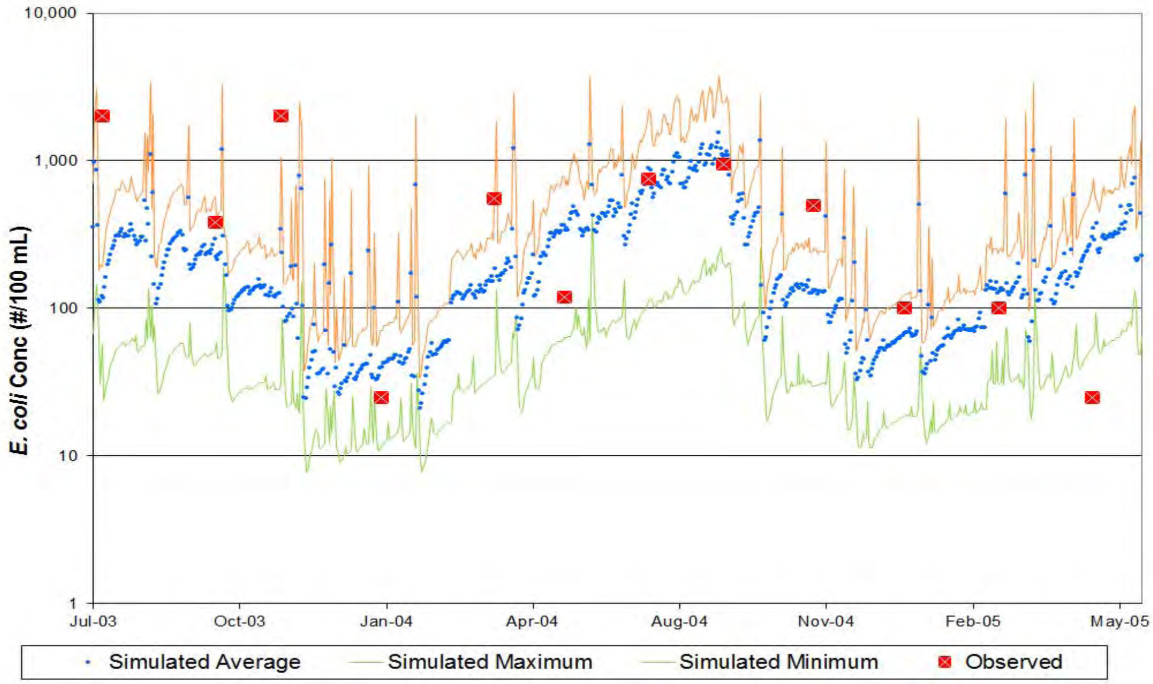

Figure 4.11. Observed *E. coli* data plotted with the daily maximum, minimum, and average *E. coli* values (translated from simulated fecal coliform values) for Cove Creek (9-CVR003.88) for the validation period (July 1, 2003 through June 15, 2005).

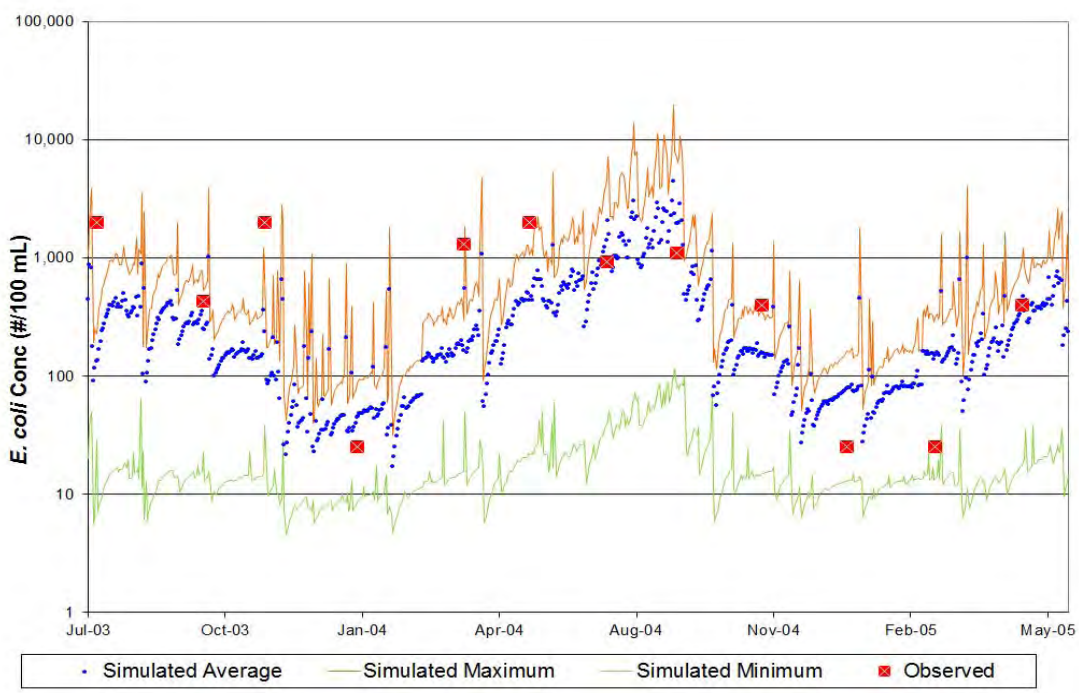

Figure 4.12. Observed *E. coli* data plotted with the daily maximum, minimum, and average *E. coli* values (translated from simulated fecal coliform values) for Miller Creek (9-MER000.09) for the validation period (July 1, 2003 through June 15, 2005).

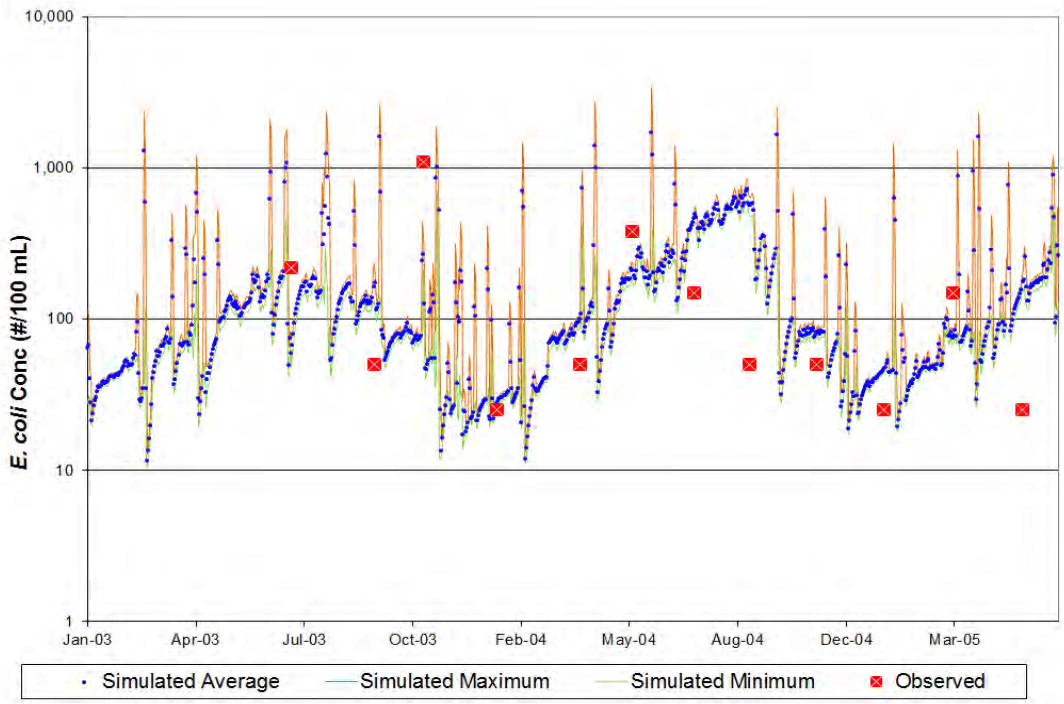

Figure 4.13. Observed *E. coli* data plotted with the daily maximum, minimum, and average *E. coli* values (translated from simulated fecal coliform values) for Reed Creek (9-RDC000.79) for the validation period (July 1, 2003 through June 15, 2005).

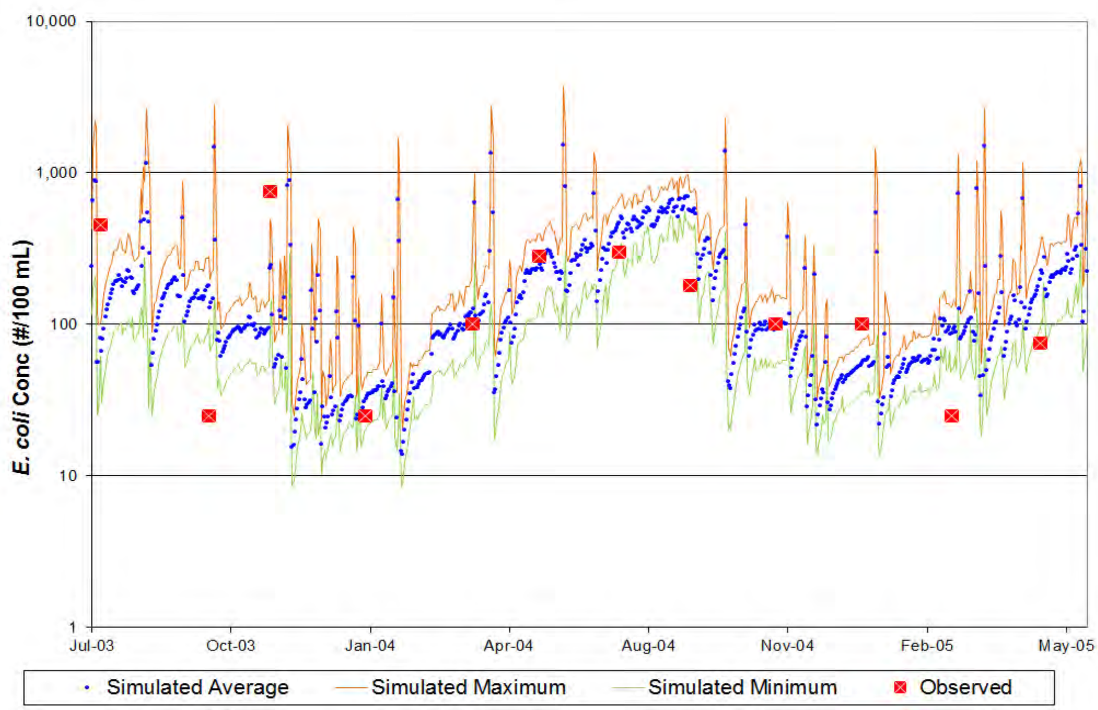

Figure 4.14. Observed *E. coli* data plotted with the daily maximum, minimum, and average *E. coli* values (translated from simulated fecal coliform values) for Reed Creek (9-RDC023.24) for the validation period (July 1, 2003 through June 15, 2005).

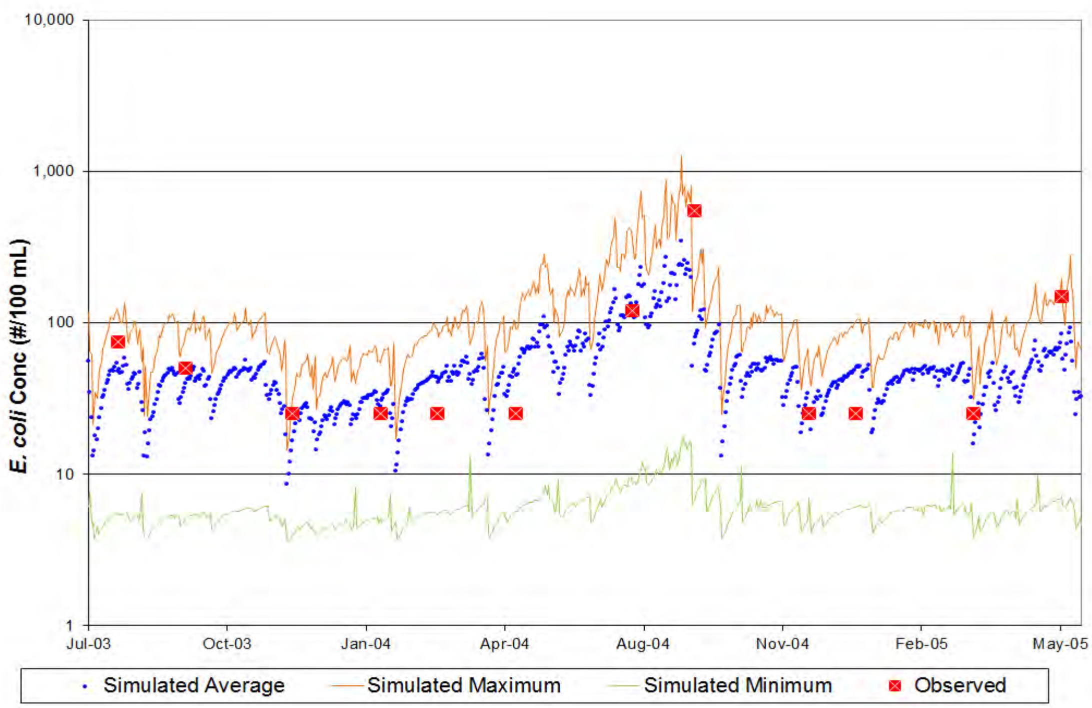

Figure 4.15. Observed *E. coli* data plotted with the daily maximum, minimum, and average *E. coli* values (translated from simulated fecal coliform values) for Gullion Fork (9-GLN000.13) for the validation period (July 1, 2003 through June 15, 2005).

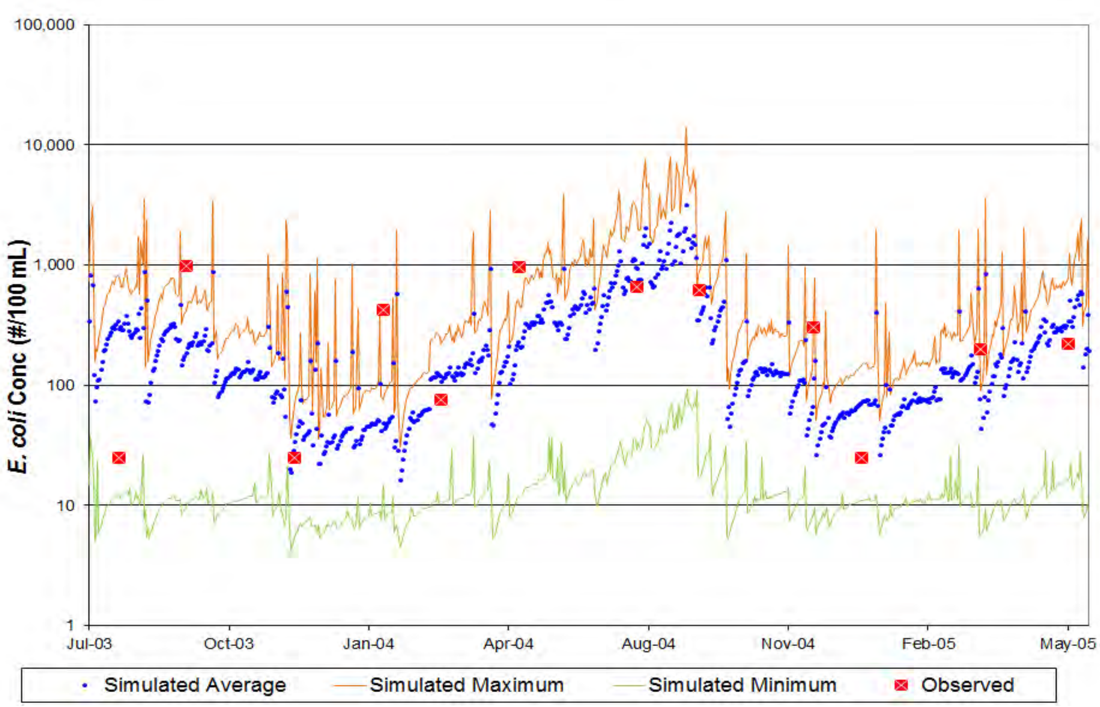

Figure 4.16. Observed *E. coli* data plotted with the daily maximum, minimum, and average *E. coli* values (translated from simulated fecal coliform values) for Mill Creek (9-MCE000.37) for the validation period (July 1, 2003 through June 15, 2005).

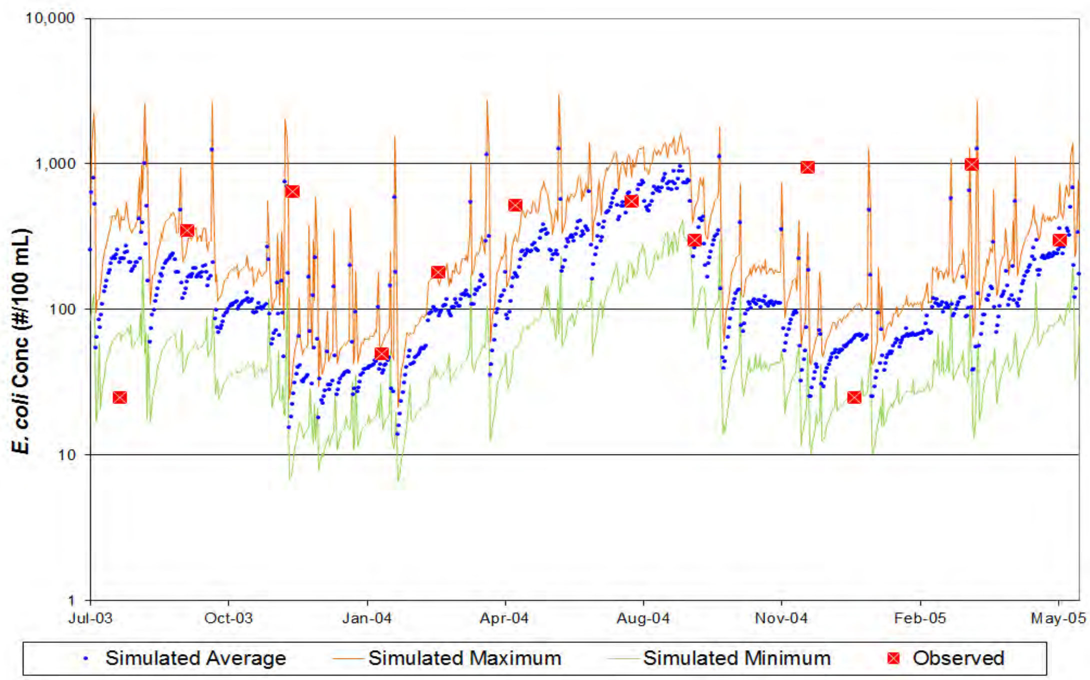

Figure 4.17. Observed *E. coli* data plotted with the daily maximum, minimum, and average *E. coli* values (translated from simulated fecal coliform values) for Reed Creek (9-RDC033.78) for the validation period (July 1, 2003 through June 15, 2005).

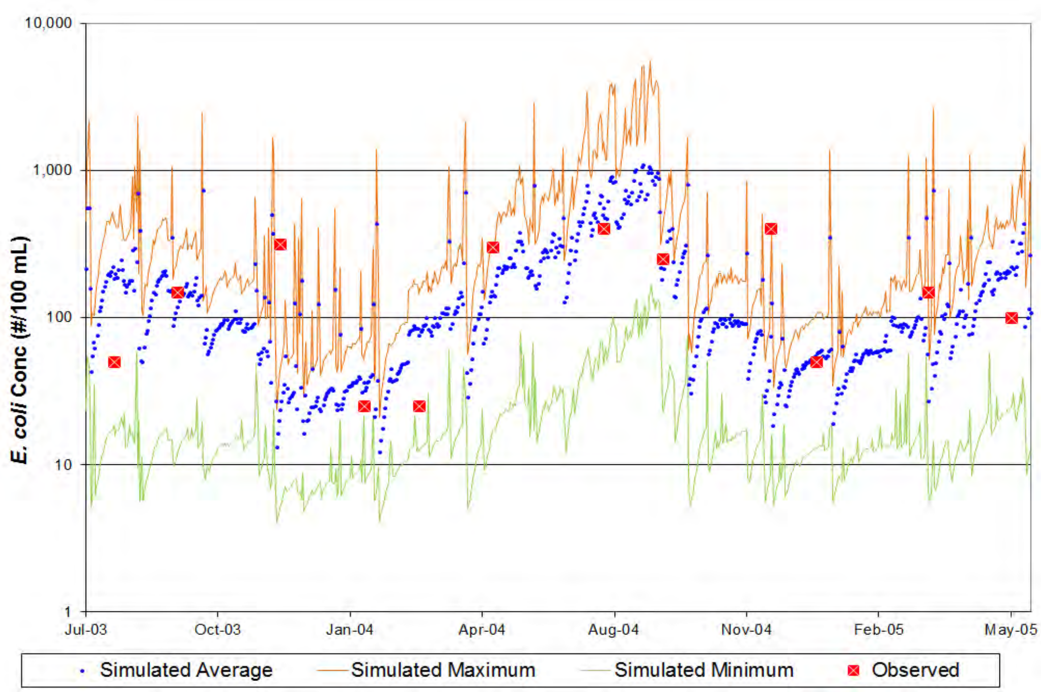

Figure 4.18. Observed *E. coli* data plotted with the daily maximum, minimum, and average *E. coli* values (translated from simulated fecal coliform values) for Reed Creek (9-RDC038.01) for the validation period (July 1, 2003 through June 15, 2005).

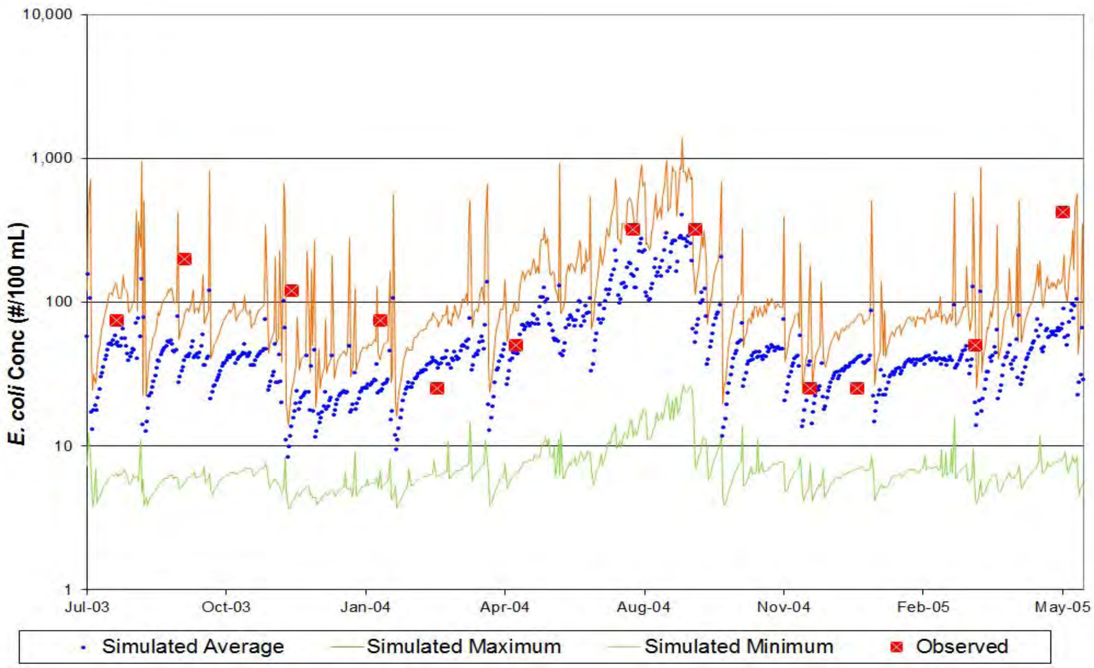

Figure 4.19. Observed *E. coli* data plotted with the daily maximum, minimum, and average *E. coli* values (translated from simulated fecal coliform values) for Reed Creek (9-RDC046.65) for the validation period (July 1, 2003 through June 15, 2005).

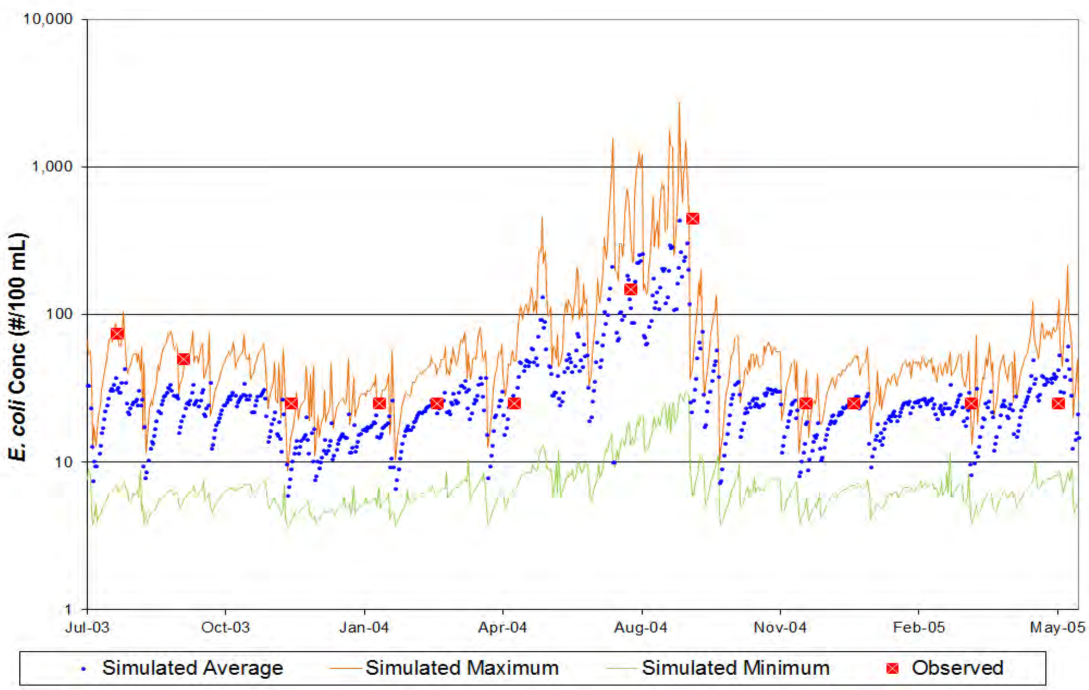

Figure 4.20. Observed *E. coli* data plotted with the daily maximum, minimum, and average *E. coli* values (translated from simulated fecal coliform values) for Reed Creek (9-RDC049.82) for the validation period (July 1, 2003 through June 15, 2005).

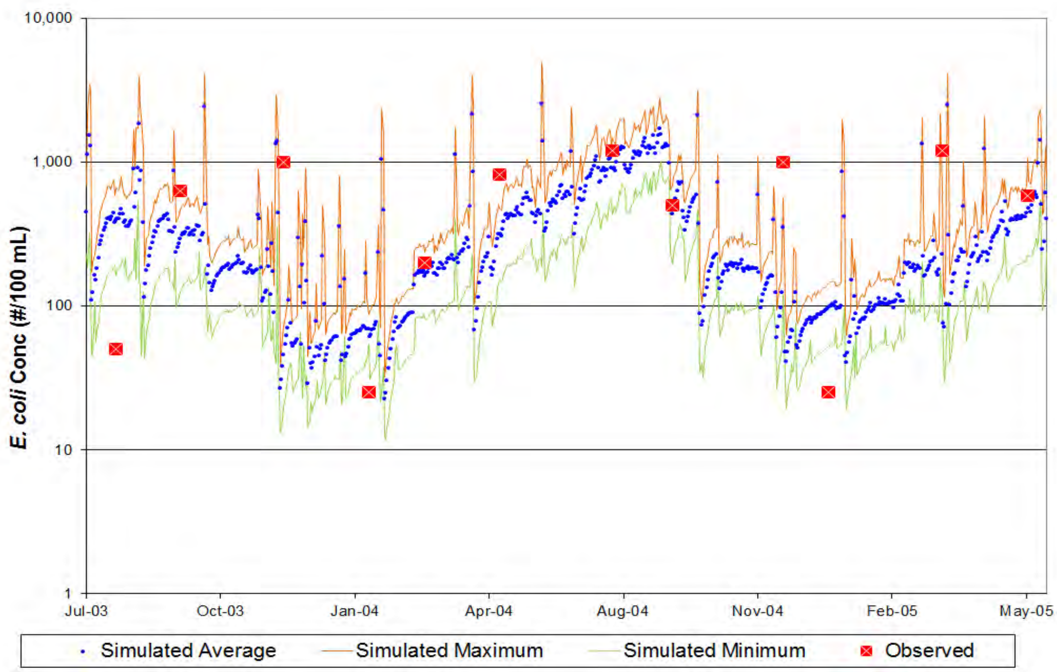

Figure 4.21. Observed *E. coli* data plotted with the daily maximum, minimum, and average *E. coli* values (translated from simulated fecal coliform values) for South Fork Reed Creek (9-RDC000.08) for the validation period (July 1, 2003 through June 15, 2005).

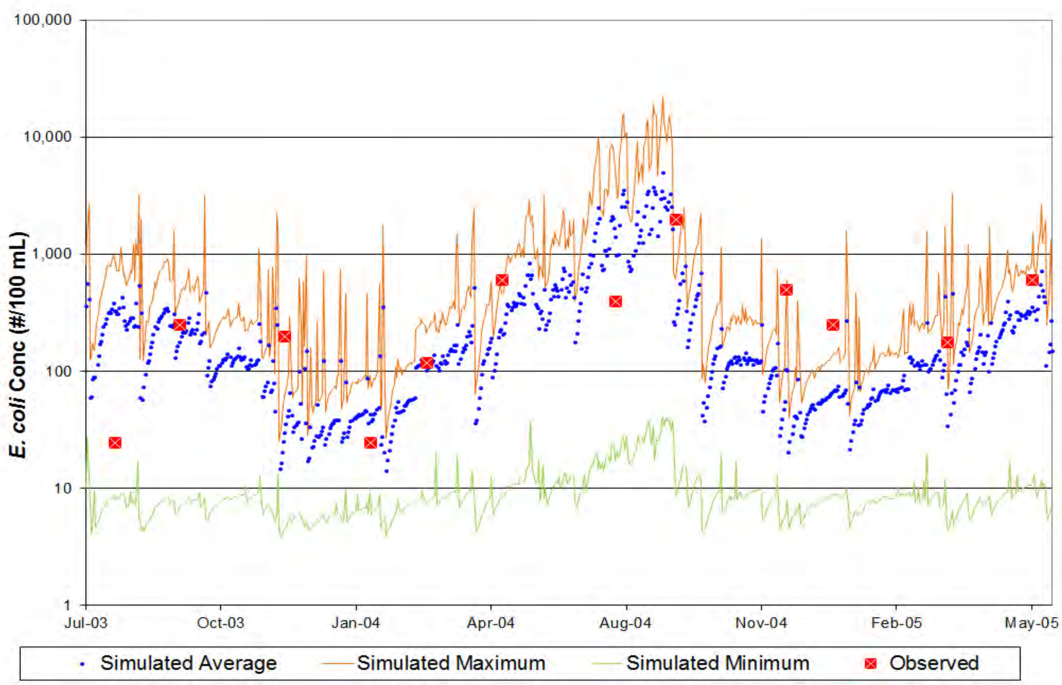

Figure 4.22. Observed *E. coli* data plotted with the daily maximum, minimum, and average *E. coli* values (translated from simulated fecal coliform values) for Stony Fork (9-SFK000.28) for the validation period (July 1, 2003 through June 15, 2005).

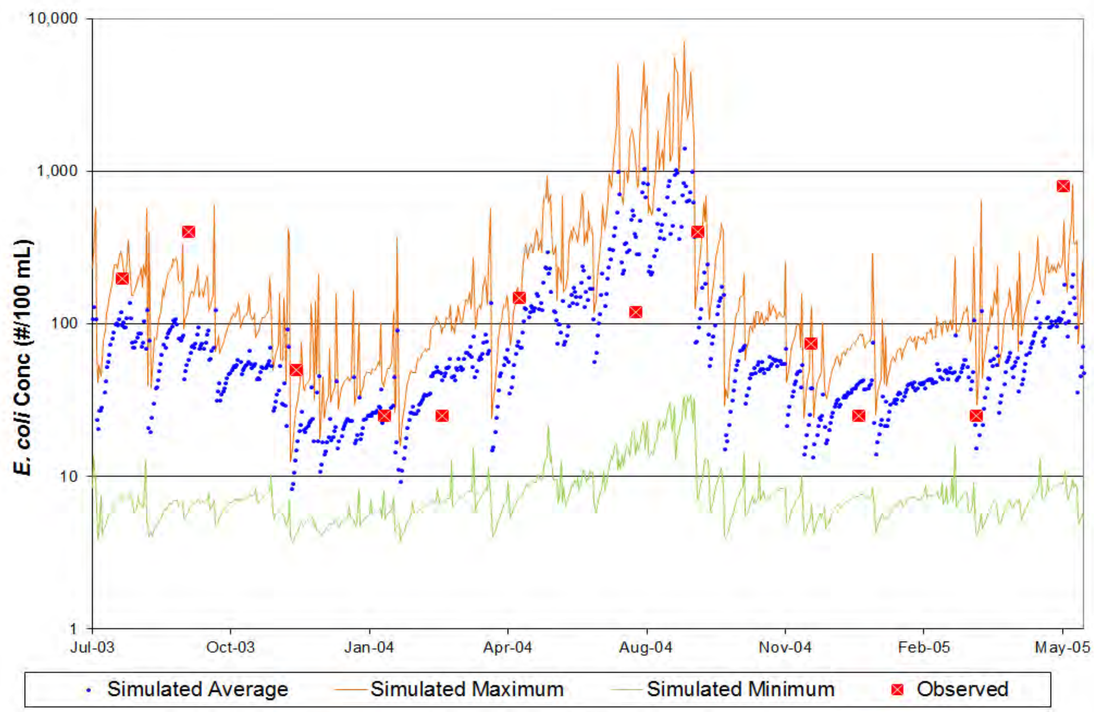

Figure 4.23. Observed *E. coli* data plotted with the daily maximum, minimum, and average *E. coli* values (translated from simulated fecal coliform values) for Stony Fork (9-SFK001.51) for the validation period (July 1, 2003 through June 15, 2005).

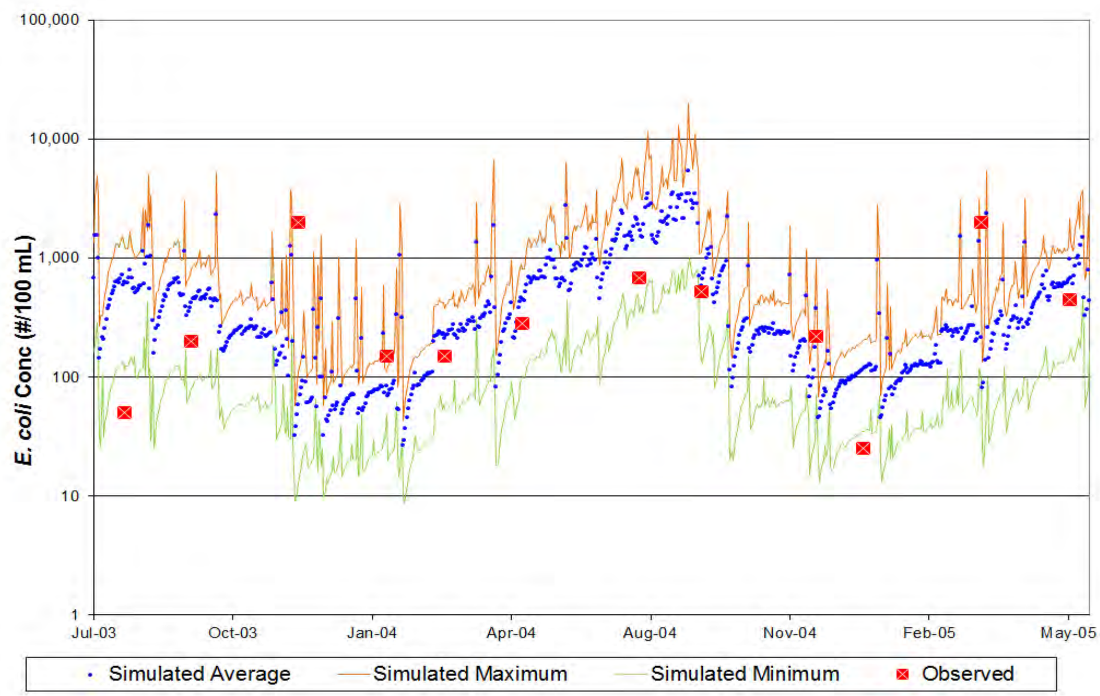

Figure 4.24. Observed *E. coli* data plotted with the daily maximum, minimum, and average *E. coli* values (translated from simulated fecal coliform values) for Tate Run (9-TAT000.46) for the validation period (July 1, 2003 through June 15, 2005).

Table 4.11. Calibrated bacteria water quality parameters for the Reed Creek watershed.

Parameter	Definition	Units	FINAL CALIBRATION	FUNCTION OF…	Appendix C 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	3
SQOLIM	Maximum accumulation of constituent	#	9 x ACQOP[a]	Land use	4
WSQOP	Wash-off rate	in/hr	1.4	Land use	
IOQC	Constituent conc. in interflow	$\#/ft^3$	2236		
AOQC	Constituent conc. in active groundwater	$\#/ft^3$	1118		
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	3.15 for tributaries; 10.15 for mainstream		
THFST	Temperature correction coeff. for FSTDEC		1.87		

[a]Values varied by month and with land use

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 Reed 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 was a calendar-month geometric mean of 126 cfu/100 mL. 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.

A TMDL accounts for critical conditions, seasonal variations and must include a margin of safety (MOS).

5.1.1. Margin of Safety

A MOS is factored into a TMDL to account for model uncertainty. The MOS can be either explicit, as an additional load reduction requirement, or implicit, which incorporates conservative assumptions within the application of the TMDL model. 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.

5.1.2. Translating Fecal Coliform to *E. coli*

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.

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

5.1.3. Accounting for Critical Conditions and Seasonal Variations

Current EPA regulations [40 CFR 130.7(c)(1)] require TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters. Such an approach ensures that TMDLs, when implemented, will not result in violations of the water quality criteria under a wide variety of flow regimes that affect E. coli concentrations.

A period of six years was used for allocation modeling. Observed meteorological data from the NCDC Cooperative Weather Station in Wytheville were extracted for 1992, 2001, 2003-2006 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 D). The bacteria loading in the model for allocation scenarios was representative of anticipated future conditions.

The continuous simulation model developed for these TMDLs explicitly incorporates the seasonal variations of rainfall and other meteorological parameters, in addition to monthly estimates of fecal coliform loads. By using an hourly time-step in the model, these measures account for the seasonal effects in fecal coliform loading within the watershed.

When developing a bacterial 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, eliminating sewage spills, and other appropriate measures included in the TMDL Implementation Plan.

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 (Table 5.1) shows that contributions from livestock direct deposits are the primary source of *E. coli* to the stream. Contributions from pervious land sources also constitute a significant portion of the in-stream concentrations in Reed Creek. Contributions from wildlife direct deposits are also noticeable contributors to the mean daily *E. coli* concentration. The results in this table 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). Table 5.1 gives 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 livestock direct deposit will violate the single sample criterion by themselves in all of the impaired segments in the watershed. Wildlife direct deposit will violate the single sample criterion by themselves in Mill Creek, Stony Fork, and Tate Run. 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.

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

Source	Mean Daily *E. coli* Concentration by Source, cfu/100 mL	Relative Contribution by Source
Nonpoint source loadings from pervious land segments	56	28%
Direct nonpoint source loadings to the stream from wildlife	22	11%
Direct nonpoint source loadings to the stream from livestock	103	53%
Interflow and groundwater contribution	3	1%
Straight-pipe discharges to stream	5	3%
Nonpoint source loadings from impervious land segments	<1	<1%
Permitted point source loadings	7	4%
All Sources	196	

The contribution of each of the sources listed in Table 5.1 to the calendar-month geometric mean *E. coli* concentration at the outlet of Reed Creek is shown in Figure 5.1. The contributions from livestock direct deposit dominate the calendar-month geometric mean concentration. The contributions from wildlife direct deposit are also a significant factor in Reed Creek. 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 also contribute a significant amount to the geometric mean concentration. It is evident that violations of the calendar-month geometric mean criterion will be most controlled by contributions from direct in-stream sources, and further, that it will be impossible to meet the calendar-month geometric mean criterion without reducing contributions from livestock direct deposit, as this source alone violates the criterion during the allocation period. Contributions from wildlife direct deposit alone will also violate the calendar-month geometric mean criterion in Mill Creek, Stony Fork, and Tate Run, and therefore must be reduced in these watersheds to meet the calendar-month geometric mean standard.

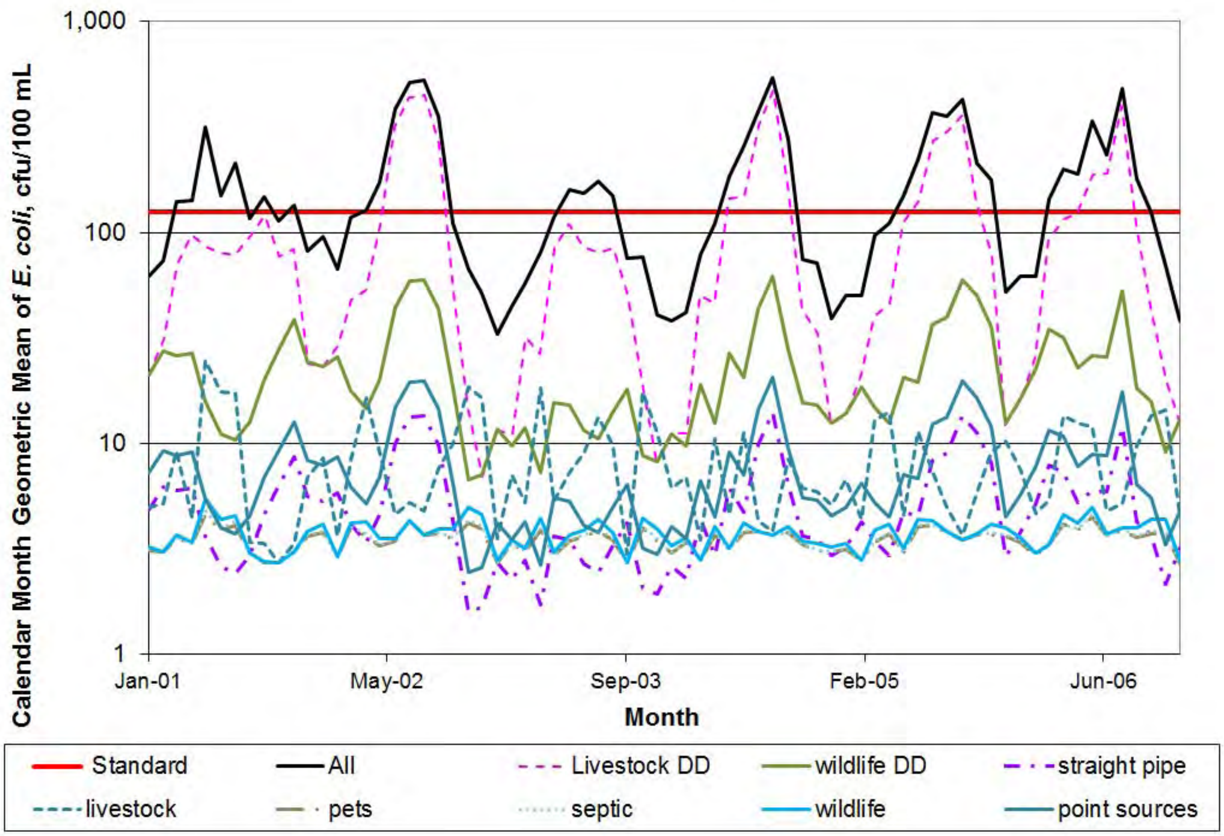

Figure 5.1. Contributions of different sources to the calendar-month geometric mean *E. coli* concentration at the outlet of Reed Creek for existing conditions.

5.3. Future Conditions

Although the Wythe County Comprehensive Plan adopted May 8, 2007 outlines potential growth in the Reed Creek watershed, this potential growth was minimal. Therefore, allocation scenarios were developed using existing conditions in the watershed.

5.4. 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. The scenarios and results are summarized in Tables 5.2 – 5.13 for South Fork Reed Creek, Tate Run, Stony Fork, Miller Creek, Cove Creek, Mill Creek, and the six segments of Reed 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 5.2 – 5.13. Note that none of the successful scenarios require reductions in loads from cropland; this is because the cropland areas are minimal in this watershed. Because there was such a small load on cropland compared to other sources, changing the reductions from 100% (in the unsuccessful runs) to 0% (in the successful runs) had no effect on attainment of the standard.

Scenarios labeled “1” are shown in Tables 5.2 – 5.13 to illustrate that there is a need for reductions in wildlife loads in Tate Run, Stony Fork, and Mill Creek to meet the water quality standard. 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.

Table 5.2. Bacteria allocation scenarios for the Mill Creek watershed.

Scenario Number	Required *E. coli* Loading Reductions to Meet the *E. coli* Standards, %						% Violation of *E. coli* Standard
	Livestock Direct Deposit	Loads from Pasture	Loads from Cropland	Straight Pipes and Failing Septic Systems	Loads from Residential Areas*	Wildlife Direct Deposit	Geo. Mean
Unsuccessful Scenarios							
Baseline Conditions	0	0	0	0	0	0	67
1	100	100	100	100	100	0	1
Successful Scenario							
2	100	85	0	100	0	20	0

* does not include loads from failing septic systems

Table 5.3. Bacteria allocation scenarios for the Cove Creek watershed.

Scenario Number	Required *E. coli* Loading Reductions to Meet the *E. coli* Standards, %						% Violation of *E. coli* Standard
	Livestock Direct Deposit	Loads from Pasture	Loads from Cropland	Straight Pipes and Failing Septic Systems	Loads from Residential Areas*	Wildlife Direct Deposit	Geo. Mean
Unsuccessful Scenario							
Baseline Conditions	0	0	0	0	0	0	67
Successful Scenarios							
1	100	100	100	100	100	0	0
2	100	0	0	100	0	0	0

* does not include loads from failing septic systems

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

Scenario Number	Required *E. coli* Loading Reductions to Meet the *E. coli* Standards, %						% Violation of *E. coli* Standard
	Livestock Direct Deposit	Loads from Pasture	Loads from Cropland	Straight Pipes and Failing Septic Systems	Loads from Residential Areas*	Wildlife Direct Deposit	Geo. Mean
Unsuccessful Scenario							
Baseline Conditions	0	0	0	0	0	0	67
Successful Scenarios							
1	100	100	100	100	100	0	0
2	100	0	0	100	0	0	0

* does not include loads from failing septic systems

Table 5.5. Bacteria allocation scenarios for the Stony Fork watershed.

Scenario Number	Required *E. coli* Loading Reductions to Meet the *E. coli* Standards, %						% Violation of *E. coli* Standard
	Livestock Direct Deposit	Loads from Pasture	Loads from Cropland	Straight Pipes and Failing Septic Systems	Loads from Residential Areas*	Wildlife Direct Deposit	Geo. Mean
Unsuccessful Scenarios							
Baseline Conditions	0	0	0	0	0	0	61
1	100	100	100	100	100	0	6
Successful Scenario							
2	100	90	0	100	0	15	0

* does not include loads from failing septic systems

Table 5.6. Bacteria allocation scenarios for the Tate Run watershed.

Scenario Number	**Required *E. coli* Loading Reductions to Meet the *E. coli* Standards, %**						**% Violation of *E. coli* Standard**
	Livestock Direct Deposit	**Loads from Pasture**	**Loads from Cropland**	**Straight Pipes and Failing Septic Systems**	**Loads from Residential Areas***	**Wildlife Direct Deposit**	**Geo. Mean**
Unsuccessful Scenarios							
Baseline Conditions	0	0	0	0	0	0	86
1	100	100	100	100	100	0	3
Successful Scenario							
2	100	95	0	100	0	10	0

* does not include loads from failing septic systems

Table 5.7. Bacteria allocation scenarios for the South Fork Reed Creek watershed.

Scenario Number	**Required *E. coli* Loading Reductions to Meet the *E. coli* Standards, %**						**% Violation of *E. coli* Standard**
	Livestock Direct Deposit	**Loads from Pasture**	**Loads from Cropland**	**Straight Pipes and Failing Septic Systems**	**Loads from Residential Areas***	**Wildlife Direct Deposit**	**Geo. Mean**
Unsuccessful Scenario							
Baseline Conditions	0	0	0	0	0	0	81
Successful Scenarios							
1	100	100	100	100	100	0	0
2	100	55	0	100	0	0	0

* does not include loads from failing septic systems

Table 5.8. Bacteria allocation scenarios for the Reed Creek watershed (N10R_RDC01B00, sub-watershed 55).

Scenario Number	Required *E. coli* Loading Reductions to Meet the *E. coli* Standards, %						% Violation of *E. coli* Standard
	Livestock Direct Deposit	Loads from Pasture	Loads from Cropland	Straight Pipes and Failing Septic Systems	Loads from Residential Areas*	Wildlife Direct Deposit	Geo. Mean
Unsuccessful Scenario							
Baseline Conditions	0	0	0	0	0	0	38
Successful Scenarios							
1	100	100	100	100	100	0	0
2	90	0	0	100	0	0	0

* does not include loads from failing septic systems

Table 5.9. Bacteria allocation scenarios for the Reed Creek watershed (N10R_RDC01A02, sub-watershed 43).

Scenario Number	Required *E. coli* Loading Reductions to Meet the *E. coli* Standards, %						% Violation of *E. coli* Standard
	Livestock Direct Deposit	Loads from Pasture	Loads from Cropland	Straight Pipes and Failing Septic Systems	Loads from Residential Areas*	Wildlife Direct Deposit	Geo. Mean
Unsuccessful Scenario							
Baseline Conditions	0	0	0	0	0	0	47
Successful Scenarios							
1	100	100	100	100	100	0	0
2	65	0	0	100	0	0	0

* does not include loads from failing septic systems

Table 5.10. Bacteria allocation scenarios for the Reed Creek watershed (N10R_RDC01A00, sub-watershed 37).

Scenario Number	Required *E. coli* Loading Reductions to Meet the *E. coli* Standards, %						% Violation of *E. coli* Standard
	Livestock Direct Deposit	Loads from Pasture	Loads from Cropland	Straight Pipes and Failing Septic Systems	Loads from Residential Areas*	Wildlife Direct Deposit	Geo. Mean
Unsuccessful Scenario							
Baseline Conditions	0	0	0	0	0	0	61
Successful Scenarios							
1	100	100	100	100	100	0	0
2	15	0	0	100	0	0	0

* does not include loads from failing septic systems

Table 5.11. Bacteria allocation scenarios for the Reed Creek watershed (N11R_RDC01B00, sub-watershed 17).

Scenario Number	Required *E. coli* Loading Reductions to Meet the *E. coli* Standards, %						% Violation of *E. coli* Standard
	Livestock Direct Deposit	Loads from Pasture	Loads from Cropland	Straight Pipes and Failing Septic Systems	Loads from Residential Areas*	Wildlife Direct Deposit	Geo. Mean
Unsuccessful Scenario							
Baseline Conditions	0	0	0	0	0	0	61
Successful Scenarios							
1	100	100	100	100	100	0	0
2	15	0	0	100	0	0	0

* does not include loads from failing septic systems

Table 5.12. Bacteria allocation scenarios for the Reed Creek watershed (N11R_RDC02B02, sub-watershed 7).

Scenario Number	Required *E. coli* Loading Reductions to Meet the *E. coli* Standards, %						% Violation of *E. coli* Standard
	Livestock Direct Deposit	Loads from Pasture	Loads from Cropland	Straight Pipes and Failing Septic Systems	Loads from Residential Areas*	Wildlife Direct Deposit	Geo. Mean
Unsuccessful Scenario							
Baseline Conditions	0	0	0	0	0	0	58
Successful Scenarios							
1	100	100	100	100	100	0	0
2	15	0	0	100	0	0	0

* does not include loads from failing septic systems

Table 5.13. Bacteria allocation scenarios for the Reed Creek watershed (N11R_RDC03B04, sub-watershed 1).

Scenario Number	Required *E. coli* Loading Reductions to Meet the *E. coli* Standards, %						% Violation of *E. coli* Standard
	Livestock Direct Deposit	Loads from Pasture	Loads from Cropland	Straight Pipes and Failing Septic Systems	Loads from Residential Areas*	Wildlife Direct Deposit	Geo. Mean
Unsuccessful Scenario							
Baseline Conditions	0	0	0	0	0	0	51
Successful Scenarios							
1	100	100	100	100	100	0	0
2	15	0	0	100	0	0	0

* does not include loads from failing septic systems

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. Figures 5.2 – 5.13 display the simulated daily average and calendar month geometric mean concentrations at the watershed outlets for scenario 2, as well as the *E. coli* standard.

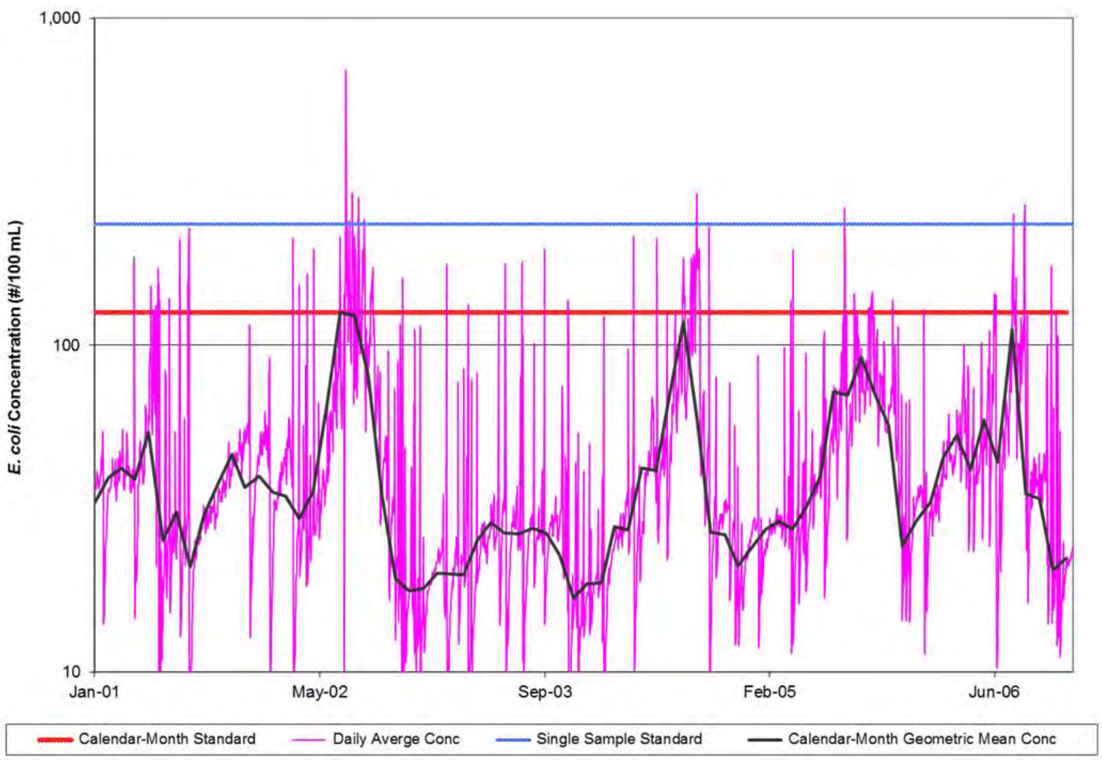

Figure 5.2. Bacteria concentrations for successful allocation scenario 2 for Mill Creek.

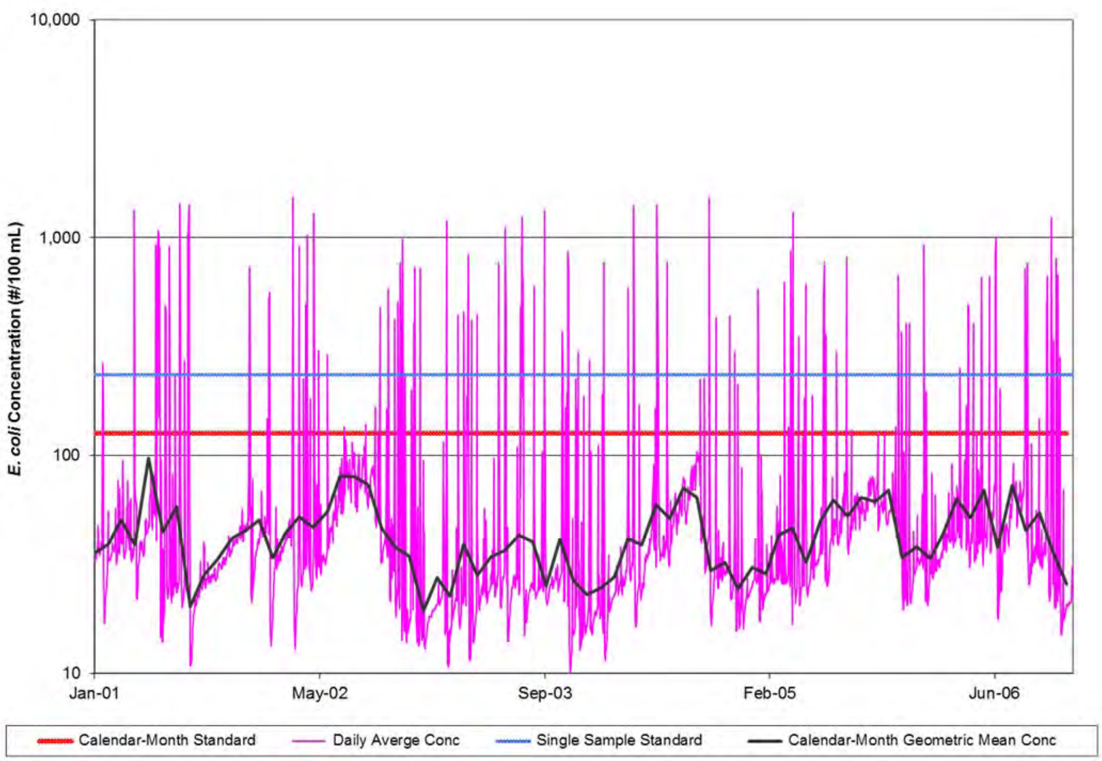

Figure 5.3. Bacteria concentrations for successful allocation scenario 2 for Cove Creek.

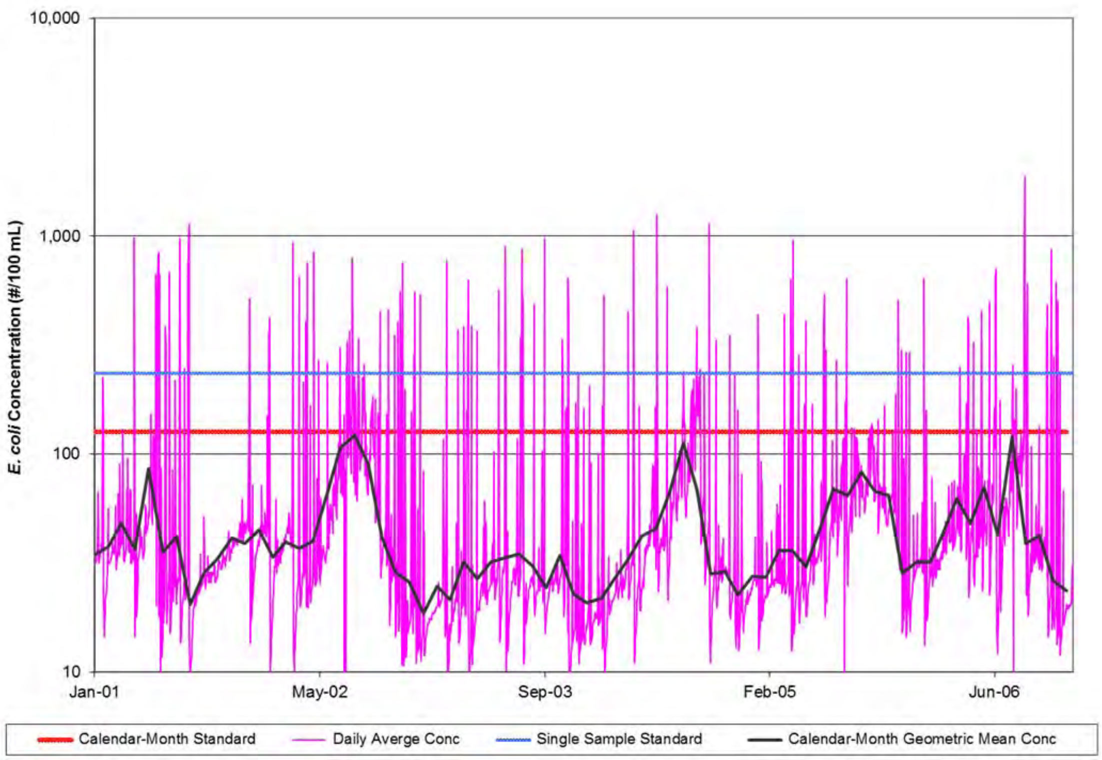

Figure 5.4. Bacteria concentrations for successful allocation scenario 2 for Miller Creek.

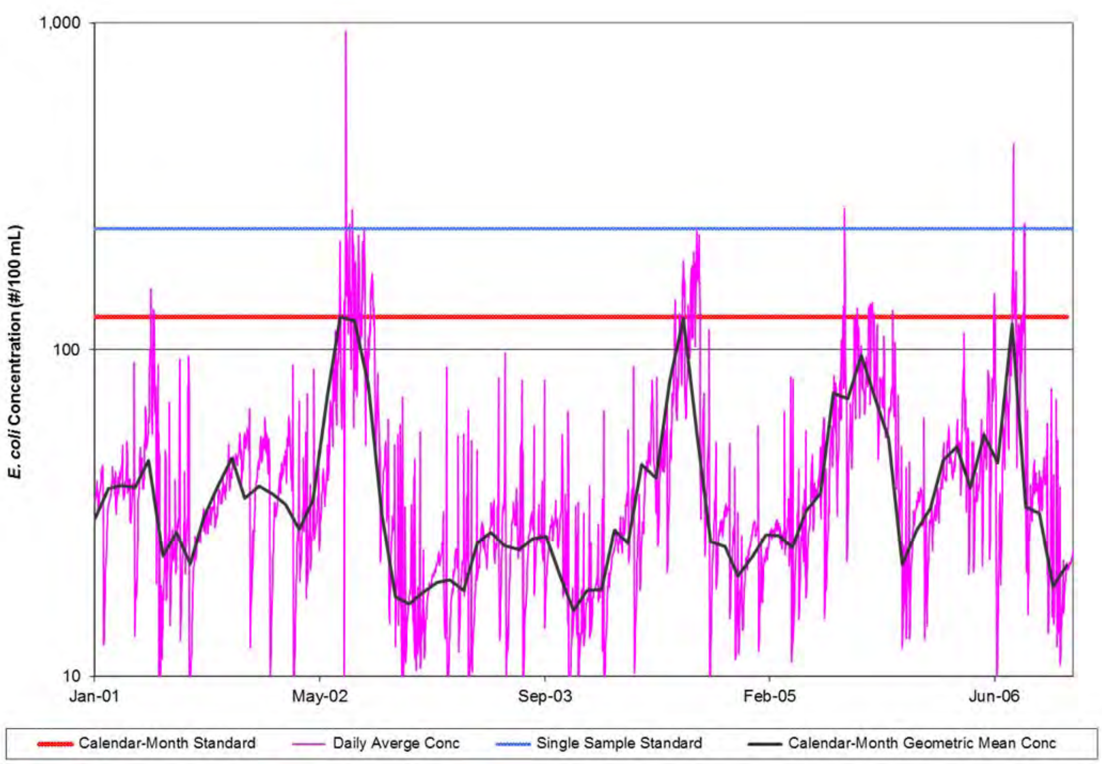

Figure 5.5. Bacteria concentrations for successful allocation scenario 2 for Stony Fork.

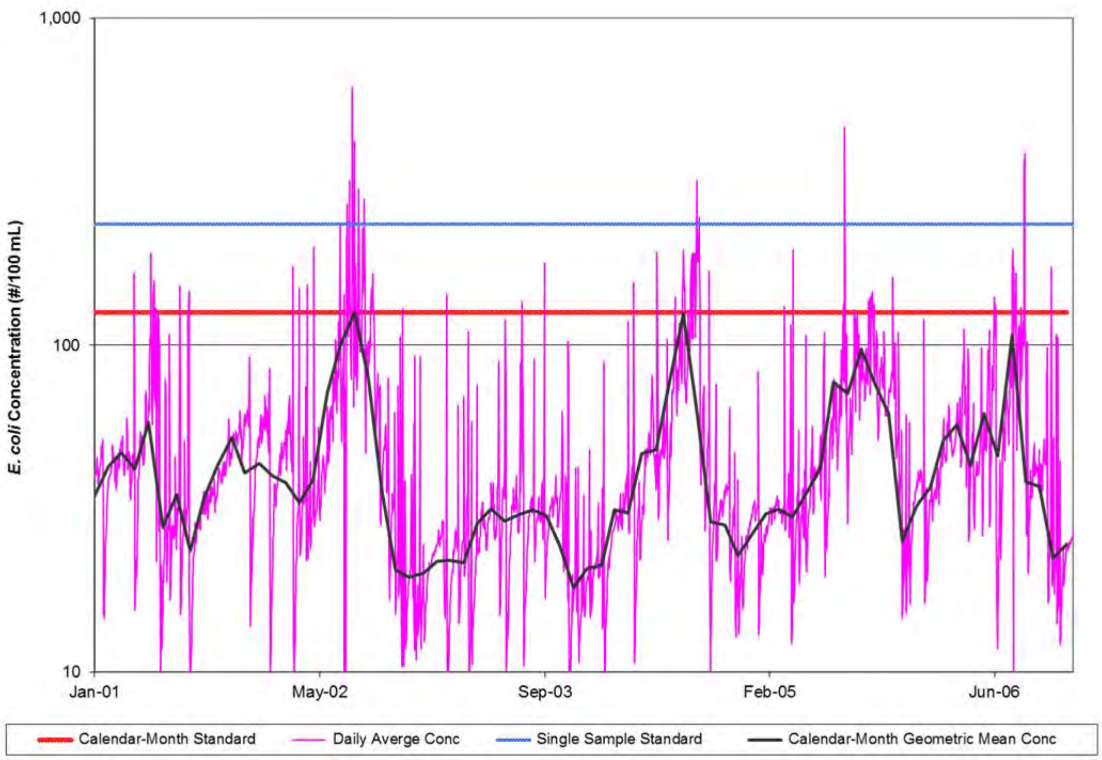

Figure 5.6. Bacteria concentrations for successful allocation scenario 2 for Tate Run.

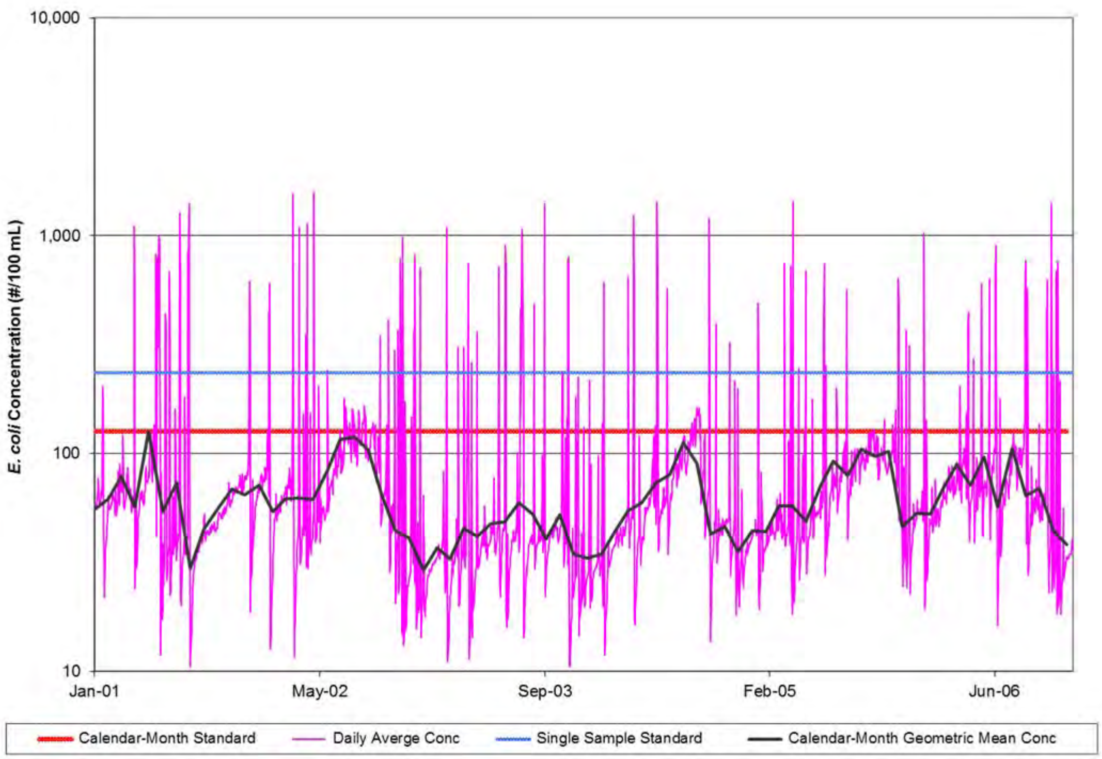

Figure 5.7. Bacteria concentrations for successful allocation scenario 2 for South Fork Reed Creek.

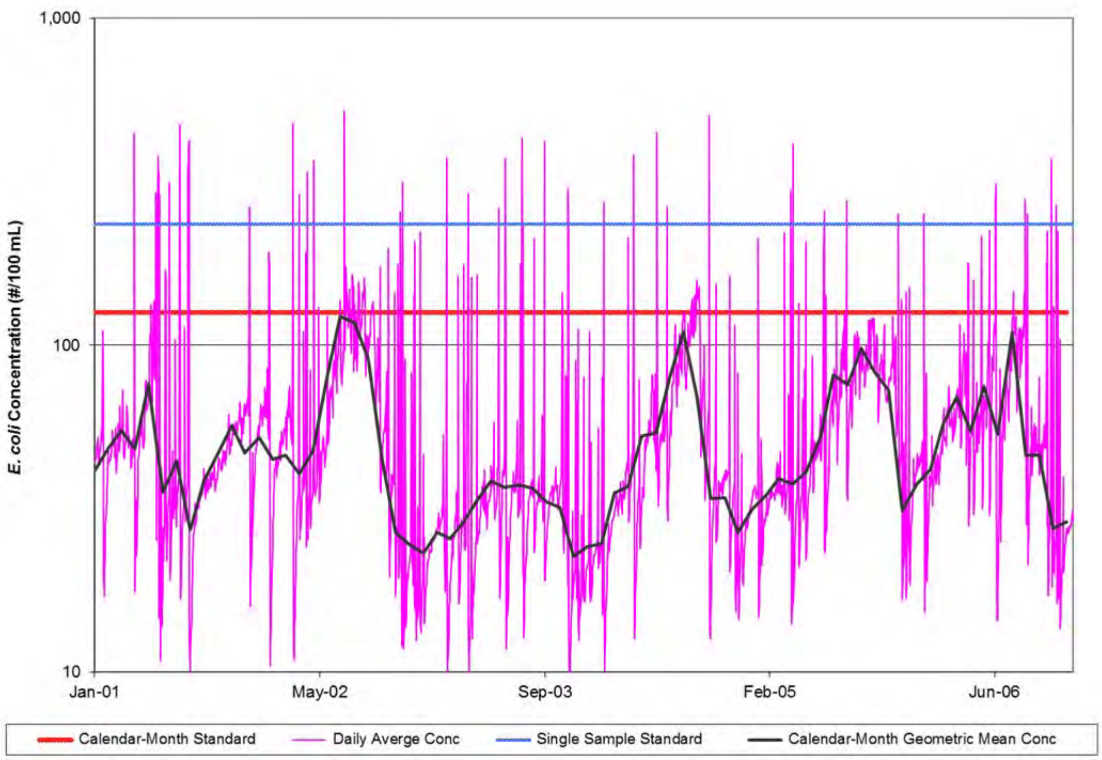

Figure 5.8. Bacteria concentrations for successful allocation scenario 2 for Reed Creek (N10R_RDC01B00, sub-watershed 55).

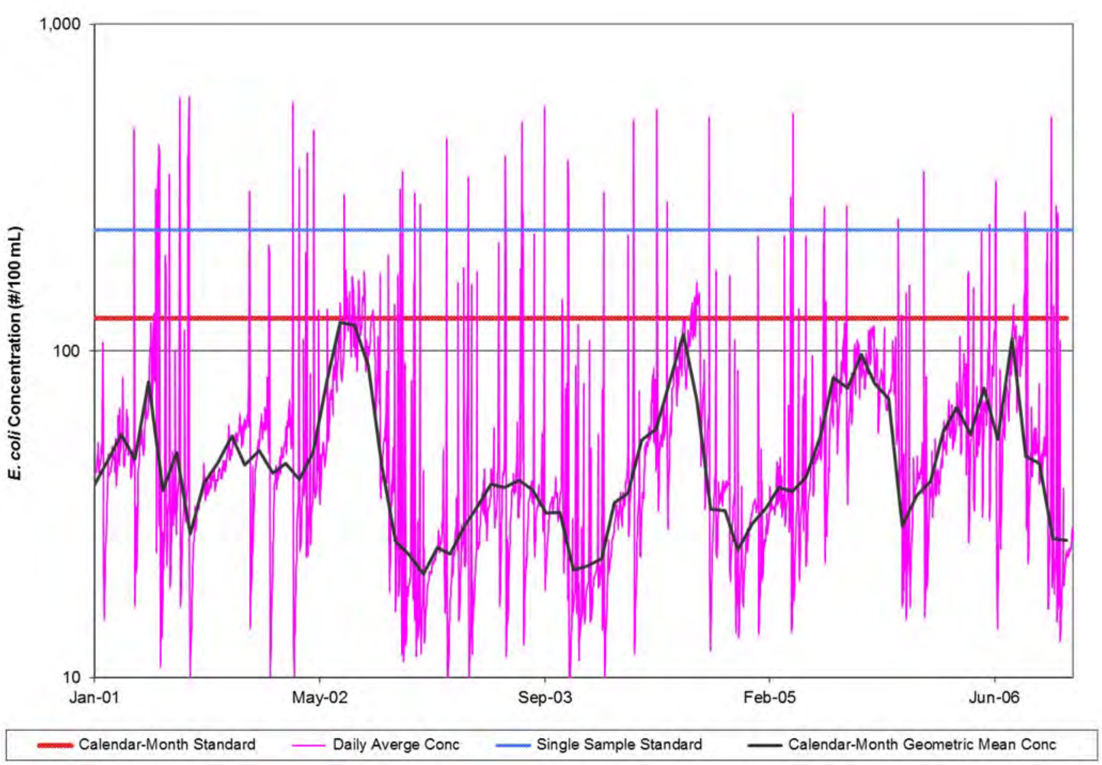

Figure 5.9. Bacteria concentrations for successful allocation scenario 2 for Reed Creek (N10R_RDC01A00, sub-watershed 43).

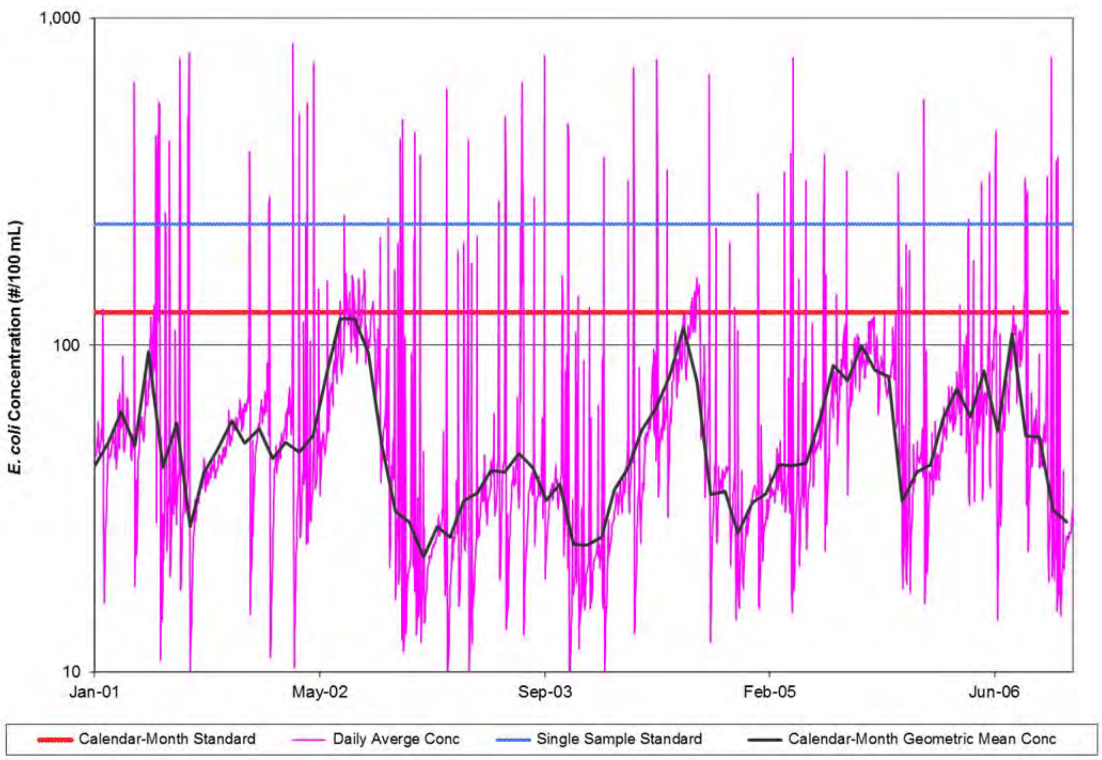

Figure 5.10. Bacteria concentrations for successful allocation scenario 2 for Reed Creek (N10R_RDC01A02, sub-watershed 37).

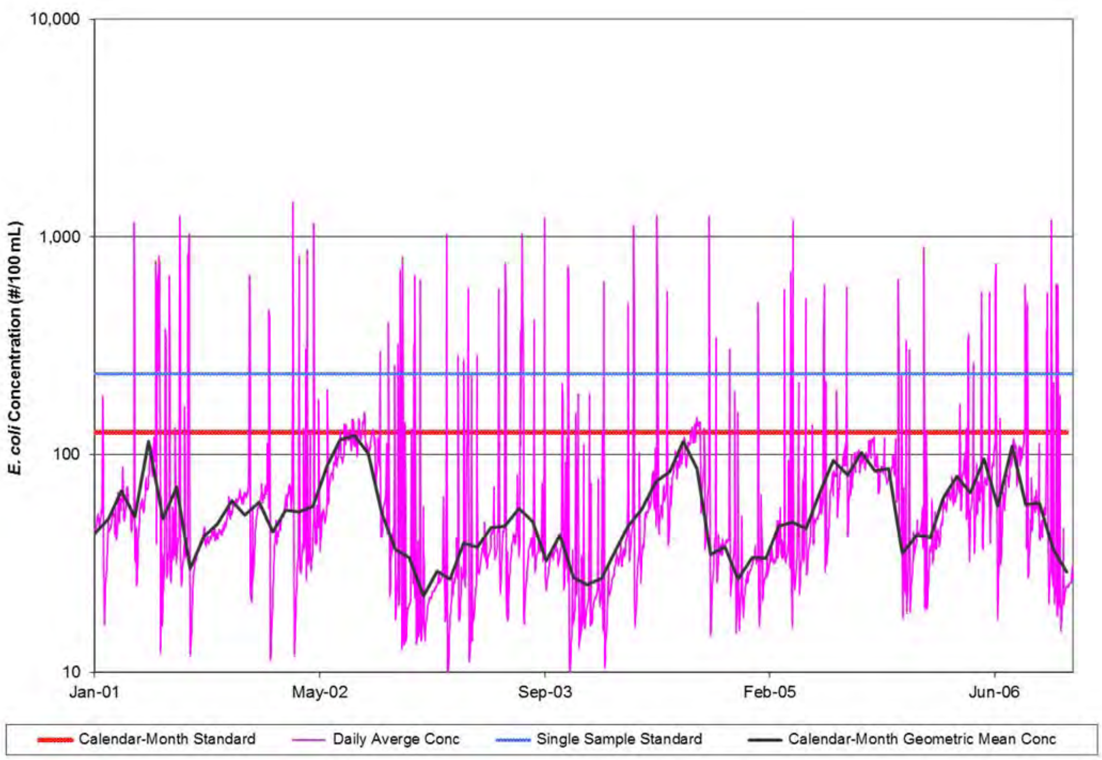

Figure 5.11. Bacteria concentrations for successful allocation scenario 2 for Reed Creek (N11R_RDC01B00, sub-watershed 17).

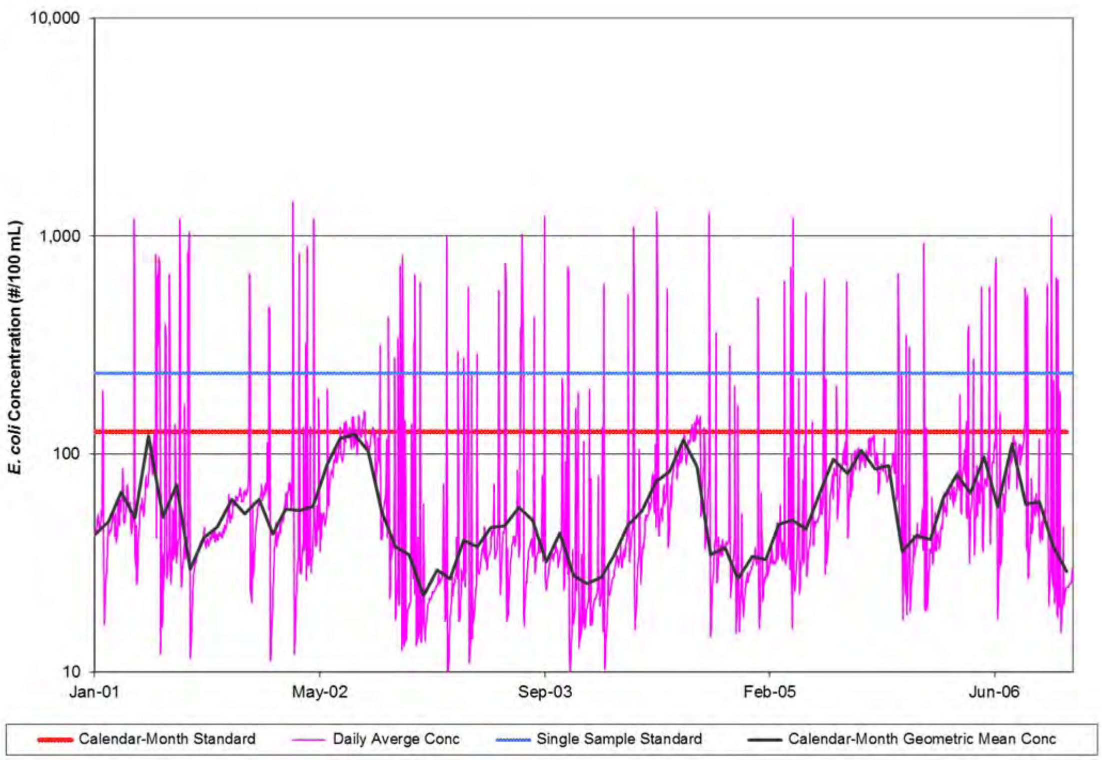

Figure 5.12. Bacteria concentrations for successful allocation scenario 2 for Reed Creek (N11R_RDC02B02, sub-watershed 7).

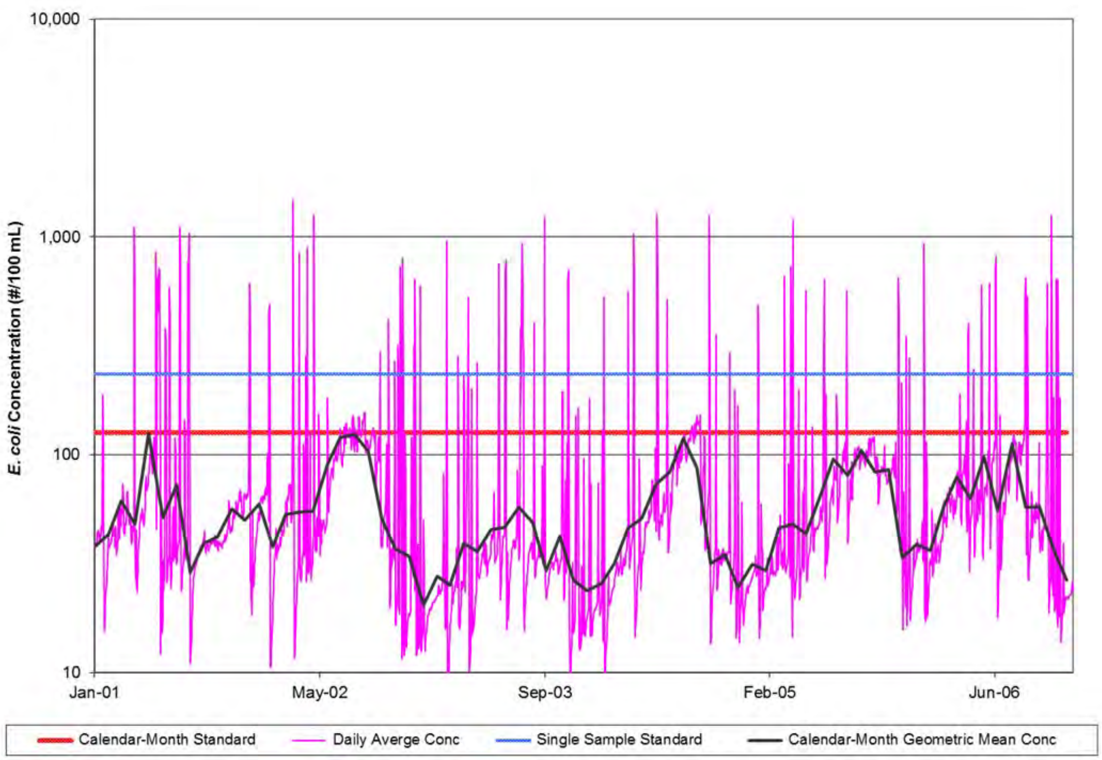

Figure 5.13. Bacteria concentrations for successful allocation scenario 2 for Reed Creek (N11R_RDC03B04, sub-watershed 1).

Loadings for the existing conditions and the chosen successful TMDL allocation scenario (2) are presented for nonpoint sources by land use in Table 5.14 – Table 5.25 and for direct nonpoint sources in Table 5.26 – Table 5.37.

Table 5.14. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for Mill 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	6	<1	6	0
Pasture	2,027	97	304	85
Residential	33	2	14	58
Forest	9	<1	9	0
Total	2,075		333	84

Table 5.15. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for Cove 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	16	<1	16	0
Pasture	4,688	98	4,688	0
Residential	38	<1	20	46
Forest	26	<1	26	0
Total	4,768		4,750	<1

Table 5.16. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for Miller 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	5	<1	5	0
Pasture	1,952	97	1,952	0
Residential	32	2	11	65
Forest	14	<1	14	0
Total	2,003		1,982	1

Table 5.17. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for Stony Fork.

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	9	<1	9	0
Pasture	1,921	96	192	90
Residential	25	1	10	60
Forest	38	2	38	0
Total	1,993		249	88

Table 5.18. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for Tate Run.

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	12	<1	12	0
Pasture	3,355	98	168	95
Residential	47	1	16	66
Forest	9	<1	9	0
Total	3,423		205	94

Table 5.19. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for South Fork Reed 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	29	<1	29	0
Pasture	4,871	97	2,192	55
Residential	86	2	42	51
Forest	8	<1	8	0
Total	4,994		2,271	55

Table 5.20. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for Reed Creek watershed (N10R_RDC01B00, sub-watershed 55).

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	5	<1	5	0
Pasture	1,707	96	1,707	0
Residential	15	<1	6	62
Forest	47	3	47	0
Total	1,774		1,765	<1

Table 5.21. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for Reed Creek watershed (N10R_RDC01A02, sub-watershed 43).

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	22	<1	22	0
Pasture	3,054	97	3,054	0
Residential	61	2	32	48
Forest	6	<1	6	0
Total	3,143		3,114	<1

Table 5.22. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for Reed Creek watershed (N10R_RDC01A00, sub-watershed 37).

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	0	0	0	0
Pasture	155	98	155	0
Residential	2	1	2	0
Forest	0.25	<1	0.25	0
Total	158		158	0

Table 5.23. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for Reed Creek watershed (N11R_RDC01B00, sub-watershed 17).

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	22	<1	22	0
Pasture	4,805	95	4,805	0
Residential	188	4	131	30
Forest	24	<1	24	0
Total	5,039		4,982	1

Table 5.24. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for Reed Creek watershed (N11R_RDC02B02, sub-watershed 7).

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	5	<1	5	0
Pasture	1,561	96	1,561	0
Residential	51	3	18	65
Forest	9	<1	9	0
Total	1,626		1,593	2

Table 5.25. Estimated annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for Reed Creek watershed (N11R_RDC03B04, sub-watershed 1).

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	14	<1	14	0
Pasture	3,735	98	3,735	0
Residential	63	2	23	63
Forest	11	<1	11	0
Total	3,823		3,783	1

Table 5.26. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for Mill 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	23	84	0	100
Wildlife in Streams	4	14	3	20
Straight Pipes	0.64	2	0	100
Total	28		3	89

Table 5.27. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for Cove 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	65	89	0	100
Wildlife in Streams	7	10	7	0
Straight Pipes	0.58	<1	0	100
Total	73		7	90

Table 5.28. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for Miller 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	31	89	0	100
Wildlife in Streams	3	8	3	0
Straight Pipes	0.92	3	0	100
Total	35		3	91

Table 5.29. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for Stony Fork.

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	30	84	0	100
Wildlife in Streams	6	15	5	15
Straight Pipes	0.27	<1	0	100
Total	36		5	86

Table 5.30. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for Tate Run.

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	53	90	0	100
Wildlife in Streams	4	8	3.6	10
Straight Pipes	1	2	0	100
Total	58		3.6	93

Table 5.31. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for South Fork Reed 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	57	84	0	100
Wildlife in Streams	8	13	8	0
Straight Pipes	2	3	0	100
Total	67		8	82

Table 5.32. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for Reed Creek watershed (N10R_RDC01B00, sub-watershed 55).

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	5	33	1	90
Wildlife in Streams	10	67	10	0
Straight Pipes	0	0	0	100
Total	15		11	27

Table 5.33. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for Reed Creek watershed (N10R_RDC01A02, sub-watershed 43).

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	7	58	2	65
Wildlife in Streams	4	31	4	0
Straight Pipes	1	11	0	100
Total	12		6	50

Table 5.34. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for Reed Creek watershed (N10R_RDC01A00, sub-watershed 37).

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	0.4	50	0.3	15
Wildlife in Streams	0.4	50	0.4	0
Straight Pipes	0	0	0	100
Total	0.8		0.7	12

Table 5.35. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for Reed Creek watershed (N11R_RDC01B00, sub-watershed 17).

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	14	54	12	15
Wildlife in Streams	9	36	9	0
Straight Pipes	3	10	0	100
Total	26		21	19

Table 5.36. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for Reed Creek watershed (N11R_RDC02B02, sub-watershed 7).

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	4	42	3	15
Wildlife in Streams	3	40	3	0
Straight Pipes	1	18	0	100
Total	8		6	25

Table 5.37. Estimated annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario 2 for Reed Creek watershed (N11R_RDC03B04, sub-watershed 1).

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	9	61	8	15
Wildlife in Streams	4	31	4	0
Straight Pipes	1	8	0	100
Total	14		12	14

The fecal coliform allocation scenario loads presented in Tables 5.14 – 5.37 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.

5.5. Waste Load Allocation

There are fourteen permitted point source facilities in the Reed Creek watershed (Table 3.2). Three of these are for single family homes and the loads from these sources were considered small relative to the load allocation. To account for future growth to the impaired segments with no permitted point sources (i.e., Mill Creek, Miller Creek, Stony Fork, and Tate Run), 1% of the TMDL was added to the waste load allocation. A WLA was assigned to the other eleven permitted point source facilities, one in the South Fork Reed Creek watershed (Rural Retreat STP – VA0021326), one in the Cove Creek watershed (SVC Manufacturing Inc. – VA0091847) and the remaining in the Reed Creek watershed. The point sources were represented in the allocation scenario by their current permit conditions; no reductions were required from the point source 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 the discharge permit. Because the permits for these facilities already protect against violating the bacteria water quality standard, there is no need to modify the existing permits.

A scenario has also been developed to account for future growth in permitted operations in the South Fork Reed Creek and Reed Creek watersheds. The point source flows in Reed Creek permitted by VADEQ were increased by a factor of five, while retaining the 126 cfu/100mL limit on *E. coli* bacteria. This effectively increased the WLAs for both South Fork Reed Creek and Reed Creek by a factor of five. The new scenario results in no violations of geometric mean standard. Therefore, it is assumed that future growth in point source dischargers with a consistent permitted bacteria concentration of 126 cfu/100 mL *E. coli* will not cause additional violations of the water quality standards.

5.6. Summary of the TMDL Allocation Scenarios for Bacteria

TMDLs for *E. coli* have been developed for South Fork Reed Creek, Tate Run, Stony Fork, Miller Creek, Cove Creek, Mill Creek, and the six segments of Reed Creek. The TMDLs address the following issues:

1. The TMDLs meet the calendar-month geometric mean 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 Reed Creek watershed, violations of the water quality standard were caused during both 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 Mill Creek, Cove Creek, Miller Creek, Stony Fork, Tate Run, and the six segments of Reed Creek for the selected allocation scenarios are given in Table 5.40 – Table 5.51, respectively.

Table 5.38. Estimated annual *E. coli* loadings (cfu/yr) at the watershed outlet used for the Mill Creek bacteria TMDL.

Parameter	ΣWLA	ΣLA	MOS*	TMDL
E. coli	6.79×10^{10}	672.27×10^{10}	--	679.06×10^{10}
Future Growth	*6.79×10^{10}*			

*Implicit MOS

Table 5.39. Estimated annual *E. coli* loadings (cfu/yr) at the watershed outlet used for the Cove Creek bacteria TMDL.

Parameter		ΣWLA	ΣLA	MOS*	TMDL
E. coli		7.40×10^{11}	733.46×10^{11}	--	740.86×10^{11}
	VA0091847	*1.48×10^{11}*			
	Future Growth	*5.92×10^{11}*			

*Implicit MOS

Table 5.40. Estimated annual *E. coli* loadings (cfu/yr) at the watershed outlet used for the Miller Creek bacteria TMDL.

Parameter		ΣWLA	ΣLA	MOS*	TMDL
E. coli		2.63×10^{11}	261.72×10^{11}	--	263.35×10^{11}
	Future Growth	*2.63×10^{11}*			

*Implicit MOS

Table 5.41. Estimated annual *E. coli* loadings (cfu/yr) at the watershed outlet used for the Stony Fork bacteria TMDL.

Parameter		ΣWLA	ΣLA	MOS*	TMDL
E. coli		9.00×10^{10}	890.63×10^{10}	--	899.63×10^{10}
	Future Growth	*9.00×10^{10}*			

*Implicit MOS

Table 5.42. Estimated annual *E. coli* loadings (cfu/yr) at the watershed outlet used for the Tate Run bacteria TMDL.

Parameter		ΣWLA	ΣLA	MOS*	TMDL
E. coli		7.99×10^{10}	773.76×10^{10}	--	781.75×10^{10}
	VAG400883	*1.74×10^{9}*			
	Future Growth	*7.64×10^{10}*			

*Implicit MOS

Table 5.43. Estimated annual *E. coli* loadings (cfu/yr) at the watershed outlet used for the South Fork Reed Creek bacteria TMDL.

Parameter		ΣWLA	ΣLA	MOS*	TMDL
E. coli		2.18×10^{12}	38.78×10^{12}	--	40.96×10^{12}
	VA0021326	*4.35×10^{11}*			
	Future Growth	*1.74×10^{12}*			

*Implicit MOS

Table 5.44. Estimated annual *E. coli* loadings (cfu/yr) at the watershed outlet used for the Reed Creek (N10R_RDC01B00, sub-watershed 55) bacteria TMDL.

Parameter		ΣWLA	ΣLA	MOS*	TMDL
E. coli		4.32×10^{11}	427.61×10^{11}	--	431.93×10^{11}
	Future Growth	*4.32×10^{11}*			

*Implicit MOS

Table 5.45. Estimated annual *E. coli* loadings (cfu/yr) at the watershed outlet used for the Reed Creek (N10R_RDC01A02, sub-watershed 43) bacteria TMDL.

Parameter	ΣWLA	ΣLA	MOS*	TMDL
E. coli	8.71×10^{11}	862.61×10^{11}	--	871.32×10^{11}
Future Growth	*8.71×10^{11}*			

*Implicit MOS

Table 5.46. Estimated annual *E. coli* loadings (cfu/yr) at the watershed outlet used for the Reed Creek (N10R_RDC01A00, sub-watershed 37) bacteria TMDL.

Parameter	ΣWLA	ΣLA	MOS*	TMDL
E. coli	2.18×10^{12}	134.01×10^{12}	--	136.19×10^{12}
VA0021326	*4.35×10^{11}*			
Future Growth	*1.74×10^{12}*			

*Implicit MOS

Table 5.47. Estimated annual *E. coli* loadings (cfu/yr) at the watershed outlet used for the Reed Creek (N11R_RDC01B00, sub-watershed 17) bacteria TMDL.

Parameter	ΣWLA	ΣLA	MOS*	TMDL
E. coli	3.80×10^{13}	32.06×10^{13}	--	35.86×10^{13}
VA0021326	*4.35×10^{11}*			
VA0020281	*6.97×10^{12}*			
VA0024490	*4.72×10^{10}*			
VA0091847	*1.48×10^{11}*			
VAG400883	*1.74×10^{9}*			
VAG400652	*1.74×10^{9}*			
Future Growth	*3.04×10^{13}*			

*Implicit MOS

Table 5.48. Estimated annual *E. coli* loadings (cfu/yr) at the watershed outlet used for the Reed Creek (N11R_RDC02B02, sub-watershed 7) bacteria TMDL.

Parameter	ΣWLA	ΣLA	MOS*	TMDL
E. coli	5.54×10^{13}	36.54×10^{13}	--	42.08×10^{13}
VA0021326	*4.35×10^{11}*			
VA0020281	*6.97×10^{12}*			
VA0024490	*4.72×10^{10}*			
VA0091847	*1.48×10^{11}*			
VA0090549	*1.74×10^{9}*			
VA0092398	*5.23×10^{8}*			
VA0074161	*3.48×10^{12}*			
VA0090956	*1.74×10^{9}*			
VAG400883	*1.74×10^{9}*			
VAG400652	*1.74×10^{9}*			
Future Growth	*4.43×10^{13}*			

*Implicit MOS

Table 5.49. Estimated annual *E. coli* loadings (cfu/yr) at the watershed outlet used for the Reed Creek (N11R_RDC03B04, sub-watershed 1) bacteria TMDL.

Parameter	ΣWLA	ΣLA	MOS*	TMDL
E. coli	6.03×10^{13}	39.32×10^{13}	--	45.35×10^{13}
VA0021326	4.35×10^{11}			
VA0020281	6.97×10^{12}			
VA0024490	4.72×10^{10}			
VA0091847	1.48×10^{11}			
VA0090549	1.74×10^{9}			
VA0092398	5.23×10^{8}			
VA0074161	3.48×10^{12}			
VA0090956	1.74×10^{9}			
VA0059137	9.41×10^{11}			
VA0068144	3.48×10^{9}			
VA0065706	2.61×10^{10}			
VAG400883	1.74×10^{9}			
VAG400652	1.74×10^{9}			
VAG400843	1.74×10^{9}			
Future Growth	4.82×10^{13}			

*Implicit MOS

5.6.1. 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 Reed Creek.

Hydrologic Considerations

According to guidance from EPA (USEPA, 2006) it is 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. Flow data from the USGS gage used in the hydrologic calibration were used to calculate the daily load. As is specified in the EPA guidance, the observed flows from Reed Creek were multiplied by the ratio of the impaired segments of the Reed Creek watershed area to the drainage area above the USGS gage. The flow rate corresponding to the 99th percentile flow (that is, the flow rate exceeded by only 1% of the observed flows) was identified for the Reed Creek at the USGS gage as 1,661 cfs.

Daily Load

Setting a *maximum daily* load will help ensure that the annual loads given in Tables 5.40 – 5.51 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 geometric mean criterion (126 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 5.50. 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 5.50. Maximum daily *E. coli* loadings (cfu/day) at the watershed outlets.

Watershed	ΣWLA†	ΣLA	MOS*	TMDL
Mill Creek	2.96×10^{9}	2.93×10^{11}	-	2.96×10^{11}
Cove Creek	7.61×10^{9}	7.54×10^{11}	-	7.62×10^{11}
Miller Creek	3.33×10^{9}	3.30×10^{11}	-	3.33×10^{11}
Stony Fork	5.23×10^{9}	5.17×10^{11}	-	5.22×10^{11}
Tate Run	3.53×10^{9}	3.42×10^{11}	-	3.46×10^{11}
South Fork Reed Creek	2.69×10^{10}	4.79×10^{11}	-	5.06×10^{11}
Reed Creek N10R_RDC01B00	1.06×10^{10}	1.05×10^{12}	-	1.06×10^{12}
Reed Creek N10R_RDC01A02	1.89×10^{10}	1.87×10^{12}	-	1.89×10^{12}
Reed Creek N10R_RDC01A00	3.86×10^{10}	2.37×10^{12}	-	2.41×10^{12}
Reed Creek N11R_RDC01B00	4.62×10^{11}	3.90×10^{12}	-	4.36×10^{12}
Reed Creek N11R_RDC02B02	6.52×10^{11}	4.30×10^{12}	-	4.95×10^{12}
Reed Creek N11R_RDC03B04	7.18×10^{11}	4.68×10^{12}	-	5.40×10^{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/Programs/Water/WaterQualityInformationTMDLs/TMDL/TMDLImplementation/TMDLImplementationPlanGuidanceManual.aspx. 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 and sewage spillage could be accomplished through a sanitary sewer inspection and management program. Other BMPs that might be appropriate for controlling urban wash-off from parking lots and roads and that could be readily implemented may include more restrictive ordinances to reduce fecal loads from pets, improved garbage collection and control, and improved street cleaning.

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

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

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

6.2. Stage 1 Scenarios

The goal of the Stage 1 scenarios is to reduce the bacteria loadings from controllable sources (excluding wildlife) such that violations of the 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. One successful scenario was selected for each of the impaired watersheds (Table 6.1).

Table 6.1. Allocation scenario for Stage 1 TMDL implementation for the Reed Creek watershed.

Impaired Segment	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 Septic Systems	Non-Human Loads from Residential Areas	Wildlife Direct Deposit	Loads from Forested Areas	
Mill Creek	95	0	0	100	0	0	0	8
Cove Creek	85	0	0	100	0	0	0	9
Miller Creek	95	0	0	100	0	0	0	8
Stony Fork	95	0	0	100	0	0	0	8
Tate Run	100	0	0	100	0	0	0	8
South Fork Reed Creek	90	0	0	100	0	0	0	10
Reed Creek N10R_01B00	0	0	0	100	0	0	0	6
Reed Creek N10R_01A02	0	0	0	100	0	0	0	6
Reed Creek N10R_01A00	0	0	0	100	0	0	0	7
Reed Creek N11R_01B00	0	0	0	100	0	0	0	6
Reed Creek N11R_02B02	0	0	0	100	0	0	0	6
Reed Creek N11R_03B04	0	0	0	100	0	0	0	6

6.3. Link to Ongoing Restoration Efforts

Implementation of this TMDL will contribute to on-going water quality improvement efforts in Reed Creek and efforts aimed at restoring water quality in the New River.

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/Programs/Water/WaterQualityInformationTMDLs/WaterQualityMonitoring/CitizenMonitoring.aspx.

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.virginia.gov/Programs/Water/WaterQualityInformationTMDLs/TMDL/Regulation.aspx.

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 Reed 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/stormwater_management/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/stormwater_management/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 Reed 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://ftp.deq.virginia.gov/wqs/documents/WQS_eff_6JAN2011.pdf.

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.

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

Public participation was elicited at every stage of the TMDL development in order to receive inputs from stakeholders and to apprise the stakeholders of the progress made. The first Public Meeting was held on November 15, 2011 at the Wythe Bland Conference Room at the Wythe Bland Community Hospital in Wytheville, Virginia. The purpose of that meeting was to introduce the public to the TMDL process and to discuss the impairments identified on stream segments in these watersheds. The public meeting was attended by six people. The first Local Steering Committee meeting was held on the same date and at the same location prior to the public meeting. The LSC meeting was attended by six people. Initial animal population estimates were presented at both meetings and comments were solicited from the stakeholder group.

A public meeting to present the draft bacteria TMDL report for Reed Creek was held on April 19, 2012 at the Wythe Bland Conference Room at the Wythe Bland Community Hospital in Wytheville, Virginia. This final TMDL public meeting had nine attendees and served as the initiation of the TMDL implementation planning phase, which is a continuation of this project. The end of the public comment period was May 18, 2012. No comments were submitted during the comment period.

References

ASAE Standards, 45th edition. 1998. D384.1 DEC93. Manure production and characteristics. St. Joseph, Mich.: ASAE.

Bicknell, B.R., J.C. Imhoff, J.L. Kittle, Jr., T.H. Jobes, A.S. Donigian, Jr. 2005. *HSPF Version 12.2 User's Manual*. Mountain View, CA: AQUA TERRA Consultants. In Cooperation with the U.S. Geological Survey and U.S. Environmental Protection Agency. 845 pp. Available at: http://water.epa.gov/scitech/datait/models/basins/bsnsdocs.cfm. Accessed 28 March 2012.

Census Bureau. 2010. Washington, D.C.: U.S. Census Bureau. Available at: http://www.census.gov.

Crane, S.R. and J.A. Moore. 1986. Modeling enteric bacterial die-off: a review. Water, Air, and Soil Pollution 27(314):411-439.

Crane, S.R., P.W. Westerman, M.R. Overcash. 1980. Die-off of fecal indicator organisms following land-application of poultry manure. J. Environ. Qual 9:531-537.

Duda, P., J. Kittle, Jr., M. Gray, P. Hummel, R. Dusenbury. 2001. WinHSPF, Version 2.0, An Interactive Windows Interface to HSPF, User Manual. Contract No. 68-C-98-010. USEPA. Washington D.C. pp. 95.

Geldreich, E.E. 1978. Bacterial populations and indicator concepts in feces, sewage, stormwater and solid wastes. In *Indicators of Viruses in Water and Food*, ed. G. Berg, ch. 4, 51-97. Ann Arbor, Mich.: Ann Arbor Science Publishers, Inc.

Giddens, J.A., M. Rao, H. W. Fordham. 1973. Microbial changes and possible groundwater pollution from poultry manure and beef cattle feedlots in Georgia. OWRR Project no. A-031-GA. Athens, Ga: Univ. of Georgia.

Helfrich, L.A., D.L. Weigmann, K.W. Nutt, R.M. Sterrett. 1990. Springs of Virginia Revisited: A Comparative Analysis of the Current and Historical Water-Quality Data. *Virginia Journal of Science* 41(1): 14-27.

HSUS (Humane Society of the United States). 2012. U.S. Pet Ownership Statistics. Available at: http://www.humanesociety.org/issues/pet_overpopulation/facts/pet_ownership_statistics.html. Accessed 26 March 2012.

MWPS. 1993. Livestock Waste Facilities Handbook. 3rd ed. MidWest Plan Service, Ames, IA.

NCDC. 2011. National Oceanic and Atmospheric Administration: National Climatic Data Center. Available at: http://www.ncdc.noaa.gov/oa/ncdc.html. Accessed 26 March 2012.

SERCC, 2012. Historical Climate Series for Virginia. Southeast Regional Climate Center. Available at http://www.sercc.com/cgi-bin/sercc/cliMAIN.pl?va9301. Accessed 26 March 2012.

Staley, N.A., T. Bright, R.W. Zeckoski, B.L. Benham, and K.M. Brannan. 2006. Comparison of HSPF Outputs Using FTABLES Generated with Field Survey and Digital Data. *J. of the Am. Water Res. Assoc.* In Press.

SWCB (State Water Control Board). 2011. 9 VAC 25-260 Virginia Water Quality Standards. Available at: http://ftp.deq.virginia.gov/wqs/documents/WQS_eff_6JAN2011.pdf. Accessed 22 May 2012.

USDA-NASS. 2009. USDA, National Agricultural Statistics Service, 2009 Virginia Cropland Data Layer Metadata. Available at: http://www.nass.usda.gov/research/Cropland/metadata/metadata_va09.htm. Accessed 17 July 2011.

USEPA. 1991. Guidance for Water Quality-based Decisions: The TMDL Process. EPA 440/4-91-001. Washington, D.C.: Office of Water, USEPA.

USEPA. 2000. BASINS Technical Note 6: Estimating Hydrology and Hydraulic Parameters for HSPF. EPA-823-R00-012. Washington, D.C.: Office of Water, USEPA. Available at: http://www.epa.gov/waterscience/basins/tecnote6.pdf. Accessed 28 February 2006.

USEPA. 2006. An Approach for Using Load Duration Curves in Developing TMDLs. Draft document received via email from DEQ on June 20, 2007. Electronic name: Duration Curve Guide(Draft – 2006-12-15).pdf. Washington, D.C.: Office of Wetlands, Oceans, & Watersheds, USEPA.

USGS. 2011. National Water Information System: Web Interface. Water Resources: United States Geological Survey. Available at: http://waterdata.usgs.gov/va/nwis/nwisman/?site_no=03167000&agency_cd=USGS;. Accessed 26 March 2012.

VADCR and VADEQ. 2003. Guidance Manual for Total Maximum Daily Load Implementation Plans. Virginia Department of Conservation and Recreation, Virginia Department of Environmental Quality. 94 pp. Available at: http://ftp.deq.virginia.gov/tmdl/ipguide.html. Accessed 22 May 2012.

VADEQ. 2004. Final 2004 305(b)/303(d) Water Quality Assessment Integrated Report. Richmond, Va: VADEQ. Available at: http://ftp.deq.virginia.gov/water/reports.html. Accessed 22 May 2012.

VADEQ, 2006. Final 2006 305(b)/303(d) Water Quality Assessment Integrated Report. Richmond, VA: VADEQ. Available at: http://ftp.deq.virginia.gov/water/reports.html. Accessed 22 May 2012.

Weiskel, P.A., B.L. Howes, and G.R. Heufelder. 1996. Coliform contamination of a coastal embayment: sources and transport pathways. *Environ. Sci. Technol.* 30: 1872-1881.

Woods, A.J., J.M. Omernik, and D.D. Brown. 1999. Level III and IV Ecoregions of Delaware, Maryland, Pennsylvania, Virginia, and West Virginia. USEPA: Corvallis, Oregon. Available at: ftp://ftp.epa.gov/wed/ecoregions/reg3/reg3_eco_desc.doc. Accessed 22 March 2012.

Yagow, G. 2001. Fecal Coliform TMDL: Mountain Run Watershed, Culpeper County, Virginia. Available at: http://www.deq.virginia.gov/portals/0/DEQ/Water/TMDL/apptmdls/rapprvr/mtrnfec.pdf. Accessed 22 March 2012.

Zeckoski, R.W., B.L. Benham, S.B. Shah, M.L. Wolfe, K.M. Brannan, M. Al-Smadi, T.A. Dillaha, S. Mostaghimi, and C.D. Heatwole. 2005. BSLC: A Tool for Bacteria Source Characterization for Watershed Management. *Applied Engineering*. 21(5): 879-889.

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.

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: Weather Data Preparation

Introduction

A weather data file for providing the weather data inputs into the HSPF Model was created for the period January 1990 through December 2009 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 449301 located Wytheville, Virginia, which was located about 15 miles due west of the Reed Creek watershed outlet. Data from other NCDC stations were also used where Wytheville 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 Wytheville, VA (449301, Lat./Long. 36°56'N / 81°06'W, elevation 2450 ft); Pulaski, VA (446955 Lat./Long. 37°03'N / 80°47'W, elevation 1850 ft); Bland, VA (440792 Lat./Long. 37°06'N / 81°07'W, elevation 2000 ft); and Lynchburg Regional Airport, VA (445120, Lat./Long. 37°19'N / 79°12'W, elevation 940 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. 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 1990 through 2009. In order to make the best use of the available water quality data, the period of record was chosen to be January 1990 - December 2009. There are 7,305 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 Wytheville STP for the entire January 1990 – December 2009 period. Of the 175,320 possible hourly values in this period, 51,912 values were missing. The Pulaski and Wytheville (daily records) 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 the Wytheville STP for the entire period. The TMAX dataset was missing 50 day of data; the TMIN dataset was missing 60 days of data. Data from the Bland 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 Wytheville 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 B.1.

Table B.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. Cloud cover and solar radiation

   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 2009 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 Wytheville 2W latitude (36°56'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 Wytheville STP latitude (36°56'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 B.2.

Table B.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 C: HSPF Parameters that Vary by Month or Land Use

Table C. 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	0.10	0.16	0.16	0.16	0.16	0.16	0.10	0.06	0.06
Pasture	0.06	0.06	0.07	0.08	0.10	0.20	0.30	0.30	0.30	0.15	0.07	0.07
Cropland	0.03	0.03	0.03	0.05	0.10	0.10	0.20	0.20	0.30	0.20	0.05	0.04
Residential	0.06	0.06	0.06	0.10	0.16	0.16	0.16	0.16	0.16	0.10	0.06	0.06

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

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Forest	0.20	0.20	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.20
Pasture	0.20	0.20	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.20
Cropland	0.20	0.20	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.20
Residential	0.20	0.20	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.20

Table C. 3. MON-LZETP - Monthly Lower Zone ET Parameter.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Forest	0.10	0.10	0.20	0.30	0.45	0.65	0.75	0.75	0.65	0.30	0.15	0.10
Pasture	0.10	0.10	0.20	0.25	0.40	0.55	0.70	0.60	0.55	0.30	0.15	0.10
Cropland	0.10	0.10	0.10	0.10	0.30	0.60	0.65	0.65	0.55	0.25	0.15	0.10
Residential	0.10	0.10	0.20	0.30	0.45	0.65	0.75	0.75	0.65	0.30	0.15	0.10

Table C. 3. 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	6.90E+06	3.20E+08	1.40E+09	1.20E+09	2.90E+08	6.90E+06	6.90E+06	6.90E+06	6.90E+06	4.40E+08	4.50E+08	6.90E+06
1	Hayland	6.90E+06	9.90E+06	2.10E+07	1.80E+07	9.60E+06	9.70E+06	9.60E+06	9.60E+06	1.30E+07	1.20E+07	1.30E+07	6.90E+06
1	Pasture	1.20E+09	1.40E+09	2.20E+09	2.30E+09	2.30E+09	2.40E+09	2.50E+09	2.50E+09	2.60E+09	1.70E+09	1.70E+09	1.20E+09
1	Residential	3.00E+07	3.00E+07	3.00E+07	3.00E+07	3.00E+07	3.00E+07	3.00E+07	3.00E+07	3.00E+07	3.00E+07	3.00E+07	3.00E+07
1	Forest	7.30E+06	7.30E+06	7.30E+06	7.30E+06	7.30E+06	7.30E+06	7.30E+06	7.30E+06	7.30E+06	7.30E+06	7.30E+06	7.30E+06
2	Cropland	5.60E+06	2.30E+08	1.00E+09	8.40E+08	2.10E+08	5.60E+06	5.60E+06	5.60E+06	5.60E+06	3.10E+08	3.20E+08	5.60E+06
2	Hayland	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06
2	Pasture	1.20E+09	1.30E+09	2.20E+09	2.30E+09	2.30E+09	2.40E+09	2.40E+09	2.50E+09	2.60E+09	1.60E+09	1.70E+09	1.10E+09
2	Residential	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08
2	Forest	5.90E+06	5.90E+06	5.90E+06	5.90E+06	5.90E+06	5.90E+06	5.90E+06	5.90E+06	5.90E+06	5.90E+06	5.90E+06	5.90E+06
3	Cropland	4.90E+06	3.20E+08	1.40E+09	1.20E+09	2.90E+08	4.90E+06	4.90E+06	4.90E+06	4.90E+06	4.40E+08	4.50E+08	4.90E+06
3	Hayland	4.90E+06	2.20E+07	8.50E+07	7.10E+07	2.10E+07	2.10E+07	2.10E+07	2.10E+07	3.80E+07	3.70E+07	3.80E+07	4.90E+06
3	Pasture	1.20E+09	1.30E+09	2.20E+09	2.30E+09	2.30E+09	2.40E+09	2.40E+09	2.50E+09	2.60E+09	1.60E+09	1.70E+09	1.10E+09
3	Residential	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
3	Forest	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06
4	Cropland	3.60E+06	3.10E+08	1.40E+09	1.20E+09	2.90E+08	3.60E+06	3.60E+06	3.60E+06	3.60E+06	4.30E+08	4.50E+08	3.60E+06
4	Hayland	3.60E+06	3.50E+07	1.50E+08	1.20E+08	3.20E+07	3.30E+07	3.20E+07	3.20E+07	6.20E+07	6.00E+07	6.20E+07	3.60E+06
4	Pasture	1.20E+09	1.30E+09	2.20E+09	2.30E+09	2.30E+09	2.40E+09	2.40E+09	2.50E+09	2.60E+09	1.60E+09	1.70E+09	1.10E+09
4	Residential	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08
4	Forest	3.80E+06	3.80E+06	3.80E+06	3.80E+06	3.80E+06	3.80E+06	3.80E+06	3.80E+06	3.80E+06	3.80E+06	3.80E+06	3.80E+06
5	Cropland	1.00E+07	1.70E+08	7.30E+08	6.10E+08	1.50E+08	1.00E+07	1.00E+07	1.00E+07	1.00E+07	2.30E+08	2.40E+08	1.00E+07
5	Hayland	1.00E+07	1.00E+07	1.00E+07	1.00E+07	1.00E+07	1.00E+07	1.00E+07	1.00E+07	1.00E+07	1.00E+07	1.00E+07	1.00E+07
5	Pasture	1.20E+09	1.40E+09	2.20E+09	2.30E+09	2.30E+09	2.40E+09	2.50E+09	2.50E+09	2.60E+09	1.60E+09	1.70E+09	1.10E+09
5	Residential	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
5	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
6	Cropland	3.90E+06	2.10E+08	9.50E+08	7.80E+08	1.90E+08	3.90E+06	3.90E+06	3.90E+06	3.90E+06	2.90E+08	3.00E+08	3.90E+06
6	Hayland	3.90E+06	3.90E+06	3.90E+06	3.90E+06	3.90E+06	3.90E+06	3.90E+06	3.90E+06	3.90E+06	3.90E+06	3.90E+06	3.90E+06
6	Pasture	1.20E+09	1.30E+09	2.20E+09	2.30E+09	2.30E+09	2.40E+09	2.40E+09	2.50E+09	2.60E+09	1.60E+09	1.70E+09	1.10E+09
6	Residential	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

6	Forest	4.20E+06	4.20E+06	4.20E+06	4.20E+06	4.20E+06	4.20E+06	4.20E+06	4.20E+06	4.20E+06	4.20E+06	4.20E+06	4.20E+06
7	Cropland	5.50E+06	3.20E+08	1.40E+09	1.20E+09	2.90E+08	5.50E+06	5.50E+06	5.50E+06	5.50E+06	4.40E+08	4.50E+08	5.50E+06
7	Hayland	5.50E+06	2.30E+07	8.50E+07	7.10E+07	2.10E+07	2.20E+07	2.10E+07	2.10E+07	3.80E+07	3.70E+07	3.80E+07	5.50E+06
7	Pasture	1.20E+09	1.30E+09	2.20E+09	2.30E+09	2.30E+09	2.40E+09	2.40E+09	2.50E+09	2.60E+09	1.60E+09	1.70E+09	1.10E+09
7	Residential	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
7	Forest	5.70E+06	5.70E+06	5.70E+06	5.70E+06	5.70E+06	5.70E+06	5.70E+06	5.70E+06	5.70E+06	5.70E+06	5.70E+06	5.70E+06
8	Cropland	6.50E+06	3.20E+08	1.40E+09	1.20E+09	2.90E+08	6.50E+06	6.50E+06	6.50E+06	6.50E+06	4.40E+08	4.50E+08	6.50E+06
8	Hayland	6.50E+06	8.20E+06	1.40E+07	1.30E+07	8.10E+06	8.10E+06	8.10E+06	8.10E+06	9.70E+06	9.60E+06	9.70E+06	6.50E+06
8	Pasture	1.20E+09	1.30E+09	2.20E+09	2.30E+09	2.30E+09	2.40E+09	2.40E+09	2.50E+09	2.60E+09	1.60E+09	1.70E+09	1.10E+09
8	Residential	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08
8	Forest	6.80E+06	6.80E+06	6.80E+06	6.80E+06	6.80E+06	6.80E+06	6.80E+06	6.80E+06	6.80E+06	6.80E+06	6.80E+06	6.80E+06
9	Hayland	1.30E+07	6.80E+07	2.60E+08	2.20E+08	6.30E+07	6.50E+07	6.30E+07	6.30E+07	1.20E+08	1.10E+08	1.20E+08	1.30E+07
9	Pasture	1.30E+09	1.40E+09	2.30E+09	2.30E+09	2.40E+09	2.50E+09	2.50E+09	2.60E+09	2.60E+09	1.70E+09	1.80E+09	1.20E+09
9	Residential	2.50E+07	2.50E+07	2.50E+07	2.50E+07	2.50E+07	2.50E+07	2.50E+07	2.50E+07	2.50E+07	2.50E+07	2.50E+07	2.50E+07
9	Forest	1.40E+07	1.40E+07	1.40E+07	1.40E+07	1.40E+07	1.40E+07	1.40E+07	1.40E+07	1.40E+07	1.40E+07	1.40E+07	1.40E+07
10	Cropland	4.80E+06	1.40E+08	6.40E+08	5.30E+08	1.30E+08	4.80E+06	4.80E+06	4.80E+06	4.80E+06	2.00E+08	2.00E+08	4.80E+06
10	Hayland	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06
10	Pasture	1.20E+09	1.30E+09	2.20E+09	2.30E+09	2.30E+09	2.40E+09	2.40E+09	2.50E+09	2.60E+09	1.60E+09	1.70E+09	1.10E+09
10	Residential	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08
10	Forest	5.10E+06	5.10E+06	5.10E+06	5.10E+06	5.10E+06	5.10E+06	5.10E+06	5.10E+06	5.10E+06	5.10E+06	5.10E+06	5.10E+06
11	Cropland	4.50E+06	1.10E+08	5.00E+08	4.20E+08	1.00E+08	4.50E+06	4.50E+06	4.50E+06	4.50E+06	1.60E+08	1.60E+08	4.50E+06
11	Hayland	4.50E+06	4.50E+06	4.50E+06	4.50E+06	4.50E+06	4.50E+06	4.50E+06	4.50E+06	4.50E+06	4.50E+06	4.50E+06	4.50E+06
11	Pasture	1.20E+09	1.30E+09	2.20E+09	2.30E+09	2.30E+09	2.40E+09	2.40E+09	2.50E+09	2.60E+09	1.60E+09	1.70E+09	1.10E+09
11	Residential	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
11	Forest	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06
12	Cropland	9.60E+06	3.20E+08	1.40E+09	1.20E+09	2.90E+08	9.60E+06	9.60E+06	9.60E+06	9.60E+06	4.40E+08	4.50E+08	9.60E+06
12	Hayland	9.60E+06	2.50E+07	7.90E+07	6.70E+07	2.40E+07	2.40E+07	2.40E+07	2.40E+07	3.80E+07	3.80E+07	3.80E+07	9.60E+06
12	Pasture	1.20E+09	1.40E+09	2.20E+09	2.30E+09	2.30E+09	2.40E+09	2.50E+09	2.50E+09	2.60E+09	1.60E+09	1.70E+09	1.10E+09
12	Residential	5.10E+08	5.10E+08	5.10E+08	5.10E+08	5.10E+08	5.10E+08	5.10E+08	5.10E+08	5.10E+08	5.10E+08	5.10E+08	5.10E+08
12	Forest	9.90E+06	9.90E+06	9.90E+06	9.90E+06	9.90E+06	9.90E+06	9.90E+06	9.90E+06	9.90E+06	9.90E+06	9.90E+06	9.90E+06
13	Hayland	7.60E+06	7.60E+07	3.20E+08	2.60E+08	6.90E+07	7.20E+07	6.90E+07	6.90E+07	1.40E+08	1.30E+08	1.40E+08	7.60E+06

13	Pasture	1.90E+09	2.20E+09	3.60E+09	3.70E+09	3.80E+09	3.80E+09	3.90E+09	4.00E+09	4.20E+09	2.60E+09	2.80E+09	1.80E+09
13	Residential	2.00E+08	2.00E+08	2.00E+08	2.00E+08	2.00E+08	2.00E+08	2.00E+08	2.00E+08	2.00E+08	2.00E+08	2.00E+08	2.00E+08
13	Forest	7.90E+06	7.90E+06	7.90E+06	7.90E+06	7.90E+06	7.90E+06	7.90E+06	7.90E+06	7.90E+06	7.90E+06	7.90E+06	7.90E+06
14	Cropland	6.10E+06	8.70E+07	3.70E+08	3.10E+08	7.90E+07	6.10E+06	6.10E+06	6.10E+06	6.10E+06	1.20E+08	1.20E+08	6.10E+06
14	Hayland	6.10E+06	6.10E+06	6.10E+06	6.10E+06	6.10E+06	6.10E+06	6.10E+06	6.10E+06	6.10E+06	6.10E+06	6.10E+06	6.10E+06
14	Pasture	1.70E+09	1.90E+09	3.20E+09	3.30E+09	3.40E+09	3.50E+09	3.50E+09	3.60E+09	3.70E+09	2.40E+09	2.50E+09	1.60E+09
14	Residential	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
14	Forest	6.30E+06	6.30E+06	6.30E+06	6.30E+06	6.30E+06	6.30E+06	6.30E+06	6.30E+06	6.30E+06	6.30E+06	6.30E+06	6.30E+06
15	Cropland	4.40E+06	1.30E+08	5.90E+08	4.90E+08	1.20E+08	4.40E+06	4.40E+06	4.40E+06	4.40E+06	9.90E+07	1.90E+08	4.40E+06
15	Hayland	4.40E+06	2.40E+07	9.40E+07	7.80E+07	2.20E+07	2.30E+07	2.20E+07	2.20E+07	4.10E+07	4.00E+07	4.10E+07	4.40E+06
15	Pasture	2.00E+09	2.30E+09	3.80E+09	3.90E+09	4.00E+09	4.10E+09	4.20E+09	4.30E+09	4.40E+09	3.00E+09	3.10E+09	1.90E+09
15	Residential	3.40E+08	3.40E+08	3.40E+08	3.40E+08	3.40E+08	3.40E+08	3.40E+08	3.40E+08	3.40E+08	3.40E+08	3.40E+08	3.40E+08
15	Forest	4.60E+06	4.60E+06	4.60E+06	4.60E+06	4.60E+06	4.60E+06	4.60E+06	4.60E+06	4.60E+06	4.60E+06	4.60E+06	4.60E+06
16	Cropland	4.80E+06	3.20E+08	1.40E+09	1.20E+09	2.90E+08	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.40E+08	4.50E+08	4.80E+06
16	Hayland	4.80E+06	9.60E+06	2.70E+07	2.30E+07	9.20E+06	9.40E+06	9.20E+06	9.20E+06	1.40E+07	1.40E+07	1.40E+07	4.80E+06
16	Pasture	1.70E+09	1.90E+09	3.20E+09	3.30E+09	3.40E+09	3.40E+09	3.50E+09	3.60E+09	3.70E+09	2.30E+09	2.50E+09	1.60E+09
16	Residential	3.10E+08	3.10E+08	3.10E+08	3.10E+08	3.10E+08	3.10E+08	3.10E+08	3.10E+08	3.10E+08	3.10E+08	3.10E+08	3.10E+08
16	Forest	5.00E+06	5.00E+06	5.00E+06	5.00E+06	5.00E+06	5.00E+06	5.00E+06	5.00E+06	5.00E+06	5.00E+06	5.00E+06	5.00E+06
17	Cropland	6.00E+06	8.90E+07	3.90E+08	3.20E+08	8.20E+07	6.00E+06	6.00E+06	6.00E+06	6.00E+06	1.20E+08	1.30E+08	6.00E+06
17	Hayland	6.00E+06	6.00E+06	6.00E+06	6.00E+06	6.00E+06	6.00E+06	6.00E+06	6.00E+06	6.00E+06	6.00E+06	6.00E+06	6.00E+06
17	Pasture	1.20E+09	1.30E+09	2.20E+09	2.30E+09	2.30E+09	2.40E+09	2.40E+09	2.50E+09	2.60E+09	1.60E+09	1.70E+09	1.10E+09
17	Residential	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
17	Forest	6.30E+06	6.30E+06	6.30E+06	6.30E+06	6.30E+06	6.30E+06	6.30E+06	6.30E+06	6.30E+06	6.30E+06	6.30E+06	6.30E+06
18	Cropland	6.10E+06	6.60E+07	2.80E+08	2.30E+08	6.00E+07	6.10E+06	6.10E+06	6.10E+06	6.10E+06	8.90E+07	9.10E+07	6.10E+06
18	Hayland	6.10E+06	6.10E+06	6.10E+06	6.10E+06	6.10E+06	6.10E+06	6.10E+06	6.10E+06	6.10E+06	6.10E+06	6.10E+06	6.10E+06
18	Pasture	1.20E+09	1.30E+09	2.20E+09	2.30E+09	2.30E+09	2.40E+09	2.50E+09	2.50E+09	2.60E+09	1.60E+09	1.70E+09	1.10E+09
18	Residential	3.20E+08	3.20E+08	3.20E+08	3.20E+08	3.20E+08	3.20E+08	3.20E+08	3.20E+08	3.20E+08	3.20E+08	3.20E+08	3.20E+08
18	Forest	6.40E+06	6.40E+06	6.40E+06	6.40E+06	6.40E+06	6.40E+06	6.40E+06	6.40E+06	6.40E+06	6.40E+06	6.40E+06	6.40E+06
19	Cropland	4.50E+06	1.90E+08	8.30E+08	6.90E+08	1.70E+08	4.50E+06	4.50E+06	4.50E+06	4.50E+06	2.60E+08	2.70E+08	4.50E+06
19	Hayland	4.50E+06	4.50E+06	4.50E+06	4.50E+06	4.50E+06	4.50E+06	4.50E+06	4.50E+06	4.50E+06	4.50E+06	4.50E+06	4.50E+06
19	Pasture	1.20E+09	1.30E+09	2.20E+09	2.30E+09	2.30E+09	2.30E+09	2.40E+09	2.50E+09	2.50E+09	1.60E+09	1.70E+09	1.10E+09

19	Residential	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
19	Forest	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06
20	Hayland	4.40E+06	9.90E+06	3.00E+07	2.50E+07	9.40E+06	9.60E+06	9.40E+06	9.40E+06	1.50E+07	1.40E+07	1.50E+07	4.40E+06
20	Pasture	1.20E+09	1.40E+09	2.20E+09	2.30E+09	2.30E+09	2.40E+09	2.40E+09	2.50E+09	2.60E+09	1.70E+09	1.70E+09	1.10E+09
20	Residential	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
20	Forest	4.50E+06	4.50E+06	4.50E+06	4.50E+06	4.50E+06	4.50E+06	4.50E+06	4.50E+06	4.50E+06	4.50E+06	4.50E+06	4.50E+06
21	Hayland	6.30E+06	1.90E+07	6.30E+07	5.30E+07	1.80E+07	1.80E+07	1.80E+07	1.80E+07	3.00E+07	2.90E+07	3.00E+07	6.30E+06
21	Pasture	1.20E+09	1.40E+09	2.20E+09	2.30E+09	2.30E+09	2.40E+09	2.40E+09	2.50E+09	2.60E+09	1.60E+09	1.70E+09	1.10E+09
21	Residential	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
21	Forest	6.70E+06	6.70E+06	6.70E+06	6.70E+06	6.70E+06	6.70E+06	6.70E+06	6.70E+06	6.70E+06	6.70E+06	6.70E+06	6.70E+06
22	Cropland	6.40E+06	3.20E+08	1.40E+09	1.20E+09	2.90E+08	6.40E+06	6.40E+06	6.40E+06	6.40E+06	4.40E+08	4.50E+08	6.40E+06
22	Hayland	6.40E+06	1.30E+07	3.50E+07	3.00E+07	1.20E+07	1.20E+07	1.20E+07	1.20E+07	1.80E+07	1.80E+07	1.80E+07	6.40E+06
22	Pasture	1.20E+09	1.30E+09	2.20E+09	2.20E+09	2.30E+09	2.30E+09	2.40E+09	2.50E+09	2.50E+09	1.60E+09	1.70E+09	1.10E+09
22	Residential	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
22	Forest	6.60E+06	6.60E+06	6.60E+06	6.60E+06	6.60E+06	6.60E+06	6.60E+06	6.60E+06	6.60E+06	6.60E+06	6.60E+06	6.60E+06
23	Cropland	4.90E+06	1.50E+08	6.70E+08	5.50E+08	1.40E+08	4.90E+06	4.90E+06	4.90E+06	4.90E+06	1.40E+08	2.10E+08	4.90E+06
23	Hayland	4.90E+06	2.20E+07	8.40E+07	7.00E+07	2.10E+07	2.10E+07	2.10E+07	2.10E+07	3.80E+07	3.70E+07	3.80E+07	4.90E+06
23	Pasture	1.60E+09	1.80E+09	3.00E+09	3.10E+09	3.10E+09	3.20E+09	3.20E+09	3.30E+09	3.40E+09	2.50E+09	2.50E+09	1.50E+09
23	Residential	1.40E+08	1.40E+08	1.40E+08	1.40E+08	1.40E+08	1.40E+08	1.40E+08	1.40E+08	1.40E+08	1.40E+08	1.40E+08	1.40E+08
23	Forest	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06
24	Cropland	4.60E+06	3.20E+08	1.40E+09	1.20E+09	2.90E+08	4.60E+06	4.60E+06	4.60E+06	4.60E+06	4.40E+08	4.50E+08	4.60E+06
24	Hayland	4.60E+06	1.60E+07	5.90E+07	4.90E+07	1.50E+07	1.60E+07	1.50E+07	1.50E+07	2.70E+07	2.60E+07	2.70E+07	4.60E+06
24	Pasture	1.20E+09	1.30E+09	2.20E+09	2.20E+09	2.30E+09	2.30E+09	2.40E+09	2.50E+09	2.50E+09	1.60E+09	1.70E+09	1.10E+09
24	Residential	1.40E+08	1.40E+08	1.40E+08	1.40E+08	1.40E+08	1.40E+08	1.40E+08	1.40E+08	1.40E+08	1.40E+08	1.40E+08	1.40E+08
24	Forest	4.90E+06	4.90E+06	4.90E+06	4.90E+06	4.90E+06	4.90E+06	4.90E+06	4.90E+06	4.90E+06	4.90E+06	4.90E+06	4.90E+06
25	Cropland	5.70E+06	3.20E+08	1.40E+09	1.20E+09	2.90E+08	5.70E+06	5.70E+06	5.70E+06	5.70E+06	4.40E+08	4.50E+08	5.70E+06
25	Hayland	5.70E+06	6.20E+06	7.80E+06	7.40E+06	6.10E+06	6.10E+06	6.10E+06	6.10E+06	6.60E+06	6.50E+06	6.60E+06	5.70E+06
25	Pasture	1.20E+09	1.30E+09	2.20E+09	2.30E+09	2.30E+09	2.30E+09	2.40E+09	2.50E+09	2.50E+09	1.60E+09	1.70E+09	1.10E+09
25	Residential	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08
25	Forest	5.90E+06	5.90E+06	5.90E+06	5.90E+06	5.90E+06	5.90E+06	5.90E+06	5.90E+06	5.90E+06	5.90E+06	5.90E+06	5.90E+06
26	Cropland	4.70E+06	1.50E+08	6.50E+08	5.40E+08	1.30E+08	4.70E+06	4.70E+06	4.70E+06	4.70E+06	2.00E+08	2.10E+08	4.70E+06

26	Hayland	4.70E+06	4.70E+06	4.70E+06	4.70E+06	4.70E+06	4.70E+06	4.70E+06	4.70E+06	4.70E+06	4.70E+06	4.70E+06	4.70E+06
26	Pasture	1.20E+09	1.30E+09	2.20E+09	2.20E+09	2.30E+09	2.30E+09	2.40E+09	2.50E+09	2.50E+09	1.60E+09	1.70E+09	1.10E+09
26	Residential	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
26	Forest	5.00E+06	5.00E+06	5.00E+06	5.00E+06	5.00E+06	5.00E+06	5.00E+06	5.00E+06	5.00E+06	5.00E+06	5.00E+06	5.00E+06
27	Cropland	5.60E+06	1.30E+08	5.90E+08	4.90E+08	1.20E+08	5.60E+06	5.60E+06	5.60E+06	5.60E+06	1.80E+08	1.90E+08	5.60E+06
27	Hayland	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06
27	Pasture	1.20E+09	1.30E+09	2.20E+09	2.30E+09	2.30E+09	2.40E+09	2.40E+09	2.50E+09	2.60E+09	1.60E+09	1.70E+09	1.10E+09
27	Residential	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
27	Forest	6.00E+06	6.00E+06	6.00E+06	6.00E+06	6.00E+06	6.00E+06	6.00E+06	6.00E+06	6.00E+06	6.00E+06	6.00E+06	6.00E+06
28	Cropland	4.60E+06	9.00E+07	3.90E+08	3.30E+08	8.20E+07	4.60E+06	4.60E+06	4.60E+06	4.60E+06	1.20E+08	1.30E+08	4.60E+06
28	Hayland	4.60E+06	4.60E+06	4.60E+06	4.60E+06	4.60E+06	4.60E+06	4.60E+06	4.60E+06	4.60E+06	4.60E+06	4.60E+06	4.60E+06
28	Pasture	1.20E+09	1.30E+09	2.20E+09	2.30E+09	2.30E+09	2.40E+09	2.50E+09	2.50E+09	2.60E+09	1.60E+09	1.70E+09	1.10E+09
28	Residential	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
28	Forest	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06
29	Cropland	4.60E+06	4.60E+07	1.90E+08	1.60E+08	4.20E+07	4.60E+06	4.60E+06	4.60E+06	4.60E+06	6.20E+07	6.40E+07	4.60E+06
29	Hayland	4.60E+06	4.60E+06	4.60E+06	4.60E+06	4.60E+06	4.60E+06	4.60E+06	4.60E+06	4.60E+06	4.60E+06	4.60E+06	4.60E+06
29	Pasture	1.20E+09	1.30E+09	2.20E+09	2.30E+09	2.30E+09	2.40E+09	2.40E+09	2.50E+09	2.60E+09	1.60E+09	1.70E+09	1.10E+09
29	Residential	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
29	Forest	4.90E+06	4.90E+06	4.90E+06	4.90E+06	4.90E+06	4.90E+06	4.90E+06	4.90E+06	4.90E+06	4.90E+06	4.90E+06	4.90E+06
30	Cropland	1.60E+06	2.20E+07	9.30E+07	7.70E+07	2.00E+07	1.60E+06	1.60E+06	1.60E+06	1.60E+06	2.90E+07	3.00E+07	1.60E+06
30	Hayland	1.60E+06	1.60E+06	1.60E+06	1.60E+06	1.60E+06	1.60E+06	1.60E+06	1.60E+06	1.60E+06	1.60E+06	1.60E+06	1.60E+06
30	Pasture	1.20E+09	1.40E+09	2.20E+09	2.30E+09	2.30E+09	2.40E+09	2.40E+09	2.50E+09	2.60E+09	1.60E+09	1.70E+09	1.10E+09
30	Residential	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08
30	Forest	2.10E+06	2.10E+06	2.10E+06	2.10E+06	2.10E+06	2.10E+06	2.10E+06	2.10E+06	2.10E+06	2.10E+06	2.10E+06	2.10E+06
31	Cropland	5.40E+06	3.20E+08	1.40E+09	1.20E+09	2.90E+08	5.40E+06	5.40E+06	5.40E+06	5.40E+06	4.40E+08	4.50E+08	5.40E+06
31	Hayland	5.40E+06	1.40E+07	4.40E+07	3.70E+07	1.30E+07	1.30E+07	1.30E+07	1.30E+07	2.10E+07	2.10E+07	2.10E+07	5.40E+06
31	Pasture	1.20E+09	1.40E+09	2.20E+09	2.30E+09	2.30E+09	2.40E+09	2.50E+09	2.50E+09	2.60E+09	1.60E+09	1.70E+09	1.10E+09
31	Residential	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08
31	Forest	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06
32	Cropland	6.40E+06	1.30E+08	5.80E+08	4.80E+08	1.20E+08	6.40E+06	6.40E+06	6.40E+06	6.40E+06	1.80E+08	1.90E+08	6.40E+06
32	Hayland	6.40E+06	6.40E+06	6.40E+06	6.40E+06	6.40E+06	6.40E+06	6.40E+06	6.40E+06	6.40E+06	6.40E+06	6.40E+06	6.40E+06

32	Pasture	1.20E+09	1.40E+09	2.20E+09	2.30E+09	2.30E+09	2.40E+09	2.50E+09	2.50E+09	2.60E+09	1.60E+09	1.70E+09	1.10E+09
32	Residential	1.40E+08	1.40E+08	1.40E+08	1.40E+08	1.40E+08	1.40E+08	1.40E+08	1.40E+08	1.40E+08	1.40E+08	1.40E+08	1.40E+08
32	Forest	6.70E+06	6.70E+06	6.70E+06	6.70E+06	6.70E+06	6.70E+06	6.70E+06	6.70E+06	6.70E+06	6.70E+06	6.70E+06	6.70E+06
33	Hayland	4.50E+06	2.60E+07	1.00E+08	8.70E+07	2.50E+07	2.50E+07	2.50E+07	2.50E+07	4.60E+07	4.50E+07	4.60E+07	4.50E+06
33	Pasture	1.40E+09	1.60E+09	2.60E+09	2.70E+09	2.70E+09	2.80E+09	2.80E+09	2.90E+09	3.00E+09	1.90E+09	2.00E+09	1.30E+09
33	Residential	2.70E+08	2.70E+08	2.70E+08	2.70E+08	2.70E+08	2.70E+08	2.70E+08	2.70E+08	2.70E+08	2.70E+08	2.70E+08	2.70E+08
33	Forest	4.70E+06	4.70E+06	4.70E+06	4.70E+06	4.70E+06	4.70E+06	4.70E+06	4.70E+06	4.70E+06	4.70E+06	4.70E+06	4.70E+06
34	Hayland	2.10E+07	3.40E+07	7.90E+07	6.90E+07	3.20E+07	3.30E+07	3.20E+07	3.20E+07	4.50E+07	4.40E+07	4.50E+07	2.10E+07
34	Pasture	1.50E+09	1.70E+09	2.70E+09	2.80E+09	2.80E+09	2.90E+09	3.00E+09	3.00E+09	3.10E+09	2.00E+09	2.10E+09	1.40E+09
34	Residential	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
34	Forest	2.10E+07	2.10E+07	2.10E+07	2.10E+07	2.10E+07	2.10E+07	2.10E+07	2.10E+07	2.10E+07	2.10E+07	2.10E+07	2.10E+07
35	Cropland	5.30E+06	3.20E+08	1.40E+09	1.20E+09	2.90E+08	5.30E+06	5.30E+06	5.30E+06	5.30E+06	4.40E+08	4.50E+08	5.30E+06
35	Hayland	5.30E+06	2.40E+07	9.00E+07	7.50E+07	2.20E+07	2.30E+07	2.20E+07	2.20E+07	4.00E+07	3.90E+07	4.00E+07	5.30E+06
35	Pasture	1.40E+09	1.60E+09	2.60E+09	2.70E+09	2.70E+09	2.80E+09	2.90E+09	2.90E+09	3.00E+09	1.90E+09	2.00E+09	1.30E+09
35	Residential	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
35	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
36	Cropland	6.10E+06	1.80E+08	8.10E+08	6.70E+08	1.70E+08	6.10E+06	6.10E+06	6.10E+06	6.10E+06	2.40E+08	2.60E+08	6.10E+06
36	Hayland	6.10E+06	6.10E+06	6.10E+06	6.10E+06	6.10E+06	6.10E+06	6.10E+06	6.10E+06	6.10E+06	6.10E+06	6.10E+06	6.10E+06
36	Pasture	1.40E+09	1.70E+09	2.80E+09	2.80E+09	2.90E+09	2.90E+09	3.00E+09	3.10E+09	3.20E+09	2.10E+09	2.10E+09	1.40E+09
36	Residential	1.90E+08	1.90E+08	1.90E+08	1.90E+08	1.90E+08	1.90E+08	1.90E+08	1.90E+08	1.90E+08	1.90E+08	1.90E+08	1.90E+08
36	Forest	6.40E+06	6.40E+06	6.40E+06	6.40E+06	6.40E+06	6.40E+06	6.40E+06	6.40E+06	6.40E+06	6.40E+06	6.40E+06	6.40E+06
37	Hayland	8.30E+06	2.40E+07	8.00E+07	6.80E+07	2.30E+07	2.30E+07	2.30E+07	2.30E+07	3.80E+07	3.70E+07	3.80E+07	8.30E+06
37	Pasture	1.20E+09	1.30E+09	2.20E+09	2.30E+09	2.30E+09	2.40E+09	2.40E+09	2.50E+09	2.60E+09	1.60E+09	1.70E+09	1.10E+09
37	Residential	9.90E+07	9.90E+07	9.90E+07	9.90E+07	9.90E+07	9.90E+07	9.90E+07	9.90E+07	9.90E+07	9.90E+07	9.90E+07	9.90E+07
37	Forest	8.70E+06	8.70E+06	8.70E+06	8.70E+06	8.70E+06	8.70E+06	8.70E+06	8.70E+06	8.70E+06	8.70E+06	8.70E+06	8.70E+06
38	Cropland	7.20E+06	5.30E+07	2.10E+08	1.80E+08	4.90E+07	7.20E+06	7.20E+06	7.20E+06	7.20E+06	7.00E+07	7.20E+07	7.20E+06
38	Hayland	7.20E+06	7.20E+06	7.20E+06	7.20E+06	7.20E+06	7.20E+06	7.20E+06	7.20E+06	7.20E+06	7.20E+06	7.20E+06	7.20E+06
38	Pasture	1.20E+09	1.30E+09	2.20E+09	2.30E+09	2.30E+09	2.40E+09	2.40E+09	2.50E+09	2.50E+09	1.60E+09	1.70E+09	1.10E+09
38	Residential	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
38	Forest	7.50E+06	7.50E+06	7.50E+06	7.50E+06	7.50E+06	7.50E+06	7.50E+06	7.50E+06	7.50E+06	7.50E+06	7.50E+06	7.50E+06
39	Cropland	7.70E+06	6.60E+07	2.70E+08	2.30E+08	6.10E+07	7.70E+06	7.70E+06	7.70E+06	7.70E+06	7.90E+07	9.10E+07	7.70E+06

39	Hayland	7.70E+06	7.70E+06	7.70E+06	7.70E+06	7.70E+06	7.70E+06	7.70E+06	7.70E+06	7.70E+06	7.70E+06	7.70E+06	7.70E+06
39	Pasture	1.30E+09	1.50E+09	2.50E+09	2.50E+09	2.60E+09	2.60E+09	2.70E+09	2.80E+09	2.80E+09	1.90E+09	2.00E+09	1.20E+09
39	Residential	2.00E+08	2.00E+08	2.00E+08	2.00E+08	2.00E+08	2.00E+08	2.00E+08	2.00E+08	2.00E+08	2.00E+08	2.00E+08	2.00E+08
39	Forest	8.10E+06	8.10E+06	8.10E+06	8.10E+06	8.10E+06	8.10E+06	8.10E+06	8.10E+06	8.10E+06	8.10E+06	8.10E+06	8.10E+06
40	Cropland	5.50E+06	3.60E+07	1.40E+08	1.20E+08	3.30E+07	5.50E+06	5.50E+06	5.50E+06	5.50E+06	4.80E+07	4.90E+07	5.50E+06
40	Hayland	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
40	Pasture	1.20E+09	1.40E+09	2.20E+09	2.30E+09	2.30E+09	2.40E+09	2.40E+09	2.50E+09	2.60E+09	1.60E+09	1.70E+09	1.10E+09
40	Residential	1.40E+08	1.40E+08	1.40E+08	1.40E+08	1.40E+08	1.40E+08	1.40E+08	1.40E+08	1.40E+08	1.40E+08	1.40E+08	1.40E+08
40	Forest	5.90E+06	5.90E+06	5.90E+06	5.90E+06	5.90E+06	5.90E+06	5.90E+06	5.90E+06	5.90E+06	5.90E+06	5.90E+06	5.90E+06
41	Cropland	5.60E+06	1.50E+08	6.50E+08	5.40E+08	1.30E+08	5.60E+06	5.60E+06	5.60E+06	5.60E+06	2.00E+08	2.10E+08	5.60E+06
41	Hayland	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06
41	Pasture	1.20E+09	1.30E+09	2.20E+09	2.30E+09	2.30E+09	2.40E+09	2.40E+09	2.50E+09	2.50E+09	1.60E+09	1.70E+09	1.10E+09
41	Residential	2.70E+08	2.70E+08	2.70E+08	2.70E+08	2.70E+08	2.70E+08	2.70E+08	2.70E+08	2.70E+08	2.70E+08	2.70E+08	2.70E+08
41	Forest	5.90E+06	5.90E+06	5.90E+06	5.90E+06	5.90E+06	5.90E+06	5.90E+06	5.90E+06	5.90E+06	5.90E+06	5.90E+06	5.90E+06
42	Cropland	6.90E+06	1.40E+08	6.20E+08	5.10E+08	1.30E+08	6.90E+06	6.90E+06	6.90E+06	6.90E+06	1.60E+08	2.00E+08	6.90E+06
42	Hayland	6.90E+06	6.90E+06	6.90E+06	6.90E+06	6.90E+06	6.90E+06	6.90E+06	6.90E+06	6.90E+06	6.90E+06	6.90E+06	6.90E+06
42	Pasture	1.50E+09	1.70E+09	2.90E+09	3.00E+09	3.00E+09	3.00E+09	3.10E+09	3.20E+09	3.20E+09	2.30E+09	2.30E+09	1.50E+09
42	Residential	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
42	Forest	7.20E+06	7.20E+06	7.20E+06	7.20E+06	7.20E+06	7.20E+06	7.20E+06	7.20E+06	7.20E+06	7.20E+06	7.20E+06	7.20E+06
43	Hayland	8.00E+06	2.70E+07	9.40E+07	7.90E+07	2.50E+07	2.60E+07	2.50E+07	2.50E+07	4.30E+07	4.20E+07	4.30E+07	8.00E+06
43	Pasture	1.20E+09	1.30E+09	2.20E+09	2.30E+09	2.30E+09	2.40E+09	2.40E+09	2.50E+09	2.60E+09	1.60E+09	1.70E+09	1.10E+09
43	Residential	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08
43	Forest	8.30E+06	8.30E+06	8.30E+06	8.30E+06	8.30E+06	8.30E+06	8.30E+06	8.30E+06	8.30E+06	8.30E+06	8.30E+06	8.30E+06
44	Cropland	5.10E+06	1.70E+08	7.80E+08	6.40E+08	1.60E+08	5.10E+06	5.10E+06	5.10E+06	5.10E+06	2.10E+08	2.50E+08	5.10E+06
44	Hayland	5.10E+06	5.10E+06	5.10E+06	5.10E+06	5.10E+06	5.10E+06	5.10E+06	5.10E+06	5.10E+06	5.10E+06	5.10E+06	5.10E+06
44	Pasture	1.30E+09	1.50E+09	2.60E+09	2.70E+09	2.70E+09	2.80E+09	2.80E+09	2.90E+09	3.00E+09	2.00E+09	2.10E+09	1.30E+09
44	Residential	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
44	Forest	5.40E+06	5.40E+06	5.40E+06	5.40E+06	5.40E+06	5.40E+06	5.40E+06	5.40E+06	5.40E+06	5.40E+06	5.40E+06	5.40E+06
45	Cropland	5.20E+06	3.00E+08	1.30E+09	1.10E+09	2.70E+08	5.20E+06	5.20E+06	5.20E+06	5.20E+06	4.10E+08	4.30E+08	5.20E+06
45	Hayland	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06
45	Pasture	1.20E+09	1.30E+09	2.20E+09	2.30E+09	2.30E+09	2.40E+09	2.50E+09	2.50E+09	2.60E+09	1.60E+09	1.70E+09	1.10E+09

45	Residential	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
45	Forest	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06
46	Cropland	4.80E+06	1.40E+08	6.10E+08	5.00E+08	1.30E+08	4.80E+06	4.80E+06	4.80E+06	4.80E+06	1.30E+08	2.00E+08	4.80E+06
46	Hayland	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06
46	Pasture	2.40E+09	2.60E+09	4.70E+09	4.90E+09	5.00E+09	5.10E+09	5.10E+09	5.20E+09	5.20E+09	4.30E+09	4.20E+09	2.40E+09
46	Residential	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
46	Forest	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06
47	Hayland	1.00E+07	2.00E+07	5.70E+07	4.90E+07	1.90E+07	2.00E+07	1.90E+07	1.90E+07	2.90E+07	2.90E+07	2.90E+07	1.00E+07
47	Pasture	1.20E+09	1.40E+09	2.10E+09	2.20E+09	2.20E+09	2.30E+09	2.40E+09	2.40E+09	2.50E+09	1.60E+09	1.70E+09	1.20E+09
47	Residential	5.70E+07	5.70E+07	5.70E+07	5.70E+07	5.70E+07	5.70E+07	5.70E+07	5.70E+07	5.70E+07	5.70E+07	5.70E+07	5.70E+07
47	Forest	1.00E+07	1.00E+07	1.00E+07	1.00E+07	1.00E+07	1.00E+07	1.00E+07	1.00E+07	1.00E+07	1.00E+07	1.00E+07	1.00E+07
48	Hayland	1.00E+07	1.90E+07	5.10E+07	4.40E+07	1.80E+07	1.90E+07	1.80E+07	1.80E+07	2.70E+07	2.70E+07	2.70E+07	1.00E+07
48	Pasture	1.20E+09	1.40E+09	2.30E+09	2.30E+09	2.40E+09	2.50E+09	2.50E+09	2.60E+09	2.60E+09	1.70E+09	1.80E+09	1.20E+09
48	Residential	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
48	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
49	Cropland	5.30E+06	3.20E+08	1.40E+09	1.20E+09	2.90E+08	5.30E+06	5.30E+06	5.30E+06	5.30E+06	4.40E+08	4.50E+08	5.30E+06
49	Hayland	5.30E+06	1.20E+07	3.40E+07	2.90E+07	1.10E+07	1.10E+07	1.10E+07	1.10E+07	1.70E+07	1.70E+07	1.70E+07	5.30E+06
49	Pasture	1.40E+09	1.60E+09	2.60E+09	2.70E+09	2.70E+09	2.80E+09	2.80E+09	2.90E+09	3.00E+09	1.90E+09	2.00E+09	1.30E+09
49	Residential	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
49	Forest	5.70E+06	5.70E+06	5.70E+06	5.70E+06	5.70E+06	5.70E+06	5.70E+06	5.70E+06	5.70E+06	5.70E+06	5.70E+06	5.70E+06
50	Cropland	5.40E+06	1.90E+08	8.40E+08	7.00E+08	1.70E+08	5.40E+06	5.40E+06	5.40E+06	5.40E+06	2.30E+08	2.70E+08	5.40E+06
50	Hayland	5.40E+06	5.40E+06	5.40E+06	5.40E+06	5.40E+06	5.40E+06	5.40E+06	5.40E+06	5.40E+06	5.40E+06	5.40E+06	5.40E+06
50	Pasture	1.50E+09	1.70E+09	2.90E+09	3.00E+09	3.00E+09	3.10E+09	3.20E+09	3.20E+09	3.30E+09	2.20E+09	2.30E+09	1.50E+09
50	Residential	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
50	Forest	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06	5.60E+06
51	Hayland	6.10E+06	2.50E+07	9.30E+07	7.80E+07	2.40E+07	2.40E+07	2.40E+07	2.40E+07	4.20E+07	4.10E+07	4.20E+07	6.10E+06
51	Pasture	1.70E+09	1.90E+09	3.20E+09	3.30E+09	3.40E+09	3.40E+09	3.50E+09	3.60E+09	3.70E+09	2.30E+09	2.50E+09	1.60E+09
51	Residential	9.70E+07	9.70E+07	9.70E+07	9.70E+07	9.70E+07	9.70E+07	9.70E+07	9.70E+07	9.70E+07	9.70E+07	9.70E+07	9.70E+07
51	Forest	6.30E+06	6.30E+06	6.30E+06	6.30E+06	6.30E+06	6.30E+06	6.30E+06	6.30E+06	6.30E+06	6.30E+06	6.30E+06	6.30E+06
52	Cropland	5.00E+06	1.50E+08	6.70E+08	5.50E+08	1.40E+08	5.00E+06	5.00E+06	5.00E+06	5.00E+06	2.10E+08	2.10E+08	5.00E+06
52	Hayland	5.00E+06	5.00E+06	5.00E+06	5.00E+06	5.00E+06	5.00E+06	5.00E+06	5.00E+06	5.00E+06	5.00E+06	5.00E+06	5.00E+06

52	Pasture	1.60E+09	1.90E+09	3.30E+09	3.40E+09	3.40E+09	3.50E+09	3.60E+09	3.70E+09	3.80E+09	2.40E+09	2.50E+09	1.60E+09
52	Residential	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07
52	Forest	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06
53	Cropland	2.80E+07	3.40E+08	1.40E+09	1.20E+09	3.10E+08	2.80E+07	2.80E+07	2.80E+07	2.80E+07	4.60E+08	4.70E+08	2.80E+07
53	Hayland	2.80E+07	3.50E+07	6.20E+07	5.60E+07	3.50E+07	3.50E+07	3.50E+07	3.50E+07	4.20E+07	4.10E+07	4.20E+07	2.80E+07
53	Pasture	2.00E+09	2.20E+09	3.60E+09	3.70E+09	3.80E+09	3.80E+09	3.90E+09	4.00E+09	4.10E+09	2.70E+09	2.80E+09	1.90E+09
53	Residential	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
53	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
54	Hayland	5.10E+06	1.70E+07	6.10E+07	5.10E+07	1.60E+07	1.70E+07	1.60E+07	1.60E+07	2.80E+07	2.80E+07	2.80E+07	5.10E+06
54	Pasture	1.90E+09	2.20E+09	3.70E+09	3.80E+09	3.80E+09	3.90E+09	4.00E+09	4.10E+09	4.20E+09	2.70E+09	2.80E+09	1.80E+09
54	Residential	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
54	Forest	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06
55	Hayland	9.70E+06	2.50E+07	7.80E+07	6.60E+07	2.30E+07	2.40E+07	2.30E+07	2.30E+07	3.80E+07	3.70E+07	3.80E+07	9.70E+06
55	Pasture	1.10E+09	1.30E+09	2.20E+09	2.20E+09	2.30E+09	2.40E+09	2.40E+09	2.50E+09	2.50E+09	1.60E+09	1.70E+09	1.10E+09
55	Residential	1.40E+08	1.40E+08	1.40E+08	1.40E+08	1.40E+08	1.40E+08	1.40E+08	1.40E+08	1.40E+08	1.40E+08	1.40E+08	1.40E+08
55	Forest	1.00E+07	1.00E+07	1.00E+07	1.00E+07	1.00E+07	1.00E+07	1.00E+07	1.00E+07	1.00E+07	1.00E+07	1.00E+07	1.00E+07
56	Cropland	6.60E+06	3.20E+08	1.40E+09	1.20E+09	2.90E+08	6.60E+06	6.60E+06	6.60E+06	6.60E+06	4.40E+08	4.50E+08	6.60E+06
56	Hayland	6.60E+06	1.50E+07	4.50E+07	3.80E+07	1.40E+07	1.40E+07	1.40E+07	1.40E+07	2.20E+07	2.20E+07	2.20E+07	6.60E+06
56	Pasture	1.20E+09	1.40E+09	2.20E+09	2.30E+09	2.30E+09	2.40E+09	2.50E+09	2.50E+09	2.60E+09	1.60E+09	1.70E+09	1.10E+09
56	Residential	3.10E+08	3.10E+08	3.10E+08	3.10E+08	3.10E+08	3.10E+08	3.10E+08	3.10E+08	3.10E+08	3.10E+08	3.10E+08	3.10E+08
56	Forest	6.80E+06	6.80E+06	6.80E+06	6.80E+06	6.80E+06	6.80E+06	6.80E+06	6.80E+06	6.80E+06	6.80E+06	6.80E+06	6.80E+06
57	Cropland	6.20E+06	1.40E+08	6.30E+08	5.20E+08	1.30E+08	6.20E+06	6.20E+06	6.20E+06	6.20E+06	2.00E+08	2.00E+08	6.20E+06
57	Hayland	6.20E+06	6.20E+06	6.20E+06	6.20E+06	6.20E+06	6.20E+06	6.20E+06	6.20E+06	6.20E+06	6.20E+06	6.20E+06	6.20E+06
57	Pasture	1.20E+09	1.30E+09	2.20E+09	2.30E+09	2.30E+09	2.40E+09	2.40E+09	2.50E+09	2.60E+09	1.60E+09	1.70E+09	1.10E+09
57	Residential	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
57	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
58	Cropland	5.20E+06	7.80E+07	3.40E+08	2.80E+08	7.10E+07	5.20E+06	5.20E+06	5.20E+06	5.20E+06	1.10E+08	1.10E+08	5.20E+06
58	Hayland	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06	5.20E+06
58	Pasture	1.20E+09	1.40E+09	2.20E+09	2.30E+09	2.30E+09	2.40E+09	2.50E+09	2.50E+09	2.60E+09	1.60E+09	1.70E+09	1.10E+09
58	Residential	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
58	Forest	5.40E+06	5.40E+06	5.40E+06	5.40E+06	5.40E+06	5.40E+06	5.40E+06	5.40E+06	5.40E+06	5.40E+06	5.40E+06	5.40E+06

59	Hayland	8.10E+06	7.20E+07	3.00E+08	2.50E+08	6.60E+07	1.30E+08	8.10E+06	6.60E+07	1.90E+08	6.60E+07	1.30E+08	8.10E+06
59	Pasture	5.20E+09	5.50E+09	1.10E+10	1.10E+10	1.10E+10	1.10E+10	1.10E+10	1.10E+10	1.10E+10	1.00E+10	9.90E+09	5.20E+09
59	Residential	2.90E+07	2.90E+07	2.90E+07	2.90E+07	2.90E+07	2.90E+07	2.90E+07	2.90E+07	2.90E+07	2.90E+07	2.90E+07	2.90E+07
59	Forest	8.60E+06	8.60E+06	8.60E+06	8.60E+06	8.60E+06	8.60E+06	8.60E+06	8.60E+06	8.60E+06	8.60E+06	8.60E+06	8.60E+06
60	Cropland	7.60E+06	3.20E+08	1.40E+09	1.20E+09	2.90E+08	7.60E+06	7.60E+06	7.60E+06	7.60E+06	4.40E+08	4.50E+08	7.60E+06
60	Hayland	7.60E+06	1.40E+07	3.70E+07	3.20E+07	1.30E+07	1.40E+07	1.30E+07	1.30E+07	2.00E+07	1.90E+07	2.00E+07	7.60E+06
60	Pasture	1.20E+09	1.30E+09	2.20E+09	2.30E+09	2.30E+09	2.40E+09	2.40E+09	2.50E+09	2.50E+09	1.60E+09	1.70E+09	1.10E+09
60	Residential	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
60	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
61	Hayland	1.20E+07	3.20E+07	1.00E+08	8.80E+07	3.00E+07	3.10E+07	3.00E+07	3.00E+07	5.00E+07	4.90E+07	5.00E+07	1.20E+07
61	Pasture	1.10E+09	1.30E+09	2.10E+09	2.20E+09	2.20E+09	2.30E+09	2.30E+09	2.40E+09	2.50E+09	1.60E+09	1.60E+09	1.10E+09
61	Residential	3.80E+07	3.80E+07	3.80E+07	3.80E+07	3.80E+07	3.80E+07	3.80E+07	3.80E+07	3.80E+07	3.80E+07	3.80E+07	3.80E+07
61	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
62	Cropland	4.70E+06	7.80E+07	3.40E+08	2.80E+08	7.20E+07	4.70E+06	4.70E+06	4.70E+06	4.70E+06	1.10E+08	1.10E+08	4.70E+06
62	Hayland	4.70E+06	4.70E+06	4.70E+06	4.70E+06	4.70E+06	4.70E+06	4.70E+06	4.70E+06	4.70E+06	4.70E+06	4.70E+06	4.70E+06
62	Pasture	1.20E+09	1.30E+09	2.20E+09	2.30E+09	2.30E+09	2.40E+09	2.40E+09	2.50E+09	2.50E+09	1.60E+09	1.70E+09	1.10E+09
62	Residential	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
62	Forest	5.00E+06	5.00E+06	5.00E+06	5.00E+06	5.00E+06	5.00E+06	5.00E+06	5.00E+06	5.00E+06	5.00E+06	5.00E+06	5.00E+06
63	Cropland	5.50E+06	3.20E+08	1.40E+09	1.20E+09	2.90E+08	5.50E+06	5.50E+06	5.50E+06	5.50E+06	4.40E+08	4.50E+08	5.50E+06
63	Hayland	5.50E+06	5.90E+06	7.20E+06	6.90E+06	5.80E+06	5.90E+06	5.80E+06	5.80E+06	6.20E+06	6.20E+06	6.20E+06	5.50E+06
63	Pasture	1.20E+09	1.30E+09	2.20E+09	2.30E+09	2.30E+09	2.40E+09	2.40E+09	2.50E+09	2.50E+09	1.60E+09	1.70E+09	1.10E+09
63	Residential	2.70E+08	2.70E+08	2.70E+08	2.70E+08	2.70E+08	2.70E+08	2.70E+08	2.70E+08	2.70E+08	2.70E+08	2.70E+08	2.70E+08
63	Forest	5.70E+06	5.70E+06	5.70E+06	5.70E+06	5.70E+06	5.70E+06	5.70E+06	5.70E+06	5.70E+06	5.70E+06	5.70E+06	5.70E+06
64	Cropland	6.20E+06	3.20E+08	1.40E+09	1.20E+09	2.90E+08	6.20E+06	6.20E+06	6.20E+06	6.20E+06	4.40E+08	4.50E+08	6.20E+06
64	Hayland	6.20E+06	1.40E+07	4.10E+07	3.50E+07	1.30E+07	1.30E+07	1.30E+07	1.30E+07	2.10E+07	2.00E+07	2.10E+07	6.20E+06
64	Pasture	1.20E+09	1.30E+09	2.20E+09	2.30E+09	2.30E+09	2.40E+09	2.40E+09	2.50E+09	2.60E+09	1.60E+09	1.70E+09	1.10E+09
64	Residential	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08
64	Forest	6.30E+06	6.30E+06	6.30E+06	6.30E+06	6.30E+06	6.30E+06	6.30E+06	6.30E+06	6.30E+06	6.30E+06	6.30E+06	6.30E+06
65	Cropland	5.70E+06	3.20E+08	1.40E+09	1.20E+09	2.90E+08	5.70E+06	5.70E+06	5.70E+06	5.70E+06	4.40E+08	4.50E+08	5.70E+06
65	Hayland	5.70E+06	1.30E+07	4.10E+07	3.40E+07	1.30E+07	1.30E+07	1.30E+07	1.30E+07	2.00E+07	2.00E+07	2.00E+07	5.70E+06
65	Pasture	1.20E+09	1.30E+09	2.20E+09	2.30E+09	2.30E+09	2.40E+09	2.50E+09	2.50E+09	2.60E+09	1.60E+09	1.70E+09	1.10E+09

65	Residential	6.70E+07	6.70E+07	6.70E+07	6.70E+07	6.70E+07	6.70E+07	6.70E+07	6.70E+07	6.70E+07	6.70E+07	6.70E+07	6.70E+07
65	Forest	5.90E+06	5.90E+06	5.90E+06	5.90E+06	5.90E+06	5.90E+06	5.90E+06	5.90E+06	5.90E+06	5.90E+06	5.90E+06	5.90E+06
66	Cropland	7.50E+06	3.20E+08	1.40E+09	1.20E+09	2.90E+08	7.50E+06	7.50E+06	7.50E+06	7.50E+06	4.40E+08	4.50E+08	7.50E+06
66	Hayland	7.50E+06	1.60E+07	4.40E+07	3.80E+07	1.50E+07	1.50E+07	1.50E+07	1.50E+07	2.30E+07	2.20E+07	2.30E+07	7.50E+06
66	Pasture	1.20E+09	1.30E+09	2.20E+09	2.30E+09	2.30E+09	2.40E+09	2.40E+09	2.50E+09	2.60E+09	1.60E+09	1.70E+09	1.10E+09
66	Residential	1.90E+08	1.90E+08	1.90E+08	1.90E+08	1.90E+08	1.90E+08	1.90E+08	1.90E+08	1.90E+08	1.90E+08	1.90E+08	1.90E+08
66	Forest	7.70E+06	7.70E+06	7.70E+06	7.70E+06	7.70E+06	7.70E+06	7.70E+06	7.70E+06	7.70E+06	7.70E+06	7.70E+06	7.70E+06
67	Hayland	7.90E+06	7.90E+06	7.90E+06	7.90E+06	7.90E+06	7.90E+06	7.90E+06	7.90E+06	7.90E+06	7.90E+06	7.90E+06	7.90E+06
67	Pasture	7.90E+06	7.90E+06	7.90E+06	7.90E+06	7.90E+06	7.90E+06	7.90E+06	7.90E+06	7.90E+06	7.90E+06	7.90E+06	7.90E+06
67	Residential	8.60E+07	8.60E+07	8.60E+07	8.60E+07	8.60E+07	8.60E+07	8.60E+07	8.60E+07	8.60E+07	8.60E+07	8.60E+07	8.60E+07
67	Forest	8.10E+06	8.10E+06	8.10E+06	8.10E+06	8.10E+06	8.10E+06	8.10E+06	8.10E+06	8.10E+06	8.10E+06	8.10E+06	8.10E+06
68	Hayland	4.70E+06	8.20E+06	2.00E+07	1.80E+07	7.90E+06	8.00E+06	7.90E+06	7.90E+06	1.10E+07	1.10E+07	1.10E+07	4.70E+06
68	Pasture	9.10E+08	1.10E+09	1.80E+09	1.90E+09	1.90E+09	2.00E+09	2.00E+09	2.10E+09	2.10E+09	1.30E+09	1.40E+09	8.70E+08
68	Residential	2.00E+07	2.00E+07	2.00E+07	2.00E+07	2.00E+07	2.00E+07	2.00E+07	2.00E+07	2.00E+07	2.00E+07	2.00E+07	2.00E+07
68	Forest	4.90E+06	4.90E+06	4.90E+06	4.90E+06	4.90E+06	4.90E+06	4.90E+06	4.90E+06	4.90E+06	4.90E+06	4.90E+06	4.90E+06
69	Hayland	4.60E+06	7.60E+06	1.80E+07	1.60E+07	7.30E+06	7.40E+06	7.30E+06	7.30E+06	1.00E+07	1.00E+07	1.00E+07	4.60E+06
69	Pasture	1.40E+09	1.60E+09	2.50E+09	2.60E+09	2.70E+09	2.70E+09	2.80E+09	2.80E+09	2.90E+09	1.90E+09	2.00E+09	1.40E+09
69	Residential	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
69	Forest	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06	4.80E+06

Table C. 4. 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	6.20E+07	2.90E+09	1.30E+10	1.10E+10	2.60E+09	6.20E+07	6.20E+07	6.20E+07	6.20E+07	3.90E+09	4.10E+09	6.20E+07
1	Hayland	6.20E+07	8.90E+07	1.80E+08	1.60E+08	8.70E+07	8.80E+07	8.70E+07	8.70E+07	1.10E+08	1.10E+08	1.10E+08	6.20E+07
1	Pasture	1.10E+10	1.20E+10	2.00E+10	2.10E+10	2.10E+10	2.20E+10	2.20E+10	2.30E+10	2.30E+10	1.50E+10	1.60E+10	1.00E+10
1	Residential	2.70E+08	2.70E+08	2.70E+08	2.70E+08	2.70E+08	2.70E+08	2.70E+08	2.70E+08	2.70E+08	2.70E+08	2.70E+08	2.70E+08
1	Forest	6.60E+07	6.60E+07	6.60E+07	6.60E+07	6.60E+07	6.60E+07	6.60E+07	6.60E+07	6.60E+07	6.60E+07	6.60E+07	6.60E+07
2	Cropland	5.10E+07	2.00E+09	9.10E+09	7.60E+09	1.90E+09	5.10E+07	5.10E+07	5.10E+07	5.10E+07	2.80E+09	2.90E+09	5.10E+07
2	Hayland	5.10E+07	5.10E+07	5.10E+07	5.10E+07	5.10E+07	5.10E+07	5.10E+07	5.10E+07	5.10E+07	5.10E+07	5.10E+07	5.10E+07
2	Pasture	1.00E+10	1.20E+10	2.00E+10	2.00E+10	2.10E+10	2.10E+10	2.20E+10	2.30E+10	2.30E+10	1.50E+10	1.50E+10	1.00E+10
2	Residential	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
2	Forest	5.30E+07	5.30E+07	5.30E+07	5.30E+07	5.30E+07	5.30E+07	5.30E+07	5.30E+07	5.30E+07	5.30E+07	5.30E+07	5.30E+07
3	Cropland	4.40E+07	2.80E+09	1.30E+10	1.10E+10	2.60E+09	4.40E+07	4.40E+07	4.40E+07	4.40E+07	3.90E+09	4.10E+09	4.40E+07
3	Hayland	4.40E+07	2.00E+08	7.60E+08	6.40E+08	1.90E+08	1.90E+08	1.90E+08	1.90E+08	3.40E+08	3.30E+08	3.40E+08	4.40E+07
3	Pasture	1.00E+10	1.20E+10	2.00E+10	2.00E+10	2.10E+10	2.10E+10	2.20E+10	2.30E+10	2.30E+10	1.50E+10	1.50E+10	1.00E+10
3	Residential	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
3	Forest	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07
4	Cropland	3.20E+07	2.80E+09	1.30E+10	1.10E+10	2.60E+09	3.20E+07	3.20E+07	3.20E+07	3.20E+07	3.90E+09	4.00E+09	3.20E+07
4	Hayland	3.20E+07	3.10E+08	1.30E+09	1.10E+09	2.90E+08	3.00E+08	2.90E+08	2.90E+08	5.60E+08	5.40E+08	5.60E+08	3.20E+07
4	Pasture	1.00E+10	1.20E+10	2.00E+10	2.00E+10	2.10E+10	2.10E+10	2.20E+10	2.30E+10	2.30E+10	1.50E+10	1.50E+10	1.00E+10
4	Residential	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
4	Forest	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07	3.40E+07
5	Cropland	9.20E+07	1.50E+09	6.60E+09	5.40E+09	1.40E+09	9.20E+07	9.20E+07	9.20E+07	9.20E+07	2.10E+09	2.10E+09	9.20E+07
5	Hayland	9.20E+07	9.20E+07	9.20E+07	9.20E+07	9.20E+07	9.20E+07	9.20E+07	9.20E+07	9.20E+07	9.20E+07	9.20E+07	9.20E+07
5	Pasture	1.10E+10	1.20E+10	2.00E+10	2.00E+10	2.10E+10	2.20E+10	2.20E+10	2.30E+10	2.30E+10	1.50E+10	1.50E+10	1.00E+10
5	Residential	8.60E+08	8.60E+08	8.60E+08	8.60E+08	8.60E+08	8.60E+08	8.60E+08	8.60E+08	8.60E+08	8.60E+08	8.60E+08	8.60E+08
5	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
6	Cropland	3.50E+07	1.90E+09	8.50E+09	7.00E+09	1.70E+09	3.50E+07	3.50E+07	3.50E+07	3.50E+07	2.60E+09	2.70E+09	3.50E+07
6	Hayland	3.50E+07	3.50E+07	3.50E+07	3.50E+07	3.50E+07	3.50E+07	3.50E+07	3.50E+07	3.50E+07	3.50E+07	3.50E+07	3.50E+07
6	Pasture	1.00E+10	1.20E+10	2.00E+10	2.00E+10	2.10E+10	2.10E+10	2.20E+10	2.30E+10	2.30E+10	1.50E+10	1.50E+10	1.00E+10
6	Residential	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

6	Forest	3.80E+07	3.80E+07	3.80E+07	3.80E+07	3.80E+07	3.80E+07	3.80E+07	3.80E+07	3.80E+07	3.80E+07	3.80E+07	3.80E+07
7	Cropland	4.90E+07	2.80E+09	1.30E+10	1.10E+10	2.60E+09	4.90E+07	4.90E+07	4.90E+07	4.90E+07	3.90E+09	4.10E+09	4.90E+07
7	Hayland	4.90E+07	2.10E+08	7.60E+08	6.40E+08	1.90E+08	2.00E+08	1.90E+08	1.90E+08	3.40E+08	3.30E+08	3.40E+08	4.90E+07
7	Pasture	1.00E+10	1.20E+10	2.00E+10	2.00E+10	2.10E+10	2.10E+10	2.20E+10	2.30E+10	2.30E+10	1.50E+10	1.50E+10	1.00E+10
7	Residential	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
7	Forest	5.10E+07	5.10E+07	5.10E+07	5.10E+07	5.10E+07	5.10E+07	5.10E+07	5.10E+07	5.10E+07	5.10E+07	5.10E+07	5.10E+07
8	Cropland	5.90E+07	2.90E+09	1.30E+10	1.10E+10	2.60E+09	5.90E+07	5.90E+07	5.90E+07	5.90E+07	3.90E+09	4.10E+09	5.90E+07
8	Hayland	5.90E+07	7.40E+07	1.30E+08	1.20E+08	7.30E+07	7.30E+07	7.30E+07	7.30E+07	8.80E+07	8.70E+07	8.80E+07	5.90E+07
8	Pasture	1.00E+10	1.20E+10	2.00E+10	2.00E+10	2.10E+10	2.10E+10	2.20E+10	2.30E+10	2.30E+10	1.50E+10	1.50E+10	1.00E+10
8	Residential	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
8	Forest	6.10E+07	6.10E+07	6.10E+07	6.10E+07	6.10E+07	6.10E+07	6.10E+07	6.10E+07	6.10E+07	6.10E+07	6.10E+07	6.10E+07
9	Hayland	1.20E+08	6.10E+08	2.40E+09	2.00E+09	5.70E+08	5.80E+08	5.70E+08	5.70E+08	1.00E+09	1.00E+09	1.00E+09	1.20E+08
9	Pasture	1.10E+10	1.30E+10	2.10E+10	2.10E+10	2.20E+10	2.20E+10	2.30E+10	2.30E+10	2.40E+10	1.50E+10	1.60E+10	1.10E+10
9	Residential	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
9	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
10	Cropland	4.30E+07	1.30E+09	5.70E+09	4.70E+09	1.20E+09	4.30E+07	4.30E+07	4.30E+07	4.30E+07	1.80E+09	1.80E+09	4.30E+07
10	Hayland	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07
10	Pasture	1.00E+10	1.20E+10	2.00E+10	2.00E+10	2.10E+10	2.10E+10	2.20E+10	2.30E+10	2.30E+10	1.50E+10	1.50E+10	1.00E+10
10	Residential	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
10	Forest	4.60E+07	4.60E+07	4.60E+07	4.60E+07	4.60E+07	4.60E+07	4.60E+07	4.60E+07	4.60E+07	4.60E+07	4.60E+07	4.60E+07
11	Cropland	4.00E+07	1.00E+09	4.50E+09	3.70E+09	9.40E+08	4.00E+07	4.00E+07	4.00E+07	4.00E+07	1.40E+09	1.40E+09	4.00E+07
11	Hayland	4.00E+07	4.00E+07	4.00E+07	4.00E+07	4.00E+07	4.00E+07	4.00E+07	4.00E+07	4.00E+07	4.00E+07	4.00E+07	4.00E+07
11	Pasture	1.00E+10	1.20E+10	2.00E+10	2.00E+10	2.10E+10	2.10E+10	2.20E+10	2.30E+10	2.30E+10	1.50E+10	1.50E+10	1.00E+10
11	Residential	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
11	Forest	4.40E+07	4.40E+07	4.40E+07	4.40E+07	4.40E+07	4.40E+07	4.40E+07	4.40E+07	4.40E+07	4.40E+07	4.40E+07	4.40E+07
12	Cropland	8.70E+07	2.90E+09	1.30E+10	1.10E+10	2.60E+09	8.70E+07	8.70E+07	8.70E+07	8.70E+07	4.00E+09	4.10E+09	8.70E+07
12	Hayland	8.70E+07	2.20E+08	7.10E+08	6.10E+08	2.10E+08	2.20E+08	2.10E+08	2.10E+08	3.50E+08	3.40E+08	3.50E+08	8.70E+07
12	Pasture	1.10E+10	1.20E+10	2.00E+10	2.10E+10	2.10E+10	2.20E+10	2.20E+10	2.30E+10	2.30E+10	1.50E+10	1.50E+10	1.00E+10
12	Residential	4.60E+09	4.60E+09	4.60E+09	4.60E+09	4.60E+09	4.60E+09	4.60E+09	4.60E+09	4.60E+09	4.60E+09	4.60E+09	4.60E+09
12	Forest	8.90E+07	8.90E+07	8.90E+07	8.90E+07	8.90E+07	8.90E+07	8.90E+07	8.90E+07	8.90E+07	8.90E+07	8.90E+07	8.90E+07
13	Hayland	6.80E+07	6.80E+08	2.90E+09	2.40E+09	6.30E+08	6.40E+08	6.30E+08	6.30E+08	1.20E+09	1.20E+09	1.20E+09	6.80E+07

13	Pasture	1.70E+10	2.00E+10	3.20E+10	3.30E+10	3.40E+10	3.50E+10	3.50E+10	3.60E+10	3.70E+10	2.40E+10	2.50E+10	1.60E+10
13	Residential	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
13	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
14	Cropland	5.50E+07	7.80E+08	3.40E+09	2.80E+09	7.10E+08	5.50E+07	5.50E+07	5.50E+07	5.50E+07	1.10E+09	1.10E+09	5.50E+07
14	Hayland	5.50E+07	5.50E+07	5.50E+07	5.50E+07	5.50E+07	5.50E+07	5.50E+07	5.50E+07	5.50E+07	5.50E+07	5.50E+07	5.50E+07
14	Pasture	1.50E+10	1.80E+10	2.90E+10	3.00E+10	3.00E+10	3.10E+10	3.20E+10	3.30E+10	3.40E+10	2.10E+10	2.20E+10	1.50E+10
14	Residential	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
14	Forest	5.70E+07	5.70E+07	5.70E+07	5.70E+07	5.70E+07	5.70E+07	5.70E+07	5.70E+07	5.70E+07	5.70E+07	5.70E+07	5.70E+07
15	Cropland	4.00E+07	1.20E+09	5.30E+09	4.40E+09	1.10E+09	4.00E+07	4.00E+07	4.00E+07	4.00E+07	8.90E+08	1.70E+09	4.00E+07
15	Hayland	4.00E+07	2.20E+08	8.50E+08	7.10E+08	2.00E+08	2.10E+08	2.00E+08	2.00E+08	3.70E+08	3.60E+08	3.70E+08	4.00E+07
15	Pasture	1.80E+10	2.00E+10	3.50E+10	3.60E+10	3.60E+10	3.70E+10	3.70E+10	3.80E+10	3.90E+10	2.70E+10	2.80E+10	1.70E+10
15	Residential	3.00E+09	3.00E+09	3.00E+09	3.00E+09	3.00E+09	3.00E+09	3.00E+09	3.00E+09	3.00E+09	3.00E+09	3.00E+09	3.00E+09
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	4.30E+07	2.80E+09	1.30E+10	1.10E+10	2.60E+09	4.30E+07	4.30E+07	4.30E+07	4.30E+07	3.90E+09	4.10E+09	4.30E+07
16	Hayland	4.30E+07	8.70E+07	2.40E+08	2.10E+08	8.30E+07	8.40E+07	8.30E+07	8.30E+07	1.30E+08	1.20E+08	1.30E+08	4.30E+07
16	Pasture	1.50E+10	1.70E+10	2.90E+10	3.00E+10	3.00E+10	3.10E+10	3.20E+10	3.20E+10	3.30E+10	2.10E+10	2.20E+10	1.40E+10
16	Residential	2.80E+09	2.80E+09	2.80E+09	2.80E+09	2.80E+09	2.80E+09	2.80E+09	2.80E+09	2.80E+09	2.80E+09	2.80E+09	2.80E+09
16	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
17	Cropland	5.40E+07	8.00E+08	3.50E+09	2.90E+09	7.40E+08	5.40E+07	5.40E+07	5.40E+07	5.40E+07	1.10E+09	1.10E+09	5.40E+07
17	Hayland	5.40E+07	5.40E+07	5.40E+07	5.40E+07	5.40E+07	5.40E+07	5.40E+07	5.40E+07	5.40E+07	5.40E+07	5.40E+07	5.40E+07
17	Pasture	1.00E+10	1.20E+10	2.00E+10	2.00E+10	2.10E+10	2.10E+10	2.20E+10	2.30E+10	2.30E+10	1.50E+10	1.50E+10	1.00E+10
17	Residential	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
17	Forest	5.70E+07	5.70E+07	5.70E+07	5.70E+07	5.70E+07	5.70E+07	5.70E+07	5.70E+07	5.70E+07	5.70E+07	5.70E+07	5.70E+07
18	Cropland	5.40E+07	5.90E+08	2.50E+09	2.10E+09	5.40E+08	5.40E+07	5.40E+07	5.40E+07	5.40E+07	8.00E+08	8.20E+08	5.40E+07
18	Hayland	5.40E+07	5.40E+07	5.40E+07	5.40E+07	5.40E+07	5.40E+07	5.40E+07	5.40E+07	5.40E+07	5.40E+07	5.40E+07	5.40E+07
18	Pasture	1.10E+10	1.20E+10	2.00E+10	2.00E+10	2.10E+10	2.20E+10	2.20E+10	2.30E+10	2.30E+10	1.50E+10	1.50E+10	1.00E+10
18	Residential	2.90E+09	2.90E+09	2.90E+09	2.90E+09	2.90E+09	2.90E+09	2.90E+09	2.90E+09	2.90E+09	2.90E+09	2.90E+09	2.90E+09
18	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
19	Cropland	4.10E+07	1.70E+09	7.50E+09	6.20E+09	1.50E+09	4.10E+07	4.10E+07	4.10E+07	4.10E+07	2.30E+09	2.40E+09	4.10E+07
19	Hayland	4.10E+07	4.10E+07	4.10E+07	4.10E+07	4.10E+07	4.10E+07	4.10E+07	4.10E+07	4.10E+07	4.10E+07	4.10E+07	4.10E+07
19	Pasture	1.00E+10	1.20E+10	2.00E+10	2.00E+10	2.10E+10	2.10E+10	2.20E+10	2.20E+10	2.30E+10	1.50E+10	1.50E+10	1.00E+10

19	Residential	9.70E+08	9.70E+08	9.70E+08	9.70E+08	9.70E+08	9.70E+08	9.70E+08	9.70E+08	9.70E+08	9.70E+08	9.70E+08	9.70E+08
19	Forest	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07
20	Hayland	4.00E+07	8.90E+07	2.70E+08	2.30E+08	8.50E+07	8.70E+07	8.50E+07	8.50E+07	1.30E+08	1.30E+08	1.30E+08	4.00E+07
20	Pasture	1.10E+10	1.20E+10	2.00E+10	2.10E+10	2.10E+10	2.10E+10	2.20E+10	2.30E+10	2.30E+10	1.50E+10	1.60E+10	1.00E+10
20	Residential	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
20	Forest	4.10E+07	4.10E+07	4.10E+07	4.10E+07	4.10E+07	4.10E+07	4.10E+07	4.10E+07	4.10E+07	4.10E+07	4.10E+07	4.10E+07
21	Hayland	5.70E+07	1.70E+08	5.70E+08	4.80E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	2.70E+08	2.60E+08	2.70E+08	5.70E+07
21	Pasture	1.10E+10	1.20E+10	2.00E+10	2.00E+10	2.10E+10	2.10E+10	2.20E+10	2.20E+10	2.30E+10	1.50E+10	1.50E+10	1.00E+10
21	Residential	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
21	Forest	6.10E+07	6.10E+07	6.10E+07	6.10E+07	6.10E+07	6.10E+07	6.10E+07	6.10E+07	6.10E+07	6.10E+07	6.10E+07	6.10E+07
22	Cropland	5.80E+07	2.90E+09	1.30E+10	1.10E+10	2.60E+09	5.80E+07	5.80E+07	5.80E+07	5.80E+07	3.90E+09	4.10E+09	5.80E+07
22	Hayland	5.80E+07	1.10E+08	3.10E+08	2.70E+08	1.10E+08	1.10E+08	1.10E+08	1.10E+08	1.60E+08	1.60E+08	1.60E+08	5.80E+07
22	Pasture	1.00E+10	1.20E+10	2.00E+10	2.00E+10	2.10E+10	2.10E+10	2.20E+10	2.20E+10	2.30E+10	1.40E+10	1.50E+10	1.00E+10
22	Residential	3.20E+08	3.20E+08	3.20E+08	3.20E+08	3.20E+08	3.20E+08	3.20E+08	3.20E+08	3.20E+08	3.20E+08	3.20E+08	3.20E+08
22	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
23	Cropland	4.40E+07	1.40E+09	6.00E+09	5.00E+09	1.20E+09	4.40E+07	4.40E+07	4.40E+07	4.40E+07	1.20E+09	1.90E+09	4.40E+07
23	Hayland	4.40E+07	2.00E+08	7.60E+08	6.30E+08	1.90E+08	1.90E+08	1.90E+08	1.90E+08	3.40E+08	3.30E+08	3.40E+08	4.40E+07
23	Pasture	1.40E+10	1.60E+10	2.70E+10	2.80E+10	2.80E+10	2.90E+10	2.90E+10	3.00E+10	3.00E+10	2.20E+10	2.20E+10	1.40E+10
23	Residential	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09
23	Forest	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07
24	Cropland	4.20E+07	2.80E+09	1.30E+10	1.10E+10	2.60E+09	4.20E+07	4.20E+07	4.20E+07	4.20E+07	3.90E+09	4.00E+09	4.20E+07
24	Hayland	4.20E+07	1.50E+08	5.30E+08	4.40E+08	1.40E+08	1.40E+08	1.40E+08	1.40E+08	2.40E+08	2.40E+08	2.40E+08	4.20E+07
24	Pasture	1.00E+10	1.20E+10	2.00E+10	2.00E+10	2.10E+10	2.10E+10	2.20E+10	2.20E+10	2.30E+10	1.40E+10	1.50E+10	1.00E+10
24	Residential	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09
24	Forest	4.40E+07	4.40E+07	4.40E+07	4.40E+07	4.40E+07	4.40E+07	4.40E+07	4.40E+07	4.40E+07	4.40E+07	4.40E+07	4.40E+07
25	Cropland	5.10E+07	2.80E+09	1.30E+10	1.10E+10	2.60E+09	5.10E+07	5.10E+07	5.10E+07	5.10E+07	3.90E+09	4.10E+09	5.10E+07
25	Hayland	5.10E+07	5.50E+07	7.00E+07	6.70E+07	5.50E+07	5.50E+07	5.50E+07	5.50E+07	5.90E+07	5.90E+07	5.90E+07	5.10E+07
25	Pasture	1.00E+10	1.20E+10	2.00E+10	2.00E+10	2.10E+10	2.10E+10	2.20E+10	2.20E+10	2.30E+10	1.50E+10	1.50E+10	1.00E+10
25	Residential	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
25	Forest	5.30E+07	5.30E+07	5.30E+07	5.30E+07	5.30E+07	5.30E+07	5.30E+07	5.30E+07	5.30E+07	5.30E+07	5.30E+07	5.30E+07
26	Cropland	4.30E+07	1.30E+09	5.90E+09	4.90E+09	1.20E+09	4.30E+07	4.30E+07	4.30E+07	4.30E+07	1.80E+09	1.90E+09	4.30E+07

26	Hayland	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07
26	Pasture	1.00E+10	1.20E+10	2.00E+10	2.00E+10	2.10E+10	2.10E+10	2.20E+10	2.20E+10	2.30E+10	1.40E+10	1.50E+10	1.00E+10
26	Residential	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
26	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
27	Cropland	5.00E+07	1.20E+09	5.30E+09	4.40E+09	1.10E+09	5.00E+07	5.00E+07	5.00E+07	5.00E+07	1.60E+09	1.70E+09	5.00E+07
27	Hayland	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
27	Pasture	1.00E+10	1.20E+10	2.00E+10	2.00E+10	2.10E+10	2.10E+10	2.20E+10	2.30E+10	2.30E+10	1.50E+10	1.50E+10	1.00E+10
27	Residential	7.80E+08	7.80E+08	7.80E+08	7.80E+08	7.80E+08	7.80E+08	7.80E+08	7.80E+08	7.80E+08	7.80E+08	7.80E+08	7.80E+08
27	Forest	5.40E+07	5.40E+07	5.40E+07	5.40E+07	5.40E+07	5.40E+07	5.40E+07	5.40E+07	5.40E+07	5.40E+07	5.40E+07	5.40E+07
28	Cropland	4.10E+07	8.10E+08	3.50E+09	2.90E+09	7.40E+08	4.10E+07	4.10E+07	4.10E+07	4.10E+07	1.10E+09	1.10E+09	4.10E+07
28	Hayland	4.10E+07	4.10E+07	4.10E+07	4.10E+07	4.10E+07	4.10E+07	4.10E+07	4.10E+07	4.10E+07	4.10E+07	4.10E+07	4.10E+07
28	Pasture	1.00E+10	1.20E+10	2.00E+10	2.00E+10	2.10E+10	2.20E+10	2.20E+10	2.30E+10	2.30E+10	1.50E+10	1.50E+10	1.00E+10
28	Residential	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
28	Forest	4.40E+07	4.40E+07	4.40E+07	4.40E+07	4.40E+07	4.40E+07	4.40E+07	4.40E+07	4.40E+07	4.40E+07	4.40E+07	4.40E+07
29	Cropland	4.10E+07	4.10E+08	1.70E+09	1.40E+09	3.80E+08	4.10E+07	4.10E+07	4.10E+07	4.10E+07	5.60E+08	5.80E+08	4.10E+07
29	Hayland	4.10E+07	4.10E+07	4.10E+07	4.10E+07	4.10E+07	4.10E+07	4.10E+07	4.10E+07	4.10E+07	4.10E+07	4.10E+07	4.10E+07
29	Pasture	1.00E+10	1.20E+10	2.00E+10	2.00E+10	2.10E+10	2.10E+10	2.20E+10	2.30E+10	2.30E+10	1.50E+10	1.50E+10	1.00E+10
29	Residential	9.40E+08	9.40E+08	9.40E+08	9.40E+08	9.40E+08	9.40E+08	9.40E+08	9.40E+08	9.40E+08	9.40E+08	9.40E+08	9.40E+08
29	Forest	4.40E+07	4.40E+07	4.40E+07	4.40E+07	4.40E+07	4.40E+07	4.40E+07	4.40E+07	4.40E+07	4.40E+07	4.40E+07	4.40E+07
30	Cropland	1.50E+07	2.00E+08	8.40E+08	7.00E+08	1.80E+08	1.50E+07	1.50E+07	1.50E+07	1.50E+07	2.70E+08	2.70E+08	1.50E+07
30	Hayland	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
30	Pasture	1.10E+10	1.20E+10	2.00E+10	2.00E+10	2.10E+10	2.10E+10	2.20E+10	2.30E+10	2.30E+10	1.50E+10	1.50E+10	1.00E+10
30	Residential	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
30	Forest	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07
31	Cropland	4.90E+07	2.80E+09	1.30E+10	1.10E+10	2.60E+09	4.90E+07	4.90E+07	4.90E+07	4.90E+07	3.90E+09	4.10E+09	4.90E+07
31	Hayland	4.90E+07	1.20E+08	4.00E+08	3.40E+08	1.20E+08	1.20E+08	1.20E+08	1.20E+08	1.90E+08	1.90E+08	1.90E+08	4.90E+07
31	Pasture	1.10E+10	1.20E+10	2.00E+10	2.10E+10	2.10E+10	2.20E+10	2.20E+10	2.30E+10	2.30E+10	1.50E+10	1.50E+10	1.00E+10
31	Residential	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
31	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
32	Cropland	5.80E+07	1.20E+09	5.20E+09	4.30E+09	1.10E+09	5.80E+07	5.80E+07	5.80E+07	5.80E+07	1.60E+09	1.70E+09	5.80E+07
32	Hayland	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

32	Pasture	1.10E+10	1.20E+10	2.00E+10	2.10E+10	2.10E+10	2.20E+10	2.20E+10	2.30E+10	2.30E+10	1.50E+10	1.50E+10	1.00E+10
32	Residential	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
32	Forest	6.00E+07	6.00E+07	6.00E+07	6.00E+07	6.00E+07	6.00E+07	6.00E+07	6.00E+07	6.00E+07	6.00E+07	6.00E+07	6.00E+07
33	Hayland	4.10E+07	2.40E+08	9.40E+08	7.90E+08	2.20E+08	2.30E+08	2.20E+08	2.20E+08	4.10E+08	4.00E+08	4.10E+08	4.10E+07
33	Pasture	1.20E+10	1.40E+10	2.30E+10	2.40E+10	2.50E+10	2.50E+10	2.60E+10	2.60E+10	2.70E+10	1.70E+10	1.80E+10	1.20E+10
33	Residential	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
33	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
34	Hayland	1.90E+08	3.00E+08	7.20E+08	6.20E+08	2.90E+08	3.00E+08	2.90E+08	2.90E+08	4.00E+08	4.00E+08	4.00E+08	1.90E+08
34	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
34	Residential	3.70E+09	3.70E+09	3.70E+09	3.70E+09	3.70E+09	3.70E+09	3.70E+09	3.70E+09	3.70E+09	3.70E+09	3.70E+09	3.70E+09
34	Forest	1.90E+08	1.90E+08	1.90E+08	1.90E+08	1.90E+08	1.90E+08	1.90E+08	1.90E+08	1.90E+08	1.90E+08	1.90E+08	1.90E+08
35	Cropland	4.70E+07	2.80E+09	1.30E+10	1.10E+10	2.60E+09	4.70E+07	4.70E+07	4.70E+07	4.70E+07	3.90E+09	4.10E+09	4.70E+07
35	Hayland	4.70E+07	2.10E+08	8.10E+08	6.80E+08	2.00E+08	2.00E+08	2.00E+08	2.00E+08	3.60E+08	3.50E+08	3.60E+08	4.70E+07
35	Pasture	1.20E+10	1.40E+10	2.30E+10	2.40E+10	2.50E+10	2.50E+10	2.60E+10	2.60E+10	2.70E+10	1.70E+10	1.80E+10	1.20E+10
35	Residential	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
35	Forest	4.90E+07	4.90E+07	4.90E+07	4.90E+07	4.90E+07	4.90E+07	4.90E+07	4.90E+07	4.90E+07	4.90E+07	4.90E+07	4.90E+07
36	Cropland	5.50E+07	1.60E+09	7.30E+09	6.00E+09	1.50E+09	5.50E+07	5.50E+07	5.50E+07	5.50E+07	2.10E+09	2.30E+09	5.50E+07
36	Hayland	5.50E+07	5.50E+07	5.50E+07	5.50E+07	5.50E+07	5.50E+07	5.50E+07	5.50E+07	5.50E+07	5.50E+07	5.50E+07	5.50E+07
36	Pasture	1.30E+10	1.50E+10	2.50E+10	2.50E+10	2.60E+10	2.60E+10	2.70E+10	2.80E+10	2.80E+10	1.90E+10	1.90E+10	1.20E+10
36	Residential	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
36	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
37	Hayland	7.50E+07	2.20E+08	7.20E+08	6.10E+08	2.00E+08	2.10E+08	2.00E+08	2.00E+08	3.40E+08	3.30E+08	3.40E+08	7.50E+07
37	Pasture	1.10E+10	1.20E+10	2.00E+10	2.00E+10	2.10E+10	2.10E+10	2.20E+10	2.30E+10	2.30E+10	1.50E+10	1.50E+10	1.00E+10
37	Residential	8.90E+08	8.90E+08	8.90E+08	8.90E+08	8.90E+08	8.90E+08	8.90E+08	8.90E+08	8.90E+08	8.90E+08	8.90E+08	8.90E+08
37	Forest	7.80E+07	7.80E+07	7.80E+07	7.80E+07	7.80E+07	7.80E+07	7.80E+07	7.80E+07	7.80E+07	7.80E+07	7.80E+07	7.80E+07
38	Cropland	6.40E+07	4.70E+08	1.90E+09	1.60E+09	4.40E+08	6.40E+07	6.40E+07	6.40E+07	6.40E+07	6.30E+08	6.50E+08	6.40E+07
38	Hayland	6.40E+07	6.40E+07	6.40E+07	6.40E+07	6.40E+07	6.40E+07	6.40E+07	6.40E+07	6.40E+07	6.40E+07	6.40E+07	6.40E+07
38	Pasture	1.00E+10	1.20E+10	2.00E+10	2.00E+10	2.10E+10	2.10E+10	2.20E+10	2.20E+10	2.30E+10	1.50E+10	1.50E+10	1.00E+10
38	Residential	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
38	Forest	6.80E+07	6.80E+07	6.80E+07	6.80E+07	6.80E+07	6.80E+07	6.80E+07	6.80E+07	6.80E+07	6.80E+07	6.80E+07	6.80E+07
39	Cropland	6.90E+07	5.90E+08	2.50E+09	2.00E+09	5.50E+08	6.90E+07	6.90E+07	6.90E+07	6.90E+07	7.20E+08	8.20E+08	6.90E+07

39	Hayland	6.90E+07	6.90E+07	6.90E+07	6.90E+07	6.90E+07	6.90E+07	6.90E+07	6.90E+07	6.90E+07	6.90E+07	6.90E+07	6.90E+07
39	Pasture	1.20E+10	1.30E+10	2.20E+10	2.30E+10	2.30E+10	2.40E+10	2.40E+10	2.50E+10	2.50E+10	1.70E+10	1.80E+10	1.10E+10
39	Residential	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
39	Forest	7.30E+07	7.30E+07	7.30E+07	7.30E+07	7.30E+07	7.30E+07	7.30E+07	7.30E+07	7.30E+07	7.30E+07	7.30E+07	7.30E+07
40	Cropland	5.00E+07	3.20E+08	1.30E+09	1.10E+09	3.00E+08	5.00E+07	5.00E+07	5.00E+07	5.00E+07	4.30E+08	4.40E+08	5.00E+07
40	Hayland	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
40	Pasture	1.10E+10	1.20E+10	2.00E+10	2.00E+10	2.10E+10	2.10E+10	2.20E+10	2.20E+10	2.30E+10	1.50E+10	1.50E+10	1.00E+10
40	Residential	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09
40	Forest	5.30E+07	5.30E+07	5.30E+07	5.30E+07	5.30E+07	5.30E+07	5.30E+07	5.30E+07	5.30E+07	5.30E+07	5.30E+07	5.30E+07
41	Cropland	5.00E+07	1.30E+09	5.80E+09	4.80E+09	1.20E+09	5.00E+07	5.00E+07	5.00E+07	5.00E+07	1.80E+09	1.90E+09	5.00E+07
41	Hayland	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
41	Pasture	1.00E+10	1.20E+10	2.00E+10	2.00E+10	2.10E+10	2.10E+10	2.20E+10	2.20E+10	2.30E+10	1.50E+10	1.50E+10	1.00E+10
41	Residential	2.40E+09	2.40E+09	2.40E+09	2.40E+09	2.40E+09	2.40E+09	2.40E+09	2.40E+09	2.40E+09	2.40E+09	2.40E+09	2.40E+09
41	Forest	5.30E+07	5.30E+07	5.30E+07	5.30E+07	5.30E+07	5.30E+07	5.30E+07	5.30E+07	5.30E+07	5.30E+07	5.30E+07	5.30E+07
42	Cropland	6.30E+07	1.30E+09	5.60E+09	4.60E+09	1.20E+09	6.30E+07	6.30E+07	6.30E+07	6.30E+07	1.40E+09	1.80E+09	6.30E+07
42	Hayland	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
42	Pasture	1.30E+10	1.50E+10	2.60E+10	2.70E+10	2.70E+10	2.70E+10	2.80E+10	2.80E+10	2.90E+10	2.10E+10	2.10E+10	1.30E+10
42	Residential	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
42	Forest	6.50E+07	6.50E+07	6.50E+07	6.50E+07	6.50E+07	6.50E+07	6.50E+07	6.50E+07	6.50E+07	6.50E+07	6.50E+07	6.50E+07
43	Hayland	7.20E+07	2.40E+08	8.40E+08	7.10E+08	2.30E+08	2.30E+08	2.30E+08	2.30E+08	3.90E+08	3.80E+08	3.90E+08	7.20E+07
43	Pasture	1.00E+10	1.20E+10	2.00E+10	2.00E+10	2.10E+10	2.10E+10	2.20E+10	2.20E+10	2.30E+10	1.50E+10	1.50E+10	1.00E+10
43	Residential	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
43	Forest	7.50E+07	7.50E+07	7.50E+07	7.50E+07	7.50E+07	7.50E+07	7.50E+07	7.50E+07	7.50E+07	7.50E+07	7.50E+07	7.50E+07
44	Cropland	4.60E+07	1.60E+09	7.00E+09	5.80E+09	1.40E+09	4.60E+07	4.60E+07	4.60E+07	4.60E+07	1.90E+09	2.20E+09	4.60E+07
44	Hayland	4.60E+07	4.60E+07	4.60E+07	4.60E+07	4.60E+07	4.60E+07	4.60E+07	4.60E+07	4.60E+07	4.60E+07	4.60E+07	4.60E+07
44	Pasture	1.20E+10	1.40E+10	2.30E+10	2.40E+10	2.40E+10	2.50E+10	2.60E+10	2.60E+10	2.70E+10	1.80E+10	1.90E+10	1.20E+10
44	Residential	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
44	Forest	4.90E+07	4.90E+07	4.90E+07	4.90E+07	4.90E+07	4.90E+07	4.90E+07	4.90E+07	4.90E+07	4.90E+07	4.90E+07	4.90E+07
45	Cropland	4.70E+07	2.70E+09	1.20E+10	1.00E+10	2.50E+09	4.70E+07	4.70E+07	4.70E+07	4.70E+07	3.70E+09	3.80E+09	4.70E+07
45	Hayland	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07
45	Pasture	1.10E+10	1.20E+10	2.00E+10	2.00E+10	2.10E+10	2.20E+10	2.20E+10	2.30E+10	2.30E+10	1.50E+10	1.50E+10	1.00E+10

45	Residential	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
45	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
46	Cropland	4.30E+07	1.20E+09	5.50E+09	4.50E+09	1.10E+09	4.30E+07	4.30E+07	4.30E+07	4.30E+07	1.20E+09	1.80E+09	4.30E+07
46	Hayland	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07
46	Pasture	2.20E+10	2.30E+10	4.20E+10	4.40E+10	4.50E+10	4.50E+10	4.60E+10	4.70E+10	4.70E+10	3.90E+10	3.70E+10	2.10E+10
46	Residential	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
46	Forest	4.60E+07	4.60E+07	4.60E+07	4.60E+07	4.60E+07	4.60E+07	4.60E+07	4.60E+07	4.60E+07	4.60E+07	4.60E+07	4.60E+07
47	Hayland	9.20E+07	1.80E+08	5.10E+08	4.40E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	2.60E+08	2.60E+08	2.60E+08	9.20E+07
47	Pasture	1.10E+10	1.20E+10	1.90E+10	2.00E+10	2.00E+10	2.10E+10	2.10E+10	2.20E+10	2.20E+10	1.50E+10	1.50E+10	1.00E+10
47	Residential	5.10E+08	5.10E+08	5.10E+08	5.10E+08	5.10E+08	5.10E+08	5.10E+08	5.10E+08	5.10E+08	5.10E+08	5.10E+08	5.10E+08
47	Forest	9.40E+07	9.40E+07	9.40E+07	9.40E+07	9.40E+07	9.40E+07	9.40E+07	9.40E+07	9.40E+07	9.40E+07	9.40E+07	9.40E+07
48	Hayland	9.40E+07	1.70E+08	4.60E+08	3.90E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	2.40E+08	2.40E+08	2.40E+08	9.40E+07
48	Pasture	1.10E+10	1.30E+10	2.10E+10	2.10E+10	2.20E+10	2.20E+10	2.30E+10	2.30E+10	2.40E+10	1.50E+10	1.60E+10	1.10E+10
48	Residential	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
48	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
49	Cropland	4.80E+07	2.80E+09	1.30E+10	1.10E+10	2.60E+09	4.80E+07	4.80E+07	4.80E+07	4.80E+07	3.90E+09	4.10E+09	4.80E+07
49	Hayland	4.80E+07	1.10E+08	3.10E+08	2.60E+08	1.00E+08	1.00E+08	1.00E+08	1.00E+08	1.60E+08	1.50E+08	1.60E+08	4.80E+07
49	Pasture	1.20E+10	1.40E+10	2.30E+10	2.40E+10	2.50E+10	2.50E+10	2.60E+10	2.60E+10	2.70E+10	1.70E+10	1.80E+10	1.20E+10
49	Residential	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
49	Forest	5.10E+07	5.10E+07	5.10E+07	5.10E+07	5.10E+07	5.10E+07	5.10E+07	5.10E+07	5.10E+07	5.10E+07	5.10E+07	5.10E+07
50	Cropland	4.80E+07	1.70E+09	7.60E+09	6.30E+09	1.60E+09	4.80E+07	4.80E+07	4.80E+07	4.80E+07	2.10E+09	2.40E+09	4.80E+07
50	Hayland	4.80E+07	4.80E+07	4.80E+07	4.80E+07	4.80E+07	4.80E+07	4.80E+07	4.80E+07	4.80E+07	4.80E+07	4.80E+07	4.80E+07
50	Pasture	1.40E+10	1.50E+10	2.60E+10	2.70E+10	2.70E+10	2.80E+10	2.80E+10	2.90E+10	3.00E+10	2.00E+10	2.10E+10	1.30E+10
50	Residential	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
50	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
51	Hayland	5.50E+07	2.30E+08	8.40E+08	7.00E+08	2.10E+08	2.20E+08	2.10E+08	2.10E+08	3.80E+08	3.70E+08	3.80E+08	5.50E+07
51	Pasture	1.50E+10	1.70E+10	2.90E+10	3.00E+10	3.00E+10	3.10E+10	3.20E+10	3.30E+10	3.40E+10	2.10E+10	2.20E+10	1.40E+10
51	Residential	8.70E+08	8.70E+08	8.70E+08	8.70E+08	8.70E+08	8.70E+08	8.70E+08	8.70E+08	8.70E+08	8.70E+08	8.70E+08	8.70E+08
51	Forest	5.70E+07	5.70E+07	5.70E+07	5.70E+07	5.70E+07	5.70E+07	5.70E+07	5.70E+07	5.70E+07	5.70E+07	5.70E+07	5.70E+07
52	Cropland	4.50E+07	1.40E+09	6.00E+09	5.00E+09	1.20E+09	4.50E+07	4.50E+07	4.50E+07	4.50E+07	1.90E+09	1.90E+09	4.50E+07
52	Hayland	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

52	Pasture	1.50E+10	1.70E+10	3.00E+10	3.00E+10	3.10E+10	3.20E+10	3.30E+10	3.30E+10	3.40E+10	2.10E+10	2.20E+10	1.40E+10
52	Residential	3.90E+08	3.90E+08	3.90E+08	3.90E+08	3.90E+08	3.90E+08	3.90E+08	3.90E+08	3.90E+08	3.90E+08	3.90E+08	3.90E+08
52	Forest	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07
53	Cropland	2.50E+08	3.00E+09	1.30E+10	1.10E+10	2.80E+09	2.50E+08	2.50E+08	2.50E+08	2.50E+08	4.10E+09	4.30E+09	2.50E+08
53	Hayland	2.50E+08	3.20E+08	5.60E+08	5.00E+08	3.10E+08	3.10E+08	3.10E+08	3.10E+08	3.80E+08	3.70E+08	3.80E+08	2.50E+08
53	Pasture	1.80E+10	2.00E+10	3.20E+10	3.30E+10	3.40E+10	3.40E+10	3.50E+10	3.60E+10	3.70E+10	2.40E+10	2.50E+10	1.70E+10
53	Residential	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09
53	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
54	Hayland	4.60E+07	1.60E+08	5.50E+08	4.60E+08	1.50E+08	1.50E+08	1.50E+08	1.50E+08	2.50E+08	2.50E+08	2.50E+08	4.60E+07
54	Pasture	1.70E+10	2.00E+10	3.30E+10	3.40E+10	3.50E+10	3.50E+10	3.60E+10	3.70E+10	3.80E+10	2.40E+10	2.50E+10	1.70E+10
54	Residential	5.20E+08	5.20E+08	5.20E+08	5.20E+08	5.20E+08	5.20E+08	5.20E+08	5.20E+08	5.20E+08	5.20E+08	5.20E+08	5.20E+08
54	Forest	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07
55	Hayland	8.70E+07	2.20E+08	7.00E+08	5.90E+08	2.10E+08	2.10E+08	2.10E+08	2.10E+08	3.40E+08	3.30E+08	3.40E+08	8.70E+07
55	Pasture	1.00E+10	1.20E+10	2.00E+10	2.00E+10	2.10E+10	2.10E+10	2.20E+10	2.20E+10	2.30E+10	1.40E+10	1.50E+10	9.90E+09
55	Residential	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09
55	Forest	9.00E+07	9.00E+07	9.00E+07	9.00E+07	9.00E+07	9.00E+07	9.00E+07	9.00E+07	9.00E+07	9.00E+07	9.00E+07	9.00E+07
56	Cropland	5.90E+07	2.90E+09	1.30E+10	1.10E+10	2.60E+09	5.90E+07	5.90E+07	5.90E+07	5.90E+07	3.90E+09	4.10E+09	5.90E+07
56	Hayland	5.90E+07	1.30E+08	4.00E+08	3.40E+08	1.30E+08	1.30E+08	1.30E+08	1.30E+08	2.00E+08	2.00E+08	2.00E+08	5.90E+07
56	Pasture	1.10E+10	1.20E+10	2.00E+10	2.10E+10	2.10E+10	2.20E+10	2.20E+10	2.30E+10	2.30E+10	1.50E+10	1.50E+10	1.00E+10
56	Residential	2.80E+09	2.80E+09	2.80E+09	2.80E+09	2.80E+09	2.80E+09	2.80E+09	2.80E+09	2.80E+09	2.80E+09	2.80E+09	2.80E+09
56	Forest	6.10E+07	6.10E+07	6.10E+07	6.10E+07	6.10E+07	6.10E+07	6.10E+07	6.10E+07	6.10E+07	6.10E+07	6.10E+07	6.10E+07
57	Cropland	5.60E+07	1.30E+09	5.70E+09	4.70E+09	1.20E+09	5.60E+07	5.60E+07	5.60E+07	5.60E+07	1.80E+09	1.80E+09	5.60E+07
57	Hayland	5.60E+07	5.60E+07	5.60E+07	5.60E+07	5.60E+07	5.60E+07	5.60E+07	5.60E+07	5.60E+07	5.60E+07	5.60E+07	5.60E+07
57	Pasture	1.00E+10	1.20E+10	2.00E+10	2.00E+10	2.10E+10	2.10E+10	2.20E+10	2.30E+10	2.30E+10	1.50E+10	1.50E+10	1.00E+10
57	Residential	9.70E+08	9.70E+08	9.70E+08	9.70E+08	9.70E+08	9.70E+08	9.70E+08	9.70E+08	9.70E+08	9.70E+08	9.70E+08	9.70E+08
57	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
58	Cropland	4.70E+07	7.00E+08	3.00E+09	2.50E+09	6.40E+08	4.70E+07	4.70E+07	4.70E+07	4.70E+07	9.50E+08	9.80E+08	4.70E+07
58	Hayland	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07	4.70E+07
58	Pasture	1.10E+10	1.20E+10	2.00E+10	2.10E+10	2.10E+10	2.20E+10	2.20E+10	2.30E+10	2.30E+10	1.50E+10	1.50E+10	1.00E+10
58	Residential	9.60E+08	9.60E+08	9.60E+08	9.60E+08	9.60E+08	9.60E+08	9.60E+08	9.60E+08	9.60E+08	9.60E+08	9.60E+08	9.60E+08
58	Forest	4.90E+07	4.90E+07	4.90E+07	4.90E+07	4.90E+07	4.90E+07	4.90E+07	4.90E+07	4.90E+07	4.90E+07	4.90E+07	4.90E+07

59	Hayland	7.30E+07	6.50E+08	2.70E+09	2.20E+09	6.00E+08	1.20E+09	7.30E+07	6.00E+08	1.70E+09	6.00E+08	1.20E+09	7.30E+07
59	Pasture	4.70E+10	4.90E+10	9.50E+10	1.00E+11	9.90E+10	1.00E+11	1.00E+11	1.00E+11	1.00E+11	9.40E+10	8.90E+10	4.70E+10
59	Residential	2.60E+08	2.60E+08	2.60E+08	2.60E+08	2.60E+08	2.60E+08	2.60E+08	2.60E+08	2.60E+08	2.60E+08	2.60E+08	2.60E+08
59	Forest	7.70E+07	7.70E+07	7.70E+07	7.70E+07	7.70E+07	7.70E+07	7.70E+07	7.70E+07	7.70E+07	7.70E+07	7.70E+07	7.70E+07
60	Cropland	6.80E+07	2.90E+09	1.30E+10	1.10E+10	2.60E+09	6.80E+07	6.80E+07	6.80E+07	6.80E+07	3.90E+09	4.10E+09	6.80E+07
60	Hayland	6.80E+07	1.30E+08	3.30E+08	2.90E+08	1.20E+08	1.20E+08	1.20E+08	1.20E+08	1.80E+08	1.70E+08	1.80E+08	6.80E+07
60	Pasture	1.00E+10	1.20E+10	2.00E+10	2.00E+10	2.10E+10	2.10E+10	2.20E+10	2.20E+10	2.30E+10	1.50E+10	1.50E+10	1.00E+10
60	Residential	9.90E+08	9.90E+08	9.90E+08	9.90E+08	9.90E+08	9.90E+08	9.90E+08	9.90E+08	9.90E+08	9.90E+08	9.90E+08	9.90E+08
60	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
61	Hayland	1.00E+08	2.90E+08	9.40E+08	8.00E+08	2.70E+08	2.80E+08	2.70E+08	2.70E+08	4.50E+08	4.40E+08	4.50E+08	1.00E+08
61	Pasture	1.00E+10	1.20E+10	1.90E+10	2.00E+10	2.00E+10	2.10E+10	2.10E+10	2.20E+10	2.20E+10	1.40E+10	1.50E+10	9.80E+09
61	Residential	3.50E+08	3.50E+08	3.50E+08	3.50E+08	3.50E+08	3.50E+08	3.50E+08	3.50E+08	3.50E+08	3.50E+08	3.50E+08	3.50E+08
61	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
62	Cropland	4.20E+07	7.00E+08	3.10E+09	2.50E+09	6.50E+08	4.20E+07	4.20E+07	4.20E+07	4.20E+07	9.60E+08	9.90E+08	4.20E+07
62	Hayland	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
62	Pasture	1.00E+10	1.20E+10	2.00E+10	2.00E+10	2.10E+10	2.10E+10	2.20E+10	2.20E+10	2.30E+10	1.50E+10	1.50E+10	1.00E+10
62	Residential	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
62	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
63	Cropland	4.90E+07	2.80E+09	1.30E+10	1.10E+10	2.60E+09	4.90E+07	4.90E+07	4.90E+07	4.90E+07	3.90E+09	4.10E+09	4.90E+07
63	Hayland	4.90E+07	5.30E+07	6.50E+07	6.20E+07	5.30E+07	5.30E+07	5.30E+07	5.30E+07	5.60E+07	5.60E+07	5.60E+07	4.90E+07
63	Pasture	1.00E+10	1.20E+10	2.00E+10	2.00E+10	2.10E+10	2.10E+10	2.20E+10	2.20E+10	2.30E+10	1.50E+10	1.50E+10	1.00E+10
63	Residential	2.40E+09	2.40E+09	2.40E+09	2.40E+09	2.40E+09	2.40E+09	2.40E+09	2.40E+09	2.40E+09	2.40E+09	2.40E+09	2.40E+09
63	Forest	5.20E+07	5.20E+07	5.20E+07	5.20E+07	5.20E+07	5.20E+07	5.20E+07	5.20E+07	5.20E+07	5.20E+07	5.20E+07	5.20E+07
64	Cropland	5.60E+07	2.90E+09	1.30E+10	1.10E+10	2.60E+09	5.60E+07	5.60E+07	5.60E+07	5.60E+07	3.90E+09	4.10E+09	5.60E+07
64	Hayland	5.60E+07	1.20E+08	3.70E+08	3.20E+08	1.20E+08	1.20E+08	1.20E+08	1.20E+08	1.90E+08	1.80E+08	1.90E+08	5.60E+07
64	Pasture	1.10E+10	1.20E+10	2.00E+10	2.00E+10	2.10E+10	2.10E+10	2.20E+10	2.20E+10	2.30E+10	1.50E+10	1.50E+10	1.00E+10
64	Residential	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
64	Forest	5.70E+07	5.70E+07	5.70E+07	5.70E+07	5.70E+07	5.70E+07	5.70E+07	5.70E+07	5.70E+07	5.70E+07	5.70E+07	5.70E+07
65	Cropland	5.10E+07	2.80E+09	1.30E+10	1.10E+10	2.60E+09	5.10E+07	5.10E+07	5.10E+07	5.10E+07	3.90E+09	4.10E+09	5.10E+07
65	Hayland	5.10E+07	1.20E+08	3.60E+08	3.10E+08	1.10E+08	1.20E+08	1.10E+08	1.10E+08	1.80E+08	1.80E+08	1.80E+08	5.10E+07
65	Pasture	1.10E+10	1.20E+10	2.00E+10	2.10E+10	2.10E+10	2.20E+10	2.20E+10	2.30E+10	2.30E+10	1.50E+10	1.50E+10	1.00E+10

65	Residential	6.00E+08	6.00E+08	6.00E+08	6.00E+08	6.00E+08	6.00E+08	6.00E+08	6.00E+08	6.00E+08	6.00E+08	6.00E+08	6.00E+08
65	Forest	5.30E+07	5.30E+07	5.30E+07	5.30E+07	5.30E+07	5.30E+07	5.30E+07	5.30E+07	5.30E+07	5.30E+07	5.30E+07	5.30E+07
66	Cropland	6.70E+07	2.90E+09	1.30E+10	1.10E+10	2.60E+09	6.70E+07	6.70E+07	6.70E+07	6.70E+07	3.90E+09	4.10E+09	6.70E+07
66	Hayland	6.70E+07	1.40E+08	4.00E+08	3.40E+08	1.30E+08	1.40E+08	1.30E+08	1.30E+08	2.00E+08	2.00E+08	2.00E+08	6.70E+07
66	Pasture	1.00E+10	1.20E+10	2.00E+10	2.00E+10	2.10E+10	2.10E+10	2.20E+10	2.20E+10	2.30E+10	1.50E+10	1.50E+10	1.00E+10
66	Residential	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
66	Forest	6.90E+07	6.90E+07	6.90E+07	6.90E+07	6.90E+07	6.90E+07	6.90E+07	6.90E+07	6.90E+07	6.90E+07	6.90E+07	6.90E+07
67	Hayland	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
67	Pasture	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
67	Residential	7.70E+08	7.70E+08	7.70E+08	7.70E+08	7.70E+08	7.70E+08	7.70E+08	7.70E+08	7.70E+08	7.70E+08	7.70E+08	7.70E+08
67	Forest	7.30E+07	7.30E+07	7.30E+07	7.30E+07	7.30E+07	7.30E+07	7.30E+07	7.30E+07	7.30E+07	7.30E+07	7.30E+07	7.30E+07
68	Hayland	4.30E+07	7.40E+07	1.80E+08	1.60E+08	7.10E+07	7.20E+07	7.10E+07	7.10E+07	1.00E+08	9.90E+07	1.00E+08	4.30E+07
68	Pasture	8.20E+09	9.60E+09	1.60E+10	1.70E+10	1.70E+10	1.80E+10	1.80E+10	1.90E+10	1.90E+10	1.20E+10	1.20E+10	7.80E+09
68	Residential	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08
68	Forest	4.40E+07	4.40E+07	4.40E+07	4.40E+07	4.40E+07	4.40E+07	4.40E+07	4.40E+07	4.40E+07	4.40E+07	4.40E+07	4.40E+07
69	Hayland	4.10E+07	6.80E+07	1.60E+08	1.40E+08	6.60E+07	6.70E+07	6.60E+07	6.60E+07	9.20E+07	9.10E+07	9.20E+07	4.10E+07
69	Pasture	1.30E+10	1.40E+10	2.30E+10	2.30E+10	2.40E+10	2.40E+10	2.50E+10	2.60E+10	2.60E+10	1.70E+10	1.80E+10	1.20E+10
69	Residential	3.70E+09	3.70E+09	3.70E+09	3.70E+09	3.70E+09	3.70E+09	3.70E+09	3.70E+09	3.70E+09	3.70E+09	3.70E+09	3.70E+09
69	Forest	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07	4.30E+07

Appendix D: Simulated Stream Flow Chart for TMDL Allocation Period

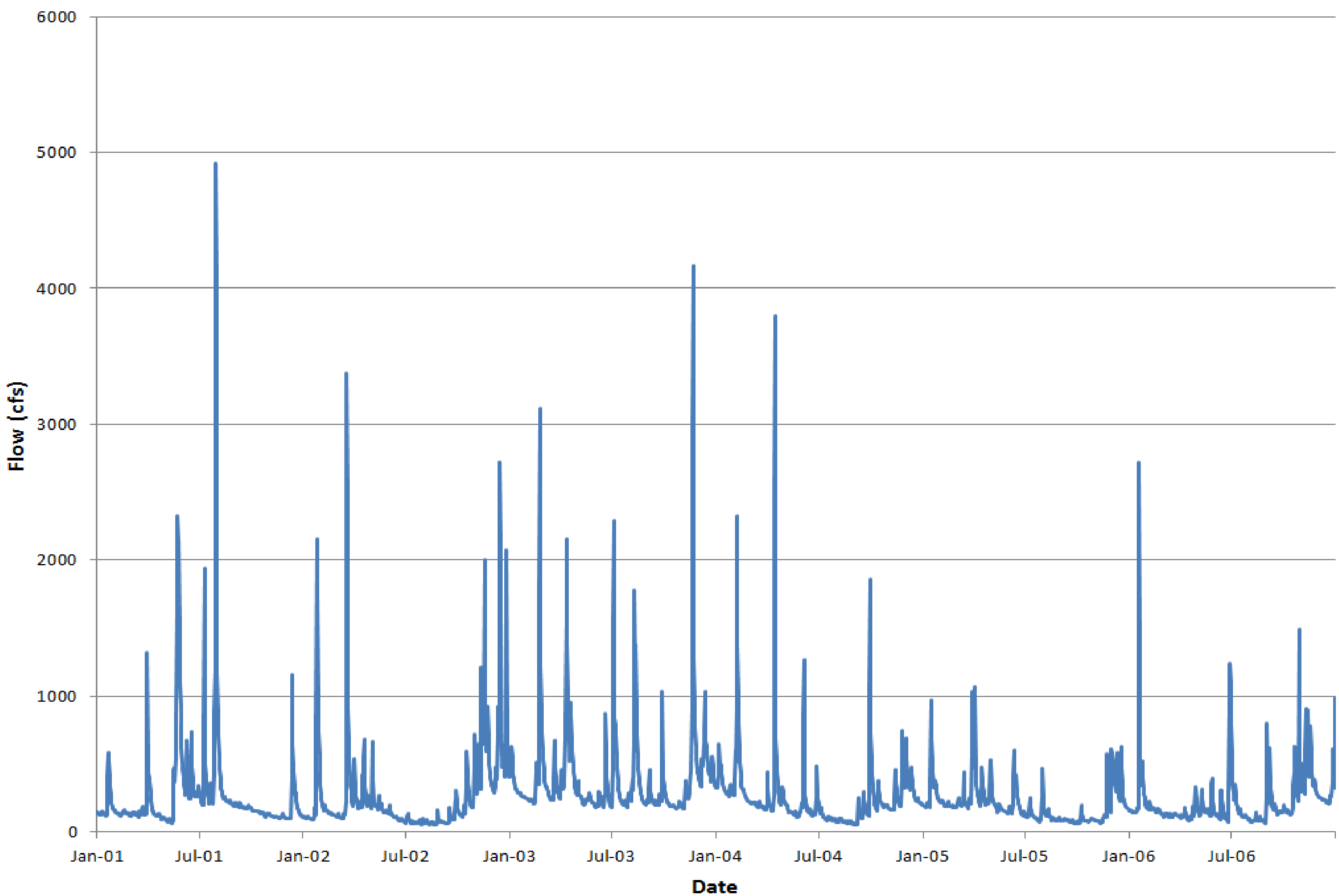

Figure D.1. Simulated stream flow at the outlet of Reed Creek for the allocation period.