Fecal Bacteria and General Standard Total Maximum Daily Load Development For Impaired Streams in the Middle River and Upper South River Watersheds,

Augusta County, VA

Prepared for:

Commonwealth of Virginia

Department of Conservation and Recreation

Division of Soil and Water

April 28, 2004

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EXECUTIVE SUMMARY

Background and Applicable Standards

Middle River was placed on the Commonwealth of Virginia's 1996 Section 303(d) TMDL Priority List because of violations of the fecal coliform bacteria water quality standard and the General Standard (benthic). The focus of these TMDLs is on the fecal coliform and benthic impairments in Middle River and Upper South River watersheds. Based on exceedances of the fecal coliform standard recorded at Virginia Department of Environmental Quality (VADEQ) monitoring stations located in the Upper Middle River, Lewis Creek, Moffett Creek, Polecat Draft, Lower Middle River and Upper South River, these streams do not support primary contact recreation (*e.g.*, swimming). All of these segments were initially placed on the Virginia 1996 303(d) TMDL Priority List and have remained on the 1998 and 2002 303(d) lists. The new applicable state standard (Virginia Water Quality Standard 9 VAC 25-260-170) specifies that the number of fecal coliform bacteria shall not exceed a maximum allowable level of 400 colony-forming units (cfu) per 100 milliliters (ml). Alternatively, if data is available, the geometric mean of two or more observations taken in a calendar month should not exceed 200-cfu/100 ml. The United States Environmental Protection Agency (EPA) directed that the state develop a water quality standard for *E. coli* bacteria to eventually replace the fecal coliform standard. This new standard specifies that the number of *E. coli* bacteria shall not exceed a maximum allowable level of 235-cfu /100 ml (Virginia Water Quality Standard 9 VAC 25-260-170). In addition, if data is available, the geometric mean of two or more observations taken in a calendar month should not exceed 126-cfu/100 ml.

The General Standard is implemented by VADEQ through application of the Rapid Bioassessment Protocol II (RBP). Using the RBP, the health of the benthic macro-invertebrate community is typically assessed through measurement of 8 biometrics that evaluate different aspects of the community's overall health. Surveys of the benthic macroinvertebrate community performed by VADEQ are assessed at the family taxonomic level. Each biometric measured at a target station is compared to the same biometric measured at a reference (non-impaired) station to determine each biometric score. These scores are then summed and used to determine the overall bioassessment (*e.g.*, non-impaired, moderately impaired, or severely impaired). Using this methodology, Christians Creek, Lewis Creek, Moffett Creek, and Upper Middle River stream segments were rated as non-impaired to slightly impaired, moderate to severely impaired, moderately impaired, and moderately impaired, respectively.

TMDL Endpoint and Water Quality Assessment

Fecal Coliform

Potential sources of fecal coliform include both point source and nonpoint source contributions. Nonpoint sources include: wildlife, grazing livestock, land application of manure, land application of biosolids, urban/suburban runoff, failed and malfunctioning septic systems, and uncontrolled discharges (straight pipes, dairy parlor waste, etc.). There are 50 Virginia Pollutant Discharge Elimination Systems (VPDES) permitted dischargers in the Middle River and Upper South River watersheds. The permits range from single-family wastewater permits to waste water treatment facilities in Staunton and Churchville.

Fecal bacteria TMDLs in the Commonwealth of Virginia are developed using the *E. coli* standard. For this TMDL development, the in-stream *E. coli* target was a geometric mean not exceeding 126-cfu/100 ml and a single sample maximum of 235-cfu/100 ml. A translator developed by VADEQ was used to convert fecal coliform values to *E. coli* values.

General Standard (benthic)

TMDLs must be developed for a specific pollutant(s). Benthic assessments are very good at determining if a particular stream segment is impaired or not, but generally do not provide enough information to determine the cause(s) of the impairment. The process outlined in the Stressor Identification Guidance Document (EPA, 2000) was used to systematically identify the most probable stressor(s) for Christians Creek, Lewis Creek, Moffett Creek and the Upper Middle River. After a comprehensive assessment, benthic TMDL development for Lewis Creek has been delayed until further tests are performed relating to the impact of sediment contamination within the watershed. A list of candidate causes was developed from published literature and VADEQ staff input. Chemical and physical monitoring data from ambient water quality data, toxicity tests and habitat assessment provided evidence to support or eliminate potential stressors. Individual metrics for the biological and habitat evaluation were used to determine if there were links to a specific stressor(s). Landuse data as well as a visual assessment of conditions along the stream provided additional information to eliminate or support candidate stressors. Potential stressors are: sediment, toxics, low dissolved oxygen, nutrients, pH, metals, conductivity, temperature and organic matter. A summary of stressor identification is included by impairment.

Christians Creek

The primary stressor on the aquatic life of Christians Creek was identified as lack of litter fall to the first order streams in the Christians Creek watershed from a lack of forest cover in the riparian corridors. A second minor stressor on the minor on the aquatic life in Christians Creek was identified as sedimentation from stream bank erosion. These two stressors are inexorably linked. A lack of riparian tree cover means that banks are likely unstable and are susceptible to erosion because tree roots are not holding and maintaining bank soils. Based on input from VADEQ and EPA, a TMDL for sediment inputs from the riparian corridor of first order streams was developed to address these stressors. Sediment loads delivered from areas in the first-order stream corridor including the stream channel were modeled and an instream input was established on a reference watershed approach. Implementing best management practices that establish riparian tree cover will increase leaf fall and decrease bank erosion and sedimentation.

One additional matter of concern in Christians Creek is the presence of toxic organics (chlordane and PCBs) that have been found in sediments from the stream. However, there is insufficient data to confirm that these pollutants are currently impacting the aquatic community.

Moffett Creek

The stressor on aquatic life in Moffett Creek was identified as excessive siltation leading to sedimentation, embeddedness, and loss of habitat.

Upper Middle River

Three stressors on the aquatic life in the Upper Middle River watershed have been identified- two major and one minor. The major stressors included (1) excessive siltation leading to sedimentation, embeddedness, and loss of habitat, and (2) lack of litterfall to the first order streams that results from lack of forest cover in the riparian corridors. The minor stressor is elevated nutrient level.

The two major stressors are interrelated and impacted by landuse in and around the riparian corridor. The third stressor, thought to be less important, is nutrient inputs. The diurnal swings do not drive Dissolved Oxygen (DO) below the standard, but the swing is pronounced, and both total phosphorus and nitrate concentrations are found at elevated levels. The results show sediment is the Most Probable Stressor and, therefore, it is the best and most practical pollutant for which to develop the TMDL because it is so interconnected with the other possible stressors.

Sediment is delivered to the impaired stream segments through surface runoff (rural and urban areas), streambank erosion, point sources, and natural erosive process. The sediment process is a natural and continual process that is often accelerated by human activity. During runoff events (natural rainfall or irrigation), sediment is transported to streams from land areas (e.g. agricultural fields, lawns, forest, etc.). Rainfall energy, soil cover, soil characteristics, topography, and land management affect the magnitude of sediment loading. Agricultural management activities such as overgrazing, particularly on steep slopes, high tillage operations, livestock concentrations, along stream edge, uncontrolled access to streams, forest harvesting, construction (roads, buildings, etc.) all tend to accelerate erosion at varying degrees. During dry periods, sediment from air or traffic builds up on impervious areas and is transported to streams during runoff events.

An increase in impervious land without appropriate stormwater control increases runoff volume and peaks and leads to greater potential for channel erosion. It has been well documented that livestock with access to streams can significantly alter physical dimensions of streams through trampling and shearing (Armour, et al., 1991; Clary and Webster, 1990; Kaufman and Kruger, 1984). Increasing the bank full width decreases stream depth, increases sediment, and adversely affects aquatic habitat (USDI, 1998).

Fine sediments are included in total suspended solids (TSS) loads that are permitted for wastewater, industrial stormwater and construction stormwater discharge. There are thirty-five permits listed in Christians Creek, Moffett Creek and the Upper Middle River impairments. These include small single-family wastewater discharge permits, one industrial stormwater discharge permit, 12 construction permits, and sewage and wastewater treatment facilities.

Reference Watershed Selection

A reference watershed approach was used to estimate the necessary load reductions for identified stressor(s) that are needed to restore a healthy aquatic community and allow impaired stream segments in Christians Creek, Moffett Creek, and Upper Middle river to achieve their designated uses. The reference watershed approach is based on selecting a non-impaired watershed in the same eco-region as the impaired watershed that has similar landuse, soils, and stream characteristics. Fourteen potential reference watersheds were initially selected based on non-impairment status, stream order, and eco-region. From the fourteen selected watersheds, individual reference watersheds were selected for Christians Creek, Moffett Creek and Upper Middle River.

Water Quality Modeling

Fecal Coliform

The US Geological Survey (USGS) Hydrologic Simulation Program - Fortran (HSPF) water quality model was selected as the modeling framework to simulate existing conditions and perform TMDL allocations. In establishing the existing and allocation conditions, seasonal variations in hydrology, climatic conditions, and watershed activities were explicitly accounted for in the model. The hydrologic calibration/validation for Middle and Upper South River watersheds used 30-minute flow data from USGS Station #01625000 (Middle River at Grottoes) and USGS Station #01626000 (South River near Waynesboro). The distribution of flow volume between surface runoff, interflow, and groundwater was 20%, 14%, and 66%, respectively for Middle River; and 17%, 26%, and 57%, respectively for South River. The water quality calibration was conducted using monitored data from 10/1/92 through 9/30/97. Four parameters used in HSPF to index in-stream first order decay rate, maximum accumulation on land, rate of surface runoff that will remove 90% of stored fecal coliform per hour, and concentration of fecal coliform in interflow were initially set at expected levels for watershed conditions and adjusted within reasonable limits until an acceptable match between measured and modeled fecal coliform concentrations was established. The water quality validation was conducted using data for the time period from 10/1/97 to 9/30/02.

General Standard (benthic) - Sediment

There is no existing in-stream criteria for sediment in Virginia; therefore, a reference watershed approach was used to define allowable TMDL loading rates in Christians Creek, Moffett Creek and the Upper Middle River watersheds. This approach pairs two watersheds: one that is supportive of its designated use(s) and one whose streams are impaired. The Opequon Creek watershed was selected as the TMDL reference for Christians Creek, Mill Creek was selected as the reference watershed for Moffett Creek, and Hays Creek was selected as the reference watershed for the Upper Middle River. The TMDL sediment load was defined as the modeled sediment load for existing conditions from the non-impaired watersheds, area-adjusted to their respective impaired watershed. The Generalized Watershed Loading Function (GWLF) model (Haith et al., 1992) was used for comparative modeling for each impairment-reference watershed combination. Although the GWLF model was originally developed for use in ungaged watersheds, hydrologic calibration was performed to ensure that streamflows were being simulated within acceptable limits. The model for Christians Creek, Moffett Creek, and Upper Middle River was calibrated using the mean daily flow from USGS Station #01624800 for the period April 1992 through September 1997. Precipitation and temperature data were obtained from Stations #448975 and #448062. The model for Christians Creek reference watershed Opequon Creek was calibrated using USGS Station #01615000 for the period April 1992 through September 1997. Precipitation and temperature data were obtained from Stations #449186, #449181, and #440670. The model for Moffett Creek reference watershed Mill Creek was calibrated from nearby USGS Station #01632900. Precipitation and temperature data were obtained from Stations #449263 and #448448. The model for Upper Middle River reference watershed Hays Creek was calibrated from nearby USGS Station #02022500 for the period April 1992 through September 1997. Precipitation and temperature data were obtained from Stations #445685, #444876, #443470, and #442064.

Existing Conditions

Fecal Coliform

Wildlife populations and ranges, biosolids application rates and practices, the rate of failure, location, and number of septic systems, domestic pet populations, numbers of cattle and other livestock, and information on livestock and manure management practices for the Middle and Upper South River watersheds were used to calculate fecal coliform load from land-based nonpoint sources in each impairment: Upper Middle River, Lewis Creek, Moffett Creek, Polecat Draft, Lower Middle River and Upper South River. The estimated fecal coliform production and accumulation rates due to these sources were calculated for the watershed and incorporated into the model. To accommodate the structure of the model, calculation of the fecal coliform accumulation and source contributions on a monthly basis accounted for seasonal variation in watershed activities such as wildlife feeding patterns and land application of manure. Also, represented in the model were direct nonpoint sources of uncontrolled discharges, direct deposition by wildlife, and direct deposition by livestock.

Contributions from all sources were updated to 2003 conditions to establish existing conditions. All runs were made using a representative precipitation record covering the period 10/1/92 through 9/30/97. Under existing conditions (2003), the HSPF model provided a comparable match to the VADEQ monitoring data, with output from the model indicating violations of both the instantaneous and geometric mean standards for all impairments: Upper Middle River, Lewis Creek, Moffett Creek, Polecat Draft, Lower Middle River and Upper South River.

General Standard (benthic) - Sediment

The benthic TMDL for Christians Creek, Moffett Creek and Upper Middle River were developed using sediment as the primary stressor and Opequon Creek, Mill Creek, and Hays Creek as the reference watersheds, respectively. The reference watershed landuse categories (sediment source areas) were area-adjusted to match the watershed area of each respective impaired watershed to establish a common basis for comparing loads between the three watershed pairs. The areas for each landuse category (sediment source areas) in the Opequon Creek watershed were multiplied by 2.029 to match the Christians Creek watershed area. The areas for landuse categories (sediment source areas) in Mill Creek were multiplied by 0.6678 to match the Moffett Creek watershed area. The areas for each landuse category (sediment source areas) in Hays Creek were multiplied by 0.5973 to match the Upper Middle River watershed area.

The average annual sediment load (metric tons per year) from the area-adjusted Opequon Creek first order stream corridor defined the TMDL sediment load for Christians Creek. The sediment loads for existing conditions were calculated using the period January 1992 through March 2000 as representative of both wet and dry periods of precipitation. The target sediment TMDL load (existing conditions for Opequon Creek) was **6,168 T/yr**. The existing load from Christians Creek was **7,302 T/yr.**

The average annual sediment load (metric tons per year) from the area-adjusted Mill Creek defined the TMDL sediment load for Moffett Creek. The sediment loads for existing conditions were calculated using the period January 1992 through March 2000 as representative of both wet and dry periods of precipitation. The target sediment TMDL load (existing conditions for Mill Creek) was **3,864 T/yr**. The existing load from Moffett Creek was **9,589 T/yr.**

The average annual sediment load (metric tons per year) from the area-adjusted Hays Creek defined the TMDL sediment load for Upper Middle River. The sediment loads for existing conditions were calculated using the period January 1992 through March 2000 as representative of both wet and dry periods of precipitation. The target sediment TMDL load (existing conditions for Hays Creek) was **6,316 T/yr**. The existing load from Upper Middle River was **12,162 T/yr.**

Load Allocation Scenarios

Fecal Coliform

The next step in the TMDL process was to reduce the various source loads to levels that would result in attainment of the water quality standards. Because Virginia's *E. coli* standard does not permit any exceedances of the standard, modeling was conducted for a target value of 0% exceedance of the 126 cfu/100 ml geometric mean standard and 0% exceedance of the sample maximum *E. coli* standard of 235 cfu/100 ml. Scenarios were evaluated to predict the effects of different combinations of source reductions on final in-stream water quality. Modeling of these scenarios provided predictions of whether the reductions would achieve the target of 0% exceedance. The final allocation in percentages in loading from existing conditions are given in Table ES.1.

Table ES.1 Final allocations in percentages in loading from existing conditions for Upper Middle River Watershed.

Impairment	Percent Reduction in Loading from Existing Condition					
	Direct Wildlife	NPS Wildlife	Direct Livestock	NPS Pasture / Livestock	Res./ Urban	Straight Pipe/ Sewer Overflow
Upper Middle River	0	99	100	99.9	99.9	100
Moffett Creek	36	93	100	99.9	99.9	100
Lewis Creek	75	99	100	99.9	99.9	100
Polecat Draft	6	0	100	99.99	83	100
Lower Middle River	0	71	100	99.9	99.9	100
Upper South River	0	97.5	55	99.9	99.9	100

General Standard (benthic) - Sediment

The target reduction load was calculated as the TMDL minus waste load allocations (WLAs) minus an explicit 10% margin of safety (MOS). Since the WLA is included in the calculation of the target reduction load, the existing watershed load (impaired watershed) only includes the nonpoint source loads plus stream channel loads.

Christians Creek

The reductions required to meet the TMDL in Christians Creek are given in Table ES.2. To meet the target-modeling load, a 25.9% overall sediment reduction will be required. Two sediment reduction allocations alternatives are presented in Table ES.3. In Alternative 1, the required sediment reduction is allocated to the stream channel. In Alternative 2, allocations are also made to pastureland and cropland within the 330-foot stream corridor. Alternatives to achieve sediment load reductions could include streamside fencing, streambank stabilization, stormwater management from urban areas, improved pasture management in the stream corridor zone, riparian tree planting to increase leaf litter and stabilize banks, etc.

Table ES.2 Required sediment reductions for Christians Creek Impairment.

Load Summary	Christians Creek (T/yr)	Reductions Required (T/yr)	Reductions Required (% of existing load)
Projected Future Load (LDR)	7,165	1,751	24.0
Projected Future Load (COM)	7,236	1,822	25.0
Existing Load	7,302	1,888	25.9
TMDL	6,168		
WLA	137		
MOS	617		
Target Modeling Load	**5,414**		

Table ES.3 TMDL reductions for the Christians Creek Impairment.

Sediment Source Categories	Existing Load (T/yr)	Sediment Load Reductions Alternative 1 (%)	Alternative 1 (T/yr)	Alternative 2 (%)	Alternative 2 (T/yr)
LDR-PER-COR	0.003		0.003		0.003
HDR-PER-COR	0.000		0.000		0.000
COM-PER-COR	0.006		0.006		0.006
Transitional-COR	0.000		0.000		0.000
Forest-COR	1.281		1.281		1.281
Pastureland	108.771		108.771	**50**	**54.4**
Cropland	19.190		19.190	**50**	**9.6**
LDR-IMP-COR	0.021		0.021		0.021
HDR-IMP-COR	0.000		0.000		0.000
COM-IMP-COR	0.060		0.060		0.060
Channel Erosion-COR	**7,173**	**28.3**	**5,143**	**27.4**	**5,208**
NPS + Channel	7,302		5,272		5,273
WLA	137		137		137
Totals	**7,426**		**5,409**		**5,410**
Target Allocation Load (TMDL-MOS-WLA)			**5,414**		**5,414**
TMDL			6,168		6,168

Moffett Creek

The reduction required to meet the TMDL from existing conditions in Moffett Creek are given in Table ES.4. For allocation scenarios, the agricultural sub-categories for pastureland and cropland have been combined into two categories: cropland and pastureland (Table ES.5). For conditions existing in Moffett Creek, the majority of the sediment reduction must come from pastureland. Sediment reductions could be achieved through pasture improvement, better pasture management, or less intensive grazing. Two sediment reduction alternatives are presented in Table ES.5. Sediment reduction Alternative 1 requires a 66% reduction from pastureland and 40% reduction from cropland. In Alternative 2, a 70.9% reduction from pastureland is required to achieve the sediment standard established by reference watershed Mill Creek.

Table ES.4 Required sediment reductions for Moffett Creek Impairment.

Load Summary	Moffett Creek (T/yr)	Reductions Required (T/yr)	Reductions Required (% of existing load)
Existing Load	9,589	5,929	61.8
TMDL	3,864		
Target Modeling Load	**3,660**		

Table ES.5 TMDL reductions for the Moffett Creek Impairment.

Sediment Source Categories	Existing Condition (T/yr)	TMDL Sediment Load Reductions Alternative 1 (%)	Alternative 1 (T/yr)	Alternative 2 (%)	Alternative 2 (T/yr)
LDR-PER	0.381	0	0.381		0.381
HDR-PER	0.000	0	0.000		0.000
COM-PER	0.003	0	0.003		0.003
Transitional	1.174	0	1.174		1.174
Forest	177.686	0	177.686		177.686
Urban Grass	0.000	0	0.000		0.000
Pastureland	**8,385**	**66.0**	**2,850.954**	**70.9**	**2,440.081**
Cropland	**1,019**	**40.0**	**611.336**		1,018.893
LDR-IMP	0.573	0	0.573		0.573
HDR-IMP	0.000	0	0.000		0.000
COM-IMP	0.009	0	0.009		0.009
Channel Erosion	5.389	0	5.389		5.389
WLA	0.000	0	0.000		0.000
Total	**9,589**		**3,647.496**		**3,644.180**
Target Allocation Load (TMDL-MOS-WLA)			**3,660.000**		**3,660.000**

Upper Middle River

The reduction required to meet the TMDL from existing conditions in Upper Middle River is given in Table ES.6. For allocation scenarios, the agricultural sub-categories for pastureland and cropland have been combined into two categories: cropland and pastureland (Table ES.7). For this situation, the majority of the reduction must come from pastureland and cropland. Reductions could be achieved through pasture improvement, better pasture management, less intensive grazing, and minimum tillage operations. Two sediment reduction alternatives are presented in Table ES.7. Sediment reduction Alternative 1 requires a 57.5% reduction from pastureland, and a 53% reduction from cropland. In Alternative 2, a 65% reduction from pastureland is required to achieve the sediment standard established by reference watershed Hays Creek.

Table ES.6 Required sediment reductions for Upper Middle River Impairment.

Load Summary	Upper Middle River (T/yr)	Reductions Required (T/yr)	Reductions Required (% of existing load)
Existing Load	12,162	6,593	54.2
TMDL	6,316		
Target Modeling Load	**5,569**		

Table ES.7 TMDL reductions for Upper Middle River Impairment.

Sediment Source Categories	Existing Conditions (T/yr)	TMDL Sediment Load Reductions Alternative 1 (%)	Alternative 1 (T/yr)	Alternative 2 (%)	Alternative 2 (T/yr)
LDR-PER	0.737		0.737		0.737
HDR-PER	0.000		0.000		0.000
COM-PER	0.000		0.000		0.000
Transitional	188.777		188.777		188.777
Forest	173.249		173.249		173.249
Pastureland	**10,355**	**57.5**	**4,401**	**65**	**3,624**
Cropland	**1,439**	**53.0**	**676**		1,438.536
LDR-IMP	1.164		1.164		1.164
HDR-IMP	0.000		0.000		0.000
COM-PER	0.000		0.000		0.000
Channel Erosion	4.648		4.648		4.648
WLA	115.000		115.000		115.000
Totals	**12,162**		**5,560**		**5,546**
Target Allocation Load (TMDL-MOS-WLA)			**5,569**		**5,569**

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 meeting water quality standards. This report represents the culmination of that effort for the bacteria and General Standard (benthic) impairments in the Middle River and Upper South River watersheds. The second step is to develop a TMDL implementation plan. The final step is to implement the TMDL implementation plan, and to monitor stream water quality to determine if water quality standards are being attained.

Once EPA has approved a TMDL, measures must be taken to reduce pollution levels in the stream. These measures, 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 recent *Guidance Manual for Total Maximum Daily Load Implementation Plans,* published in July 2003 and available upon request from the VADEQ and VADCR TMDL project staff or at http://www.deq.state.va.us/tmdl/implans/ipguide.pdf. With successful completion of implementation plans, Virginia will be well on the way to restoring impaired waters and enhancing the value of this important resource. Additionally, development of an approved implementation plan will improve a locality's chances for obtaining financial and technical assistance during implementation.

In general, Virginia intends for the required reductions to be implemented in an iterative process that first addresses those sources with the largest impact on water quality. For example, in agricultural areas of the watershed, the most promising management practice to control bacteria and minimize streambank erosion is livestock exclusion from streams. This has been shown to be very effective in lowering bacteria concentrations in streams, both by reducing the direct cattle deposits and by providing additional riparian buffers. Reduced trampling and soil shear on streambanks by livestock has been shown to reduce bank erosion. Improved pasture management (including less intensive grazing, minimizing animal concentrations by frequent movement of winter feeding areas, and improving pasture forages) can significantly reduce soil loss from pasture areas. Reducing tillage operations, farming on the contour, strip cropping, maintaining a winter cover crop, etc. has been demonstrated as effective measure to reduce erosion from cropland agriculture. Additionally, in both urban and rural areas, reducing the human bacteria loading from failing septic systems should be a primary implementation focus because of its health implications. This component could be implemented through education on septic tank pump-outs as well as a septic system repair/replacement program and the use of alternative waste treatment systems.

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 Stage I scenarios are targeted at controllable, anthropogenic bacteria and sediment sources.

Public Participation

During development of the TMDL for the Middle River and Upper South River watersheds, public involvement was encouraged through five meetings. A basic description of the TMDL process and the agencies involved was presented at the kickoff meeting on October 29, 2002. The first public meeting was held to discuss the process for TMDL development, available data, data needs and timeline for the project. A second public meeting was held to discuss the fecal bacteria impairments, specifically the source assessment input and hydrologic calibration. The third public meeting was focused on the benthic impairments, specifically stressor identification and reference watershed selection. At the fourth public meeting sediment modeling results and allocations were presented. The fifth public meeting was held to present modeling results and allocations.

The meetings served to facilitate understanding of, and involvement in, the TMDL process. Posters that graphically illustrated the “state of the watershed” were on display at each meeting to provide an additional information component for the stakeholders. MapTech personnel were on hand to provide further clarification of the data as needed. Input from these meetings was utilized in the development of the TMDL and improved confidence in the allocation scenarios that were developed.

ACKNOWLEDGEMENTS

Bill Keeling, Virginia Department of Conservation and Recreation (VADCR)

Robert Brent, Virginia Department Environmental Quality (VADEQ), Regional Office

Tamara Keeler, Watershed Coordinator, VADCR

Dave Lazarus, VADEQ Central

Charles Martin, VADEQ Central

Jutta Schneider, VADEQ Central

Bruce Wiggins, James Madison University (JMU)

Headwaters Soil and Water Conservation District

City, Town, and County staff throughout the Middle and Upper South River Watersheds

Jurisdictions and individuals who provided data and access through their property

MapTech, Inc. of Blacksburg, Virginia, supported this study through funding provided by the Virginia Department of Conservation and Recreation contract #C199-02-735

PART I: BACKGROUND AND APPLICABLE STANDARDS

1. INTRODUCTION

1.1 Background

The need for TMDLs for the Middle and Upper South River watershed areas is based on provisions of the Clean Water Act. The document, *Guidance for Water Quality-Based Decisions: The TMDL Process* (United States Environmental Protection Agency, 1999), states:

> *According to Section 303(d) of the Clean Water Act and EPA water quality planning and management regulations, States are required to identify waters that do not meet or are not expected to meet water quality standards even after technology-based or other required controls are in place. The waterbodies are considered water quality-limited and require TMDLs.*
>
> *…A TMDL is a tool for implementing State water quality standards, and is based on the relationship between pollution sources and in-stream water quality conditions. The TMDL establishes the allowable loadings or other quantifiable parameters for a waterbody and thereby provides the basis for States to establish water quality-based controls. These controls should provide the pollution reduction necessary for a waterbody to meet water quality standards.*

The Middle and Upper South River watersheds in Virginia's Augusta County are part of the Potomac and Shenandoah River basins and include these impaired segments: Upper Middle River, Lewis Creek, Christians Creek, Moffett Creek, Polecat Draft, Lower Middle River, and South River (Figure 1.1). Lewis Creek, Christians Creek, Moffett Creek, and Polecat Draft are tributaries to Middle River. Middle River flows into North River, which joins South River to form the South Fork of the Shenandoah River. The Shenandoah River drains to the Potomac River, which flows into the Chesapeake Bay.

According to the 1996 303(d) TMDL Priority List (VADEQ 1996), Upper Middle River, Lewis Creek, Christians Creek, Moffett Creek, Polecat Draft, Lower Middle River and Upper South River are listed as impaired. VADEQ has identified all of these segments as impaired with regard to fecal coliform, and some as impaired with regard to both fecal coliform and the General Standard (benthic). All of these segments have remained on the 1998 and 2002 303(d) lists.

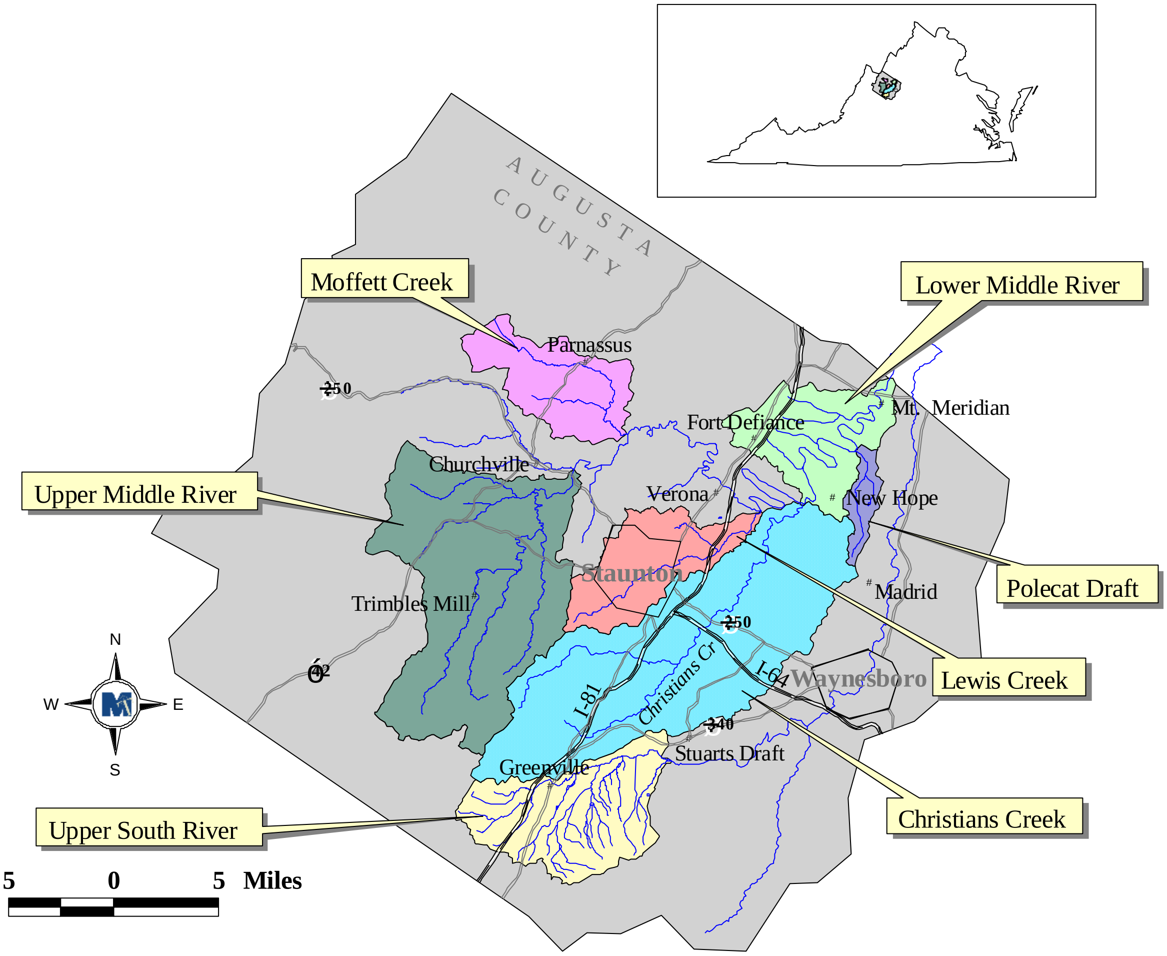

Figure 1.1 Location of impaired streams in the Middle River and Upper South River Watersheds.

The Upper Middle River (waterbody ID # VAV-B10R) was listed for fecal coliform during the 1996 assessment. During the 1998 assessment period, out of 21 samples collected at river mile 61.07, 8 violated the fecal coliform standard. During the 2002 assessment period, 6 of 13 samples taken at river mile 60.48 and 2 of 13 samples taken at river mile 61.07 violated the standard. A single benthic monitoring survey in 1995 indicated moderately impaired conditions at 2 stations in the Upper Middle River segment. The segment was over-listed for its benthic impairment by EPA in 1998, and was not sampled during the 2002 assessment. The fecal coliform impairment of the

Upper Middle River extends from the headwaters to the confluence with Jennings Branch (24.10 miles), while the benthic impairment extends only to the confluence with Eidson Creek (15.71 miles).

Lewis Creek (waterbody ID # VAV-B12R) was listed for both fecal coliform and benthic impairments. Out of 58 samples collected at river mile 2.91 during the 1998 assessment period, 36 violated the fecal coliform standard. Subsequently, during the 2002 assessment period, 25 of 58 samples violated the standard. Lewis Creek had a rating of moderately impaired during the 1998 assessment period and a rating of severely impaired during the 2002 assessment period at benthic monitoring station 1BLEW006.95. Lewis Creek is impaired beginning at the headwaters and continuing 12.06 miles downstream to its confluence with Middle River near Verona.

Christians Creek (waterbody ID # VAV-B14R) was listed for both fecal coliform and benthic impairments. A TMDL for the fecal coliform impairment has been completed and is available for review on VADEQ's web site (www.deq.state.va.us/tmdl/tmdlrpts.html). Because the biological monitoring station at the Rt. 795 bridge (1BCST007.42) indicated a moderately impaired benthic community, 31.52 stream miles were assessed as partially supporting the Clean Water Act's Aquatic Life Use Support Goal. As a result, Christians Creek was listed in the 1998 303(d) Total Maximum Daily Load Priority List and Report for violations of the General Standard (benthic). The 2002 303(d) Report on Impaired Waters showed Christians Creek as fully supporting the aquatic life use, based on several benthic assessments with "slightly impaired" scores. However, EPA will not accept a "slightly impaired" status as adequate to remove a stream from the list, and a TMDL was therefore required.

Moffett Creek (waterbody ID # VAV-B13R) was listed for both fecal coliform and benthic impairments. Out of 21 samples collected at the Rt. 42 bridge (river mile 6.24) during the 1998 assessment period, 7 violated the fecal coliform standard. During the 2002 assessment period, 6 of 23 samples violated the standard. Moffett Creek had a rating of moderately impaired during the 1998 assessment period at benthic monitoring station 1BMFT006.24. At two benthic monitoring stations (1BMFT006.20 and

1BMFT005.11), Moffett Creek had ratings of moderately impaired during the 2002 assessment period. The impaired segment of Moffett Creek extends from the confluence with Tunnel Branch 8.73 miles downstream to its confluence with Middle River.

Polecat Draft (waterbody ID # VAV-B15R) was listed for fecal coliform impairments. Out of 44 samples collected at the Rt. 776 bridge (river mile 1.03) during the 1998 assessment period, 26 violated the fecal coliform standard. During the 2002 assessment period, 35 of 54 samples violated the standard. Polecat Draft's impaired segment begins at the headwaters and continues 7.28 miles downstream to its confluence with Middle River.

Lower Middle River (waterbody ID # VAV-B15R) was listed for fecal coliform impairments. Out of 54 samples collected at the Rt. 769 bridge (river mile 1.83) during the 1998 assessment period, 10 violated the fecal coliform standard. During the 2002 assessment period, 7 of 56 samples violated the standard. Lower Middle River, beginning at Middle River's confluence with Christians Creek and continuing downstream 18.12 miles to its confluence with North River, is impaired.

Upper South River (waterbody ID # VAV-B30R) was listed for fecal coliform impairments. Out of 47 samples collected at the Rt. 671 bridge (river mile 41.68) during the 1998 assessment period, 17 violated the fecal coliform standard. During the 2002 assessment period, 13 of 55 samples violated the standard. The impaired segment of South River begins at its headwaters and continues 12.60 miles downstream to its confluence with Stony Run.

The Middle River and Upper South River watersheds (USGS Hydrologic Unit Code #02070005) are part of the Potomac and Shenandoah River basins. The land area of the affected watersheds is approximately 266,000 acres, with improved pasture and forest as the primary landuses (Figure 1.2).

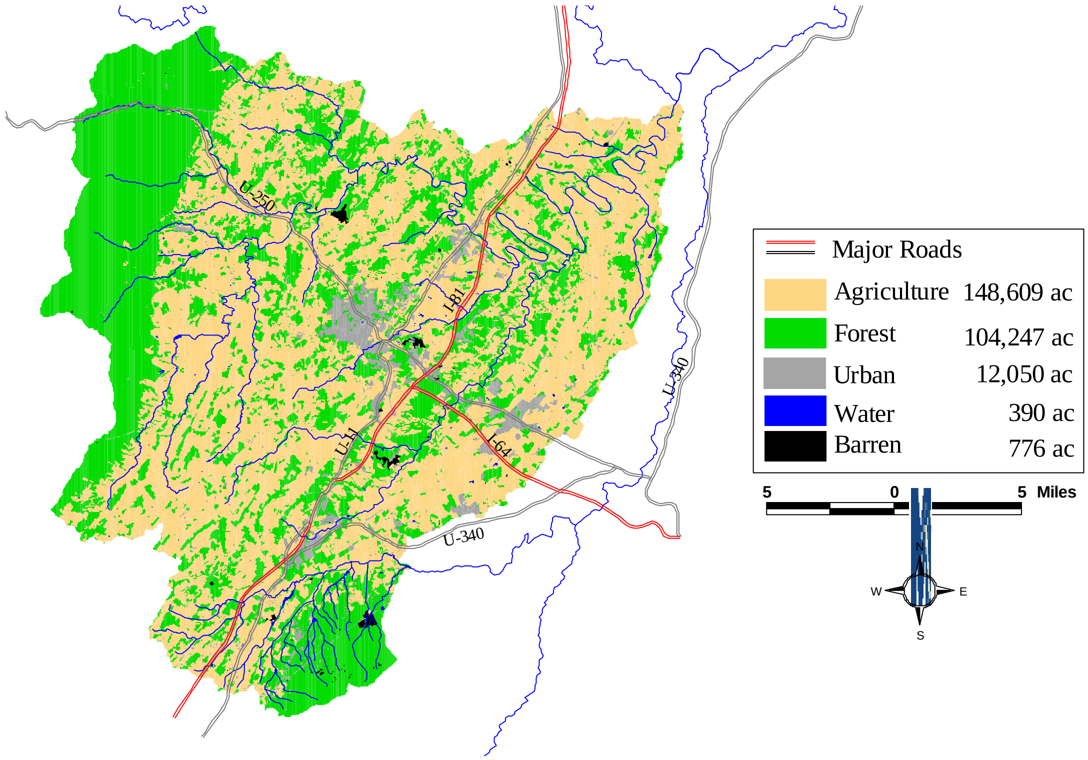

Figure 1.2 Landuses in the Middle River Watershed.

Using remotely-sensed data (specifically, Carterra imagery) consisting of 1996, 1997, and 1998 five-meter resolution panchromatic Indian Remote Sensing – 1C (IRS-1C) satellite images fused with 1997 LandSat-5 30-meter resolution color infrared satellite imagery (resulting in a twenty five-meter resolution fused color infrared image), VADCR developed a digital landuse coverage map utilizing ESRI-ArcInfo GIS software that identifies up to 32 possible landuse types. Landuse classification was done manually in ArcInfo on top of the fused twenty five-meter resolution imagery and was ground verified in the respective watersheds between 2001 and 2002. Approximate acreages and land-use proportions for each impaired segment are given in Table 1.1.

Table 1.1 Area affecting the impairment and contributing landuses.

Impaired area	Acreage	Landuse Contributions (%)			
		Agriculture	Forest	Water	Urban/Developing
Upper Middle River	49,646	63.6	17.7	10.1	8.6
Lewis Creek	17,941	54.7	24.9	0.2	20.2
Christians Creek	68,429	63.0	28.9	0.0	8.1
Moffett Creek	16,968	49.6	50	0.0	0.4
Polecat Draft	3,510	64.3	26.6	0.0	9.1
Lower Middle River	19,242	80.8	16.9	0.0	2.3
South River	26,629	43.1	52.1	0.4	4.4

The estimated human population within the drainage area is 45,558 (United States Census Bureau, 1990, 2000). Among Virginia counties, Augusta County ranks 2nd for the number of dairy cows, 2nd for the number of all cattle and calves, 1st for beef cattle, 4th for the number of horses/ponies, and 2nd for production of corn silage. Livestock, poultry, and poultry products sold were the leading source of Augusta farm income in 1997. Poultry and poultry products ranked second with 54 percent of this income (VASS 2001). Augusta County is also home to 487 species of wildlife, including 59 types of mammals (*e.g.,* beaver, raccoon, white-tailed deer) and 193 types of birds (*e.g.,* wood duck, wild turkey, Canada goose) (VDGIF, 1999).

For the period from 1948 to 2000, the Middle and South River watersheds received average annual precipitation of approximately 37.4 inches, with 56% of the precipitation occurring during the May through October growing season (SERCC, 2002). Average annual snowfall is 20.7 inches with the highest snowfall occurring during February (SERCC, 2002). Average annual daily temperature is 53 ºF. The highest average daily temperature of 84.8 ºF occurs in July, while the lowest average daily temperature of 22 ºF occurs in January (SERCC, 2002).

1.2 Applicable Water Quality Standards

According to 9 VAC 25-260-5 of Virginia's State Water Control Board *Water Quality Standards*, the term "water quality standards" means "…provisions of state or federal law which consist of a designated use or uses for the waters of the Commonwealth and water quality criteria for such waters based upon such uses. Water quality standards are to protect the public health or welfare, enhance the quality of water and serve the purposes of the State Water Control Law and the federal Clean Water Act."

As stated in Virginia state law 9 VAC 25-260-10 (Designation of uses),

> *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.*
>
> ♦
>
> *D. At a minimum, uses are deemed attainable if they can be achieved by the imposition of effluent limits required under §§301(b) and 306 of the Clean Water Act and cost-effective and reasonable best management practices for nonpoint source control.*

Because this study addresses both fecal coliform and benthic impairments, two water quality criteria are applicable. 9 VAC 25-260-170 applies to the fecal coliform impairment, whereas the General Standard section (9 VAC25-260-20) applies to the benthic impairment.

1.3 Applicable Criteria for Fecal Coliform Impairment

Prior to 2002, Virginia Water Quality Standards specified the following criteria for a non-shellfish supporting waterbody to be in compliance with Virginia's fecal standard for contact recreational use:

> *A. General requirements. In all surface waters, except shellfish waters and certain waters addressed in subsection B of this section, the fecal coliform bacteria shall not exceed a geometric mean of 200 fecal coliform bacteria per 100 ml of water for two or more samples over a 30-day period, or a fecal coliform bacteria level of 1,000 per 100 ml at any time.*

If the waterbody exceeded either criterion more than 10% of the time, the waterbody was classified as impaired and the development and implementation of a TMDL was indicated in order to bring the waterbody into compliance with the water quality criterion. Based on the sampling frequency, only one criterion was applied to a particular datum or data set. If the sampling frequency was one sample or less per 30 days, the instantaneous criterion was applied; for a higher sampling frequency, the geometric criterion was applied. This was the criterion used for listing the impairments included in this study. Sufficient fecal coliform bacteria standard violations were recorded at VADEQ water quality monitoring stations to indicate that the recreational use designations are not being supported.

EPA subsequently recommended that all states adopt an *Escherichia coli* (*E. coli*) or *enterococci* standard for fresh water and *enterococci* criteria for marine waters by 2003. EPA is pursuing the states' adoption of these standards because there is a stronger correlation between the concentration of these organisms (*E. coli* and *enterococci*) and the incidence of gastrointestinal illness than with fecal coliform. *E. coli* and *enterococci* are both bacteria that can be found in the intestinal tract of primarily warm-blooded animals. *E. coli* is a species of bacteria included in the broader fecal coliform category. Like fecal coliform bacteria, these organisms indicate the presence of fecal contamination. The adoption of the *E. coli* and *enterococci* standard is now in effect in Virginia as of January 15, 2003.

The new criteria, outlined in 9 VAC 25-260-170, read as follows

> *A. In surface waters, except shellfish waters and certain waters identified in subsection B of this section, the following criteria shall apply to protect primary contact recreational uses:*
>
> *1. Fecal coliform bacteria shall not exceed a geometric mean of 200 fecal coliform bacteria per 100 ml of water for two or more samples over a calendar month nor shall more than 10% of the total samples taken during any calendar month exceed 400 fecal coliform bacteria per 100 ml of water. This criterion shall not apply for a sampling station after the bacterial indicators described in subdivision 2 of this subsection have a minimum of 12 data points or after June 30, 2008, whichever comes first.*
>
> *2. E. coli and enterococci bacteria per 100 ml of water shall not exceed the following:*

	Geometric Mean[1]	*Single Sample Maximum*[2]
Freshwater[3]		
E. coli	*126*	*235*

Saltwater and Transition Zone[3]		
enterococci	*35*	*104*

[1] For two or more samples taken during any calendar month.
[2] No single sample maximum for *enterococc*i and *E. coli* shall exceed a 75% upper one-sided confidence limit based on a site-specific log standard deviation. If site data are insufficient to establish a site-specific log standard deviation, then 0.4 shall be used as the log standard deviation in freshwater and 0.7 shall be as the log standard deviation in saltwater and transition zone. Values shown are based on a log standard deviation of 0.4 in freshwater and 0.7 in saltwater.
[3] See 9 VAC 25-260-140 C for freshwater and transition zone delineation.

The *E. coli* criteria were used in developing the bacteria TMDLs included in this study.

1.4 Applicable Criterion for Benthic Impairment

The **General Standard,** as defined in Virginia state law 9 VAC25-260-20, states:

> *A. All state waters, including wetlands, shall be free from substances attributable to sewage, industrial waste, or other waste in concentrations, amounts, or combinations which contravene established standards or interfere directly or indirectly with designated uses of such water or which are inimical or harmful to human, animal, plant, or aquatic life.*

The General Standard is implemented by VADEQ through application of the Rapid Bioassessment Protocol II (RBP). Using the RBP, the health of the benthic macroinvertebrate community is typically assessed through measurement of 8 biometrics (Table 1.2) that evaluate different aspects of the community's overall health. Surveys of the benthic macroinvertebrate community performed by VADEQ are assessed at the family taxonomic level.

Each biometric measured at a target station is compared to the same biometric measured at a reference (non-impaired) station to determine each biometric score. These scores are then summed and used to determine the overall bioassessment (*e.g.*, non-impaired, slightly impaired, moderately impaired, or severely impaired).

Table 1.2 Components of the RBP Assessment.

Biometric	Benthic Health [1]
Taxa Richness	↑
Modified Family Biotic Index	↓
Scraper to Filtering Collector Ratio	↑
EPT / Chironomid Ratio	↑
% Contribution of Dominant Family	↓
EPT Index	↑
Community Loss Index	↓
Shredder to Total Ratio	↑

[1] An upward arrow indicates a positive response in benthic health when the associated biometric increases.

PART II: FECAL BACTERIA TMDLS

2. TMDL ENDPOINT AND WATER QUALITY ASSESSMENT

2.1 Selection of a TMDL Endpoint and Critical Condition

Upper Middle River, Lewis Creek, Moffett Creek, Polecat Draft, Lower Middle River and Upper South River were initially placed on the Virginia 1996 303(d) TMDL Priority List based on monitoring performed by VADEQ. All of these segments have remained on the 1998 and 2002 303(d) lists. Elevated levels of fecal coliform bacteria recorded at VADEQ ambient water quality monitoring stations showed that these stream segments do not support the primary contact recreation use designation.

The first step in developing a TMDL is the establishment of in-stream numeric endpoints, which are used to evaluate the attainment of acceptable water quality. In-stream numeric endpoints, therefore, represent the water quality goals that are to be achieved by implementing the load reductions specified in the TMDL. For the Middle and South Rivers TMDLs, the applicable endpoints and associated target values can be determined directly from the Virginia water quality regulations (Section 1.2 of this document). In order to remove a water body from a state’s list of impaired waters, the Clean Water Act requires compliance with that state's water quality standard. The in-stream *E. coli* targets for these TMDLs were a calendar month geometric mean not exceeding 126 cfu/100 ml and a single sample not exceeding 235 cfu/100 ml.

EPA regulations at 40 CFR 130.7 (c)(1) require TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters. The intent of this requirement is to ensure that the water quality of streams is protected during times when it is most vulnerable.

Critical conditions are important because they describe the factors that combine to cause a violation of water quality standards and help in identifying the actions that may have to be undertaken to meet water quality standards. Fecal coliform sources within the Middle and South River watersheds are attributed to both point and nonpoint sources. Critical conditions for waters impacted by land-based nonpoint sources generally occur during periods of wet weather and high surface runoff. In contrast, critical conditions for point source-dominated systems generally occur during low flow and low dilution conditions. Point sources, in this context also, include nonpoint sources that are not precipitation driven (*e.g.*, direct fecal deposition to stream).

In order to assess the existence of a critical flow regime, data from all stations in Middle River were considered (Figure 2.1 through Figure 2.7), as the hydrologic model was calibrated at the outlet. While violations at some stations (*i.e.*, 1BMDL060.48, 1BMDL061.48, and 1BMFT006.20) appear to be associated with low-flow conditions, and violations at other stations (*i.e.*, 1BMDL001.83 and 1BMDL036.08) appear to be associated with high-flow conditions, high concentrations of fecal coliform were recorded in all flow regimes when considering all of the stations. Similarly, data collected from South River (*i.e.*, 1BSTH041.68) indicated that violations were recorded in all flow regimes. Based on this assessment, a period for calibration and validation (Section 4.5) was chosen based on the overall distribution of wet and dry seasons.

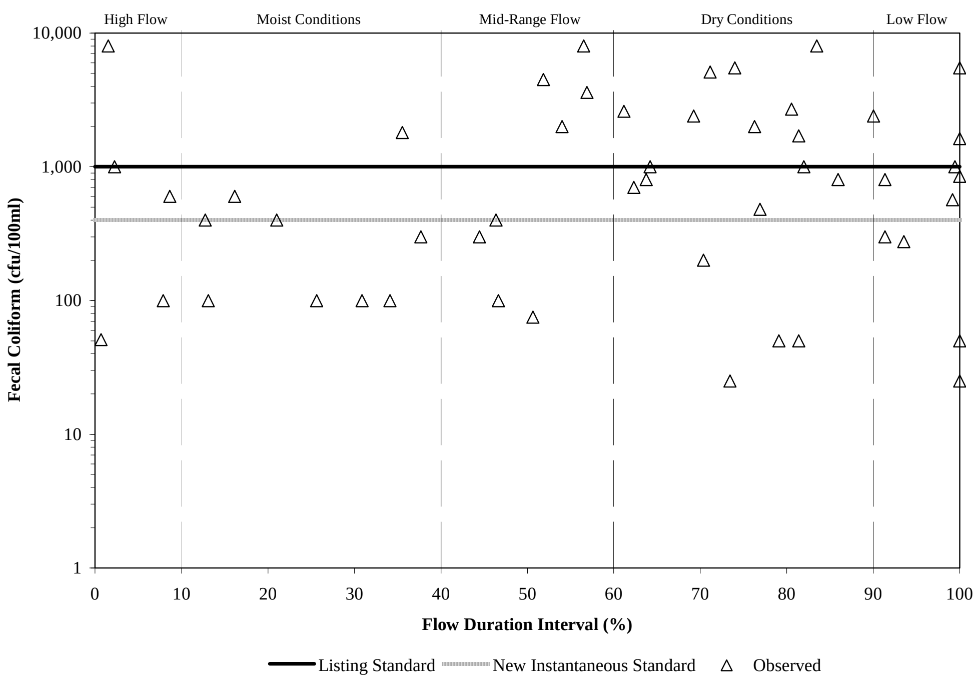

Figure 2.1 Relationship between fecal coliform concentrations and flow duration interval in the Upper Middle River Impairment. (VADEQ Stations 1BMDL060.48 and 1BMDL061.48).

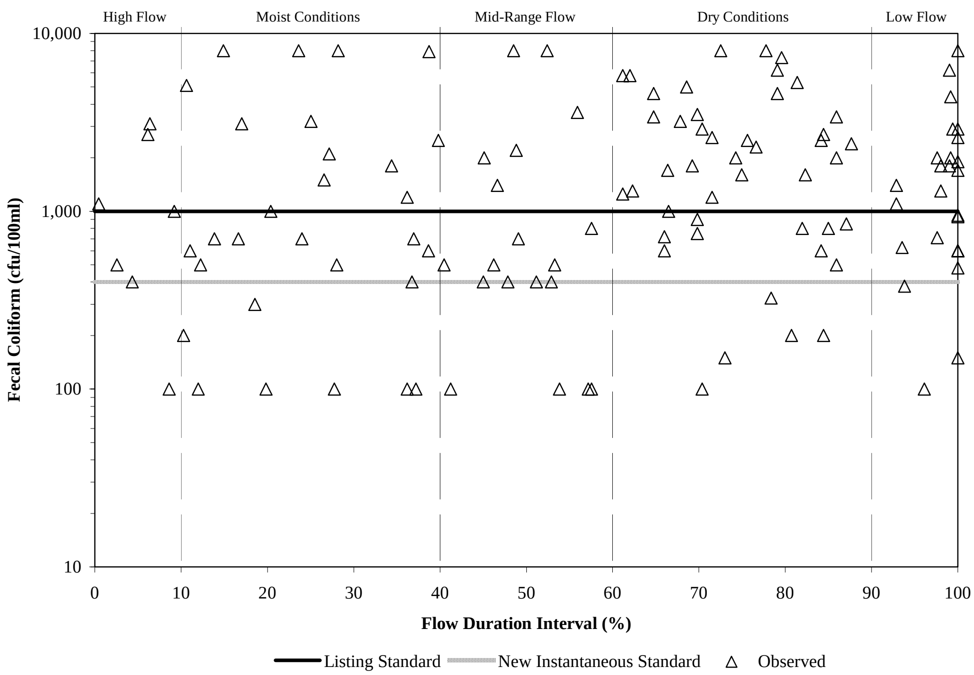

Figure 2.2 Relationship between fecal coliform concentrations and flow duration interval in the Lewis Creek impairment (1BLEW002.91).

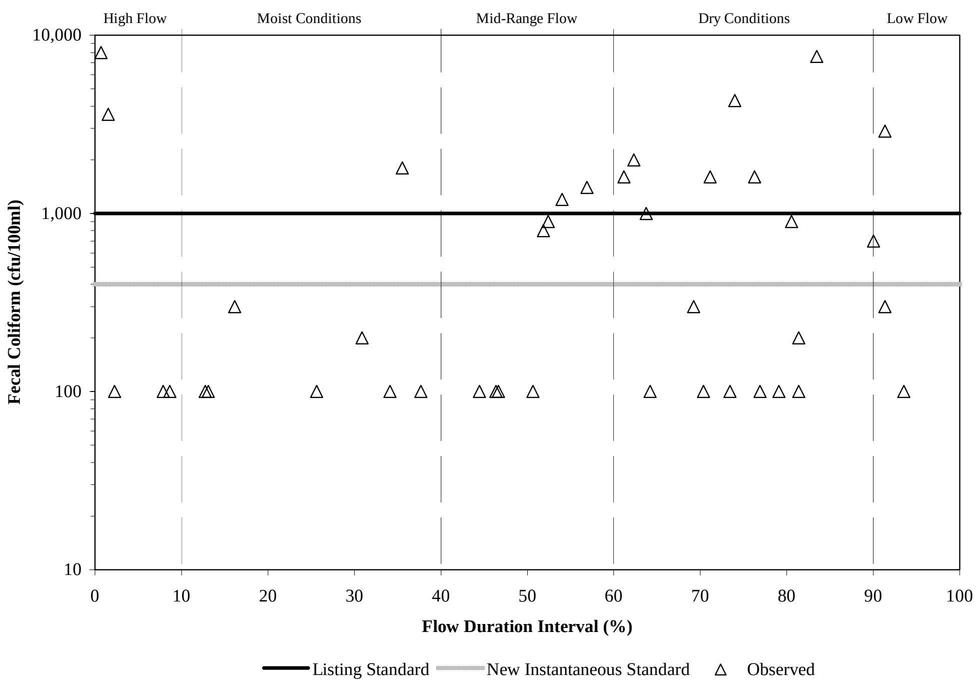

Figure 2.3 Relationship between fecal coliform concentrations and flow duration interval in the Moffett Creek impairment (VADEQ station 1BMFT006.20).

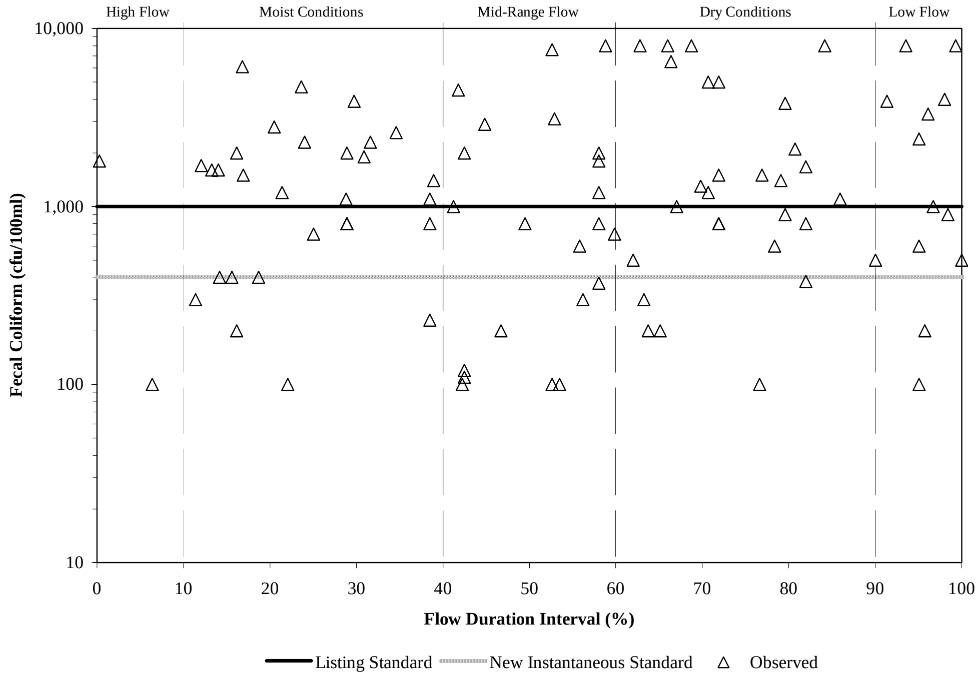

Figure 2.4 Relationship between fecal coliform concentrations and flow duration interval in the Polecat Draft impairment (VADEQ Station 1BPCD001.03).

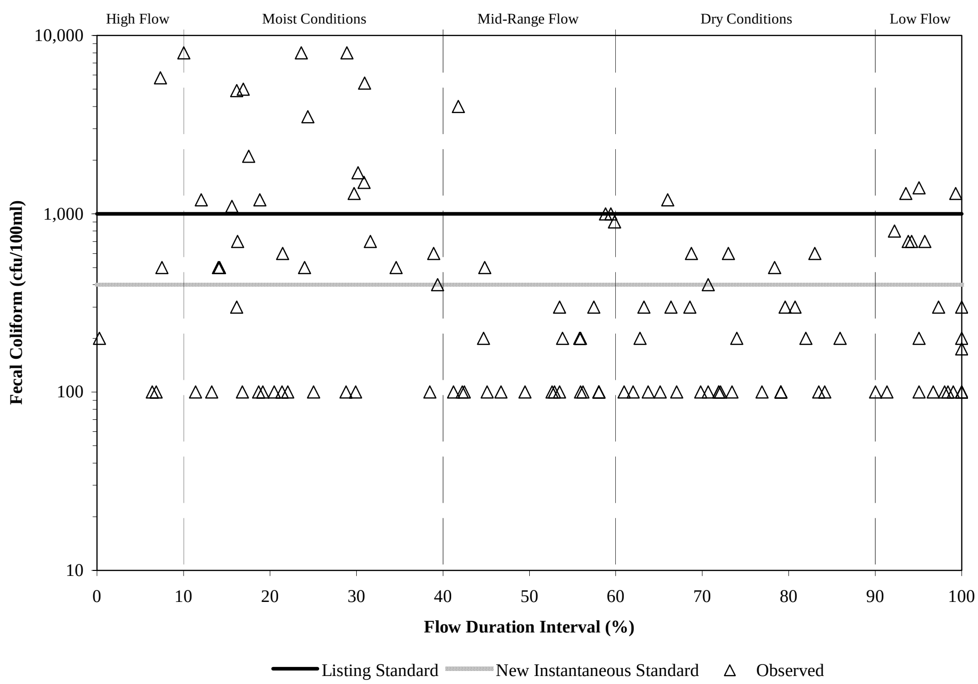

Figure 2.5 Relationship between fecal coliform concentrations and flow duration interval in the Lower Middle River impairment (VADEQ Station 1BMDL001.83).

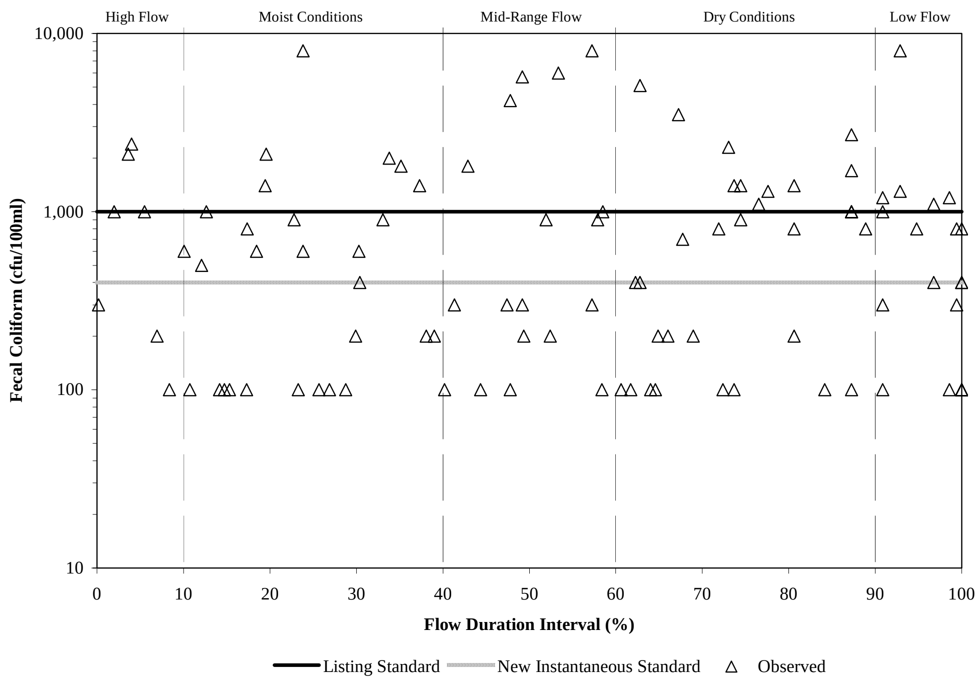

Figure 2.6 **Relationship between fecal coliform concentrations and flow duration interval in the South River impairment (VADEQ Station 1BSTH041.68).**

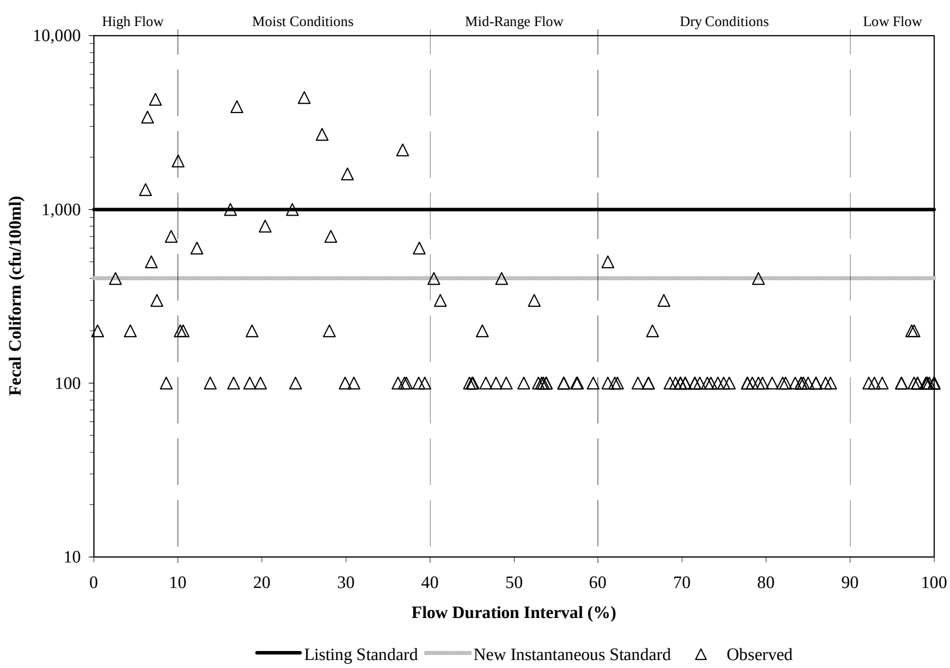

Figure 2.7 **Relationship between fecal coliform concentrations and flow duration interval in the non-impaired section of Middle River (VADEQ Station 1BMDL036.08).**

2.2 Discussion of In-stream Water Quality

This section provides an inventory and analysis of available observed in-stream fecal coliform monitoring data throughout the Middle River and Upper South River watersheds. An examination of all data available for the entire study area was analyzed. Sources of data and pertinent results are discussed.

2.2.1 Inventory of Water Quality Monitoring Data

The primary sources of available water quality information are:

- 19 VADEQ in-stream monitoring stations located in the Middle and Upper South River watersheds;
- water quality monitoring conducted by James Madison University (JMU) as part of the services contracted for this TMDL;
- water quality monitoring performed by the City of Staunton to assess the city's impact on fecal coliform levels; and
- monitoring conducted by the Izaak Walton League in cooperation with Virginia Department of Game and Inland Fisheries (VDGIF).

2.2.1.1 Water Quality Monitoring Conducted by VADEQ

Data from in-stream fecal coliform samples, collected by VADEQ within the study area are available from April 1973 through June 2001 (Figure 2.8) and are included in the analysis. Samples were taken for the express purpose of determining compliance with the state instantaneous standard limiting concentrations to less than 1,000 cfu/100 ml. Therefore, as a matter of economy, the vast majority of samples showing fecal coliform concentrations below 100 cfu/100 ml or in excess of 8,000 cfu/100 ml were not further analyzed to determine the precise concentration of fecal coliform bacteria. The result is that reported concentrations of 100 cfu/100 ml most likely represent concentrations below 100 cfu/100 ml, and reported concentrations of 8,000 cfu/100 ml most likely represent concentrations in excess of this value. Table 2.1 summarizes the fecal coliform samples collected at the in-stream monitoring stations.

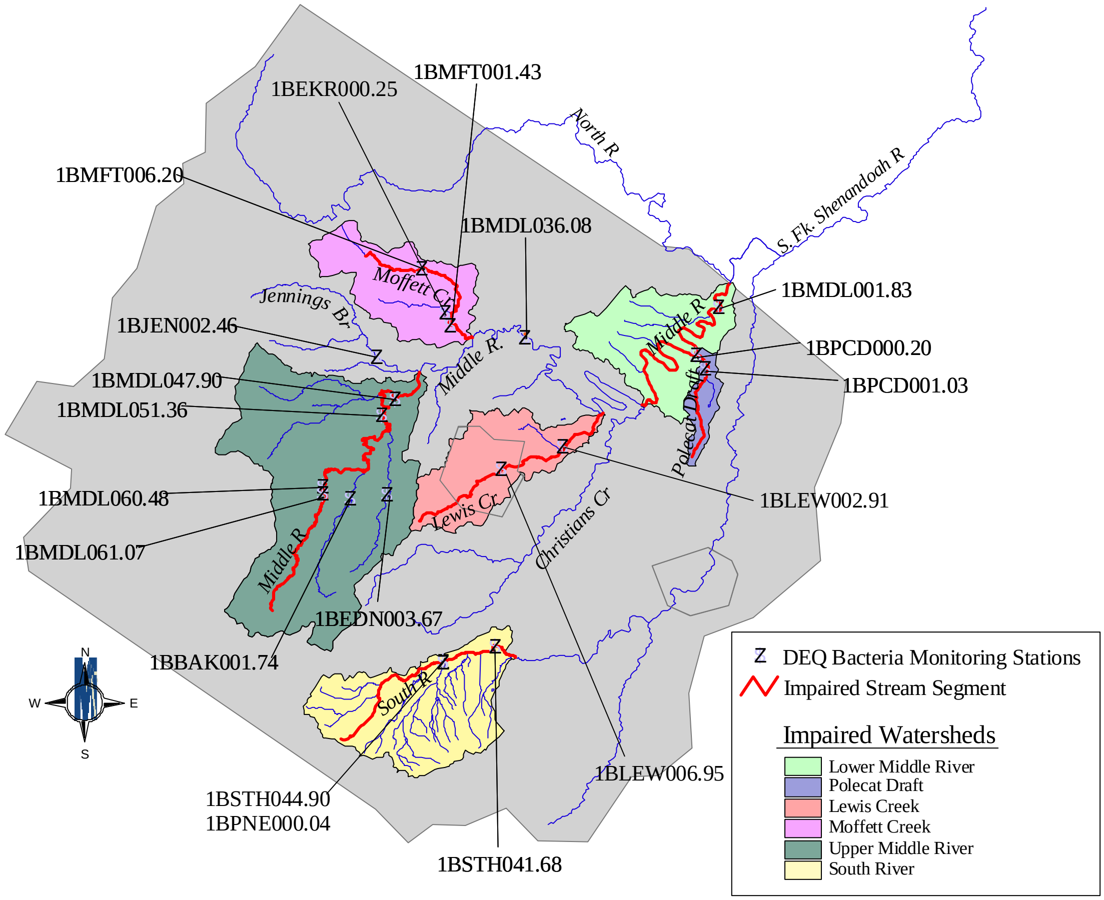

Figure 2.8 Location of VADEQ water quality monitoring stations in the Middle River watershed.

Table 2.1 Summary of fecal coliform monitoring conducted by VADEQ for period April 1973 through June 2001.

Impairment	VADEQ Station	Count (#)	Minimum (cfu/100ml)	Maximum (cfu/100ml)	Mean (cfu/100ml)	Median (cfu/100ml)	Violations[1] %	Violations[2] %
Back Creek	1BBAK001.74	9	100	3,800	944	500	22	56
Eidson Creek	1BEDN003.67	7	100	3,900	1,471	600	43	71
Elk Run	1BEKR000.25	7	100	1,700	371	200	14	14
Jennings Branch	1BJEN002.46	39	100	800	154	100	0	5
Lewis Creek	1BLEW002.91	143	90	8,000	1,893	900	46	78
Lewis Creek	1BLEW006.95	2	1,000	2,000	1,500	1,500	50	100
Middle River	1BMDL001.83	119	100	8,000	783	200	17	34
Middle River	1BMDL036.08	129	100	4,400	358	100	7	14
Middle River	1BMDL047.90	7	100	500	157	100	0	14
Middle River	1BMDL051.36	37	25	2500	266	100	8	8
Middle River	1BMDL060.48	23	25	8,000	1,573	568	35	57
Middle River	1BMDL061.07	28	51	8,000	1,605	800	32	61
Moffett Creek	1BMFT001.43	7	100	1,600	343	100	14	14
Moffett Creek	1BMFT006.20	41	100	8,000	1,100	200	29	41
Polecat Draft	1BPCD000.20	6	100	5400	2483	1650	83	83
Polecat Draft	1BPCD001.03	94	100	8,000	2,035	1,150	53	76
Pine Run	1BPNE000.04	7	100	1,100	257	100	14	14
South River	1BSTH041.68	103	100	8,000	1,083	600	27	51
South River	1BSTH044.90	7	100	600	257	200	0	29

[1] Violations are based on the pre-2003 fecal coliform instantaneous standard (*i.e.*, 1,000 cfu/100ml)
[2] Violations are based on the interim fecal coliform instantaneous standard (*i.e.*, 400 cfu/100ml)

2.2.1.2 Water Quality Monitoring Conducted by James Madison University.

Water quality samples were taken at 20 sites throughout the Middle and Upper South River watersheds over a twelve month period (Figure 2.9). A total of 216 stream samples were collected. All samples were analyzed for fecal coliform, *E. coli*, and *enterococci* concentrations. Additionally, samples were analyzed for fecal type. Table 2.2 summarizes the fecal coliform concentration data collected by JMU at the ambient stations.

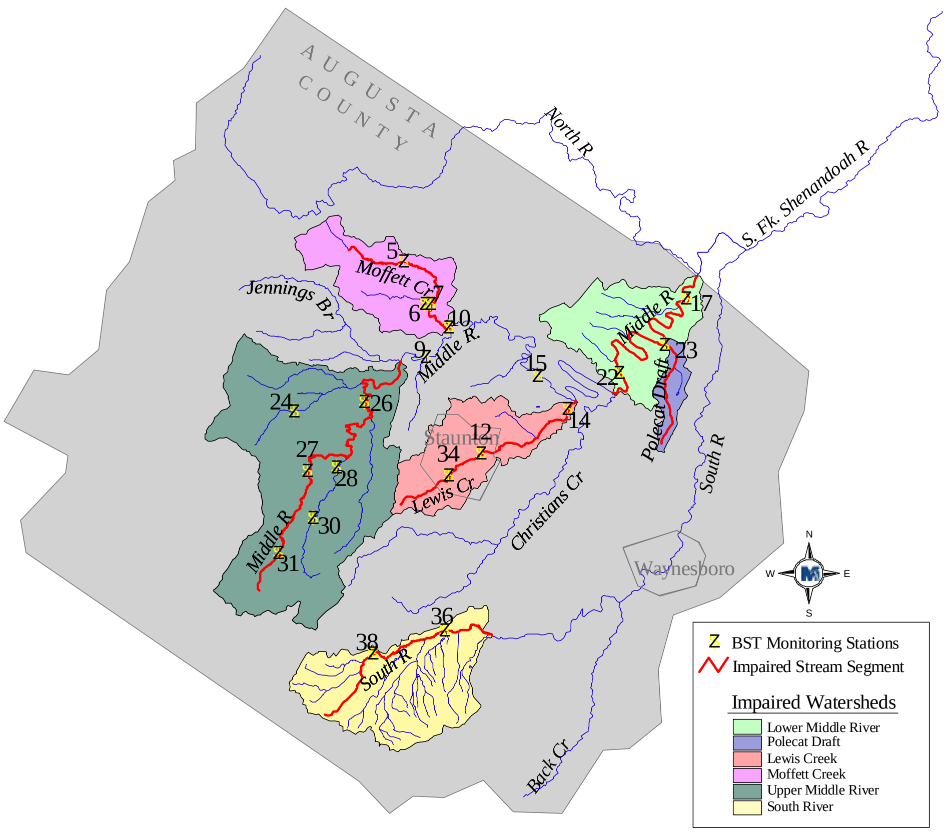

Figure 2.9 Location of JMU water quality monitoring stations in the Middle River watershed.

Table 2.2 Summary of water quality sampling conducted by James Madison University. Fecal coliform concentrations (cfu/100 ml).

Site	Count (#)	Minimum (cfu/100ml)	Maximum (cfu/100ml)	Mean (cfu/100ml)	Median (cfu/100ml)
Moffett Creek (HU B13)					
5 @ Route 42	9	3	3,600	658	210
6 Elk Run @ Route 835	12	3	3,100	570	348
7 @ Route 733	12	20	1,650	472	192
10@ Route 732	11	7	3,550	694	303
Upper Middle River (HU B10)					
31 @ Route 602	12	78	11,750	2,310	846
27 @ Route 705	12	35	4,900	1,076	402
30 Back Creek @ Route 841	12	22	2,100	662	379
28 Back Creek @ Route 707	8	43	8,350	2,150	1,028
26 @ Route 720	11	0	1,300	409	115
24 Buffalo Branch @ Route 703	12	1	172	28	13
Middle Middle River (HU B12)					
9 @ Route 732	11	0	2,605	386	170
15 @ Route 11	12	0	667	165	37
Lewis Creek (HU B12)					
34 @ Route 252	9	15	2,600	639	195
12 @ Route 254	12	242	24,000	4,158	1,083
14 @ Route 612	11	62	3,300	694	390
Lower Middle River (HU B15)					
22 @ Route 16	12	7	10,000	1,232	129
23 Polecat Draft @ Route 608	8	0	1,095	497	535
17 @ Route 769	11	5	4,900	663	130
Upper South River (HU B30)					
38 @ Route 662	12	45	10,750	1,769	440
36 @ Route 652	11	30	2,115	570	395

2.2.1.3 Water Quality Monitoring Conducted by the City of Staunton

The city of Staunton performed water quality monitoring in the Lewis Creek watershed in order to assess the city's impact on fecal coliform levels. Although the analysis was not conducted under a VADEQ approved Quality Assurance Project Plan (QAPP), and therefore cannot be used for quantitative assessment, the data are presented here for use as a qualitative record of fecal coliform levels in this area.

Monitoring locations were selected to determine if any fecal coliform is present coming into the City of Staunton. The City sampled at 35 different locations. These sites were used to narrow locations where spikes in fecal coliform counts occurred. Ten sites were chosen for monthly monitoring. Monitoring at these sites was started in October 1998 and continues to be done monthly. The location of sampling stations is shown in Figure 2.10, and the results of the analysis are shown in Table 2.3.

The sampling performed by the city revealed problems with the sewer system, and helped in targeting repair efforts. It is evident that there are still fecal coliform problems in the Lewis Creek watershed, as most of the sampling was performed after repairs to the sewer line were made, and fecal coliform concentrations continue to exceed the standard.

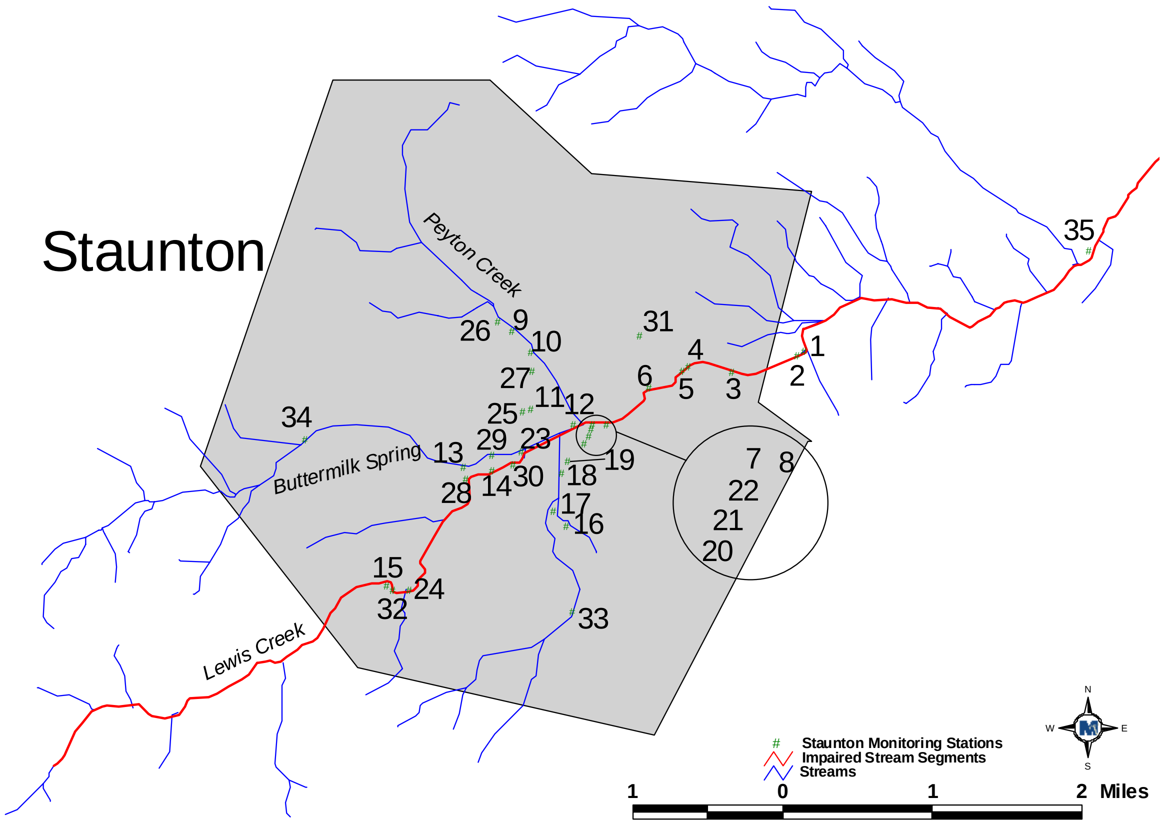

Figure 2.10 Location of stations monitored during a Water Quality Study conducted by the City of Staunton.

Table 2.3 Summary of water quality sampling conducted by the City of Staunton.

Impairment	Station	Count (#)	Minimum (cfu/100ml)	Maximum (cfu/100ml)	Mean (cfu/100ml)	Median (cfu/100ml)
Lewis Creek	1	54	9	26,900	2,015	535
Lewis Creek	2	4	190	20,900	6,768	2,990
Lewis Creek	3	1	20,000	20,000	20,000	20,000
Lewis Creek	4	5	320	20,000	6,964	4,000
Lewis Creek	5	5	70	20,000	5,362	1,380
Lewis Creek	6	2	4,500	5,900	5,200	5,200
Lewis Creek	7	52	150	20,000	4,053	1,990
Lewis Creek	8	5	600	21,500	7,340	5,000
Lewis Creek	9	3	320	6,100	2,623	1,450
Lewis Creek	10	5	260	20,000	7,372	5,300
Lewis Creek	11	58	390	20,000	4,911	3,400
Lewis Creek	12	4	780	19,000	6,645	3,400
Lewis Creek	13	7	200	20,000	3,559	600
Lewis Creek	14	6	1,670	20,000	6,845	4,800
Lewis Creek	15	55	5	8,600	787	320
Lewis Creek	16	1	1,143	1,143	1,143	1,143
Lewis Creek	17	3	100	4,000	1,749	1,147
Lewis Creek	18	3	70	3,600	1,323	300
Lewis Creek	19	3	900	2,600	1,533	1,100
Lewis Creek	20	3	1,800	3,000	2,331	2,193
Lewis Creek	21	1	2,100	2,100	2,100	2,100
Lewis Creek	22	5	2,800	7,200	5,020	4,600
Lewis Creek	23	7	730	7,900	4,287	2,900
Lewis Creek	24	6	380	20,000	8,170	4,800
Lewis Creek	25	3	800	1,733	1,211	1,100
Lewis Creek	26	53	12	6,100	566	208
Lewis Creek	27	5	1,000	20,000	7,320	3,400
Lewis Creek	28	4	1,335	20,000	9,164	7,660
Lewis Creek	29	59	1	21,600	2,862	578
Lewis Creek	30	3	450	1,330	863	810
Lewis Creek	31	1	1,180	1,180	1,180	1,180
Lewis Creek	32	3	820	10,100	4,030	1,170
Lewis Creek	33	1	3,100	3,100	3,100	3,100
Lewis Creek	34	49	2	2,900	421	98
Lewis Creek	35	49	3	20,400	1,166	256

2.2.1.4 Water Quality Monitoring Conducted by the Izaak Walton League

The Izaak Walton League, in conjunction with VDGIF, conducted monitoring of streams throughout Augusta County to assess levels of fecal bacteria. As with the city of Staunton data, the monitoring was conducted without a VADEQ approved QAPP. The data are presented here as a qualitative record of fecal bacterial levels in the study area. The location of sampling stations is shown in Figure 2.11, and the results of the analysis are shown in Table 2.4.

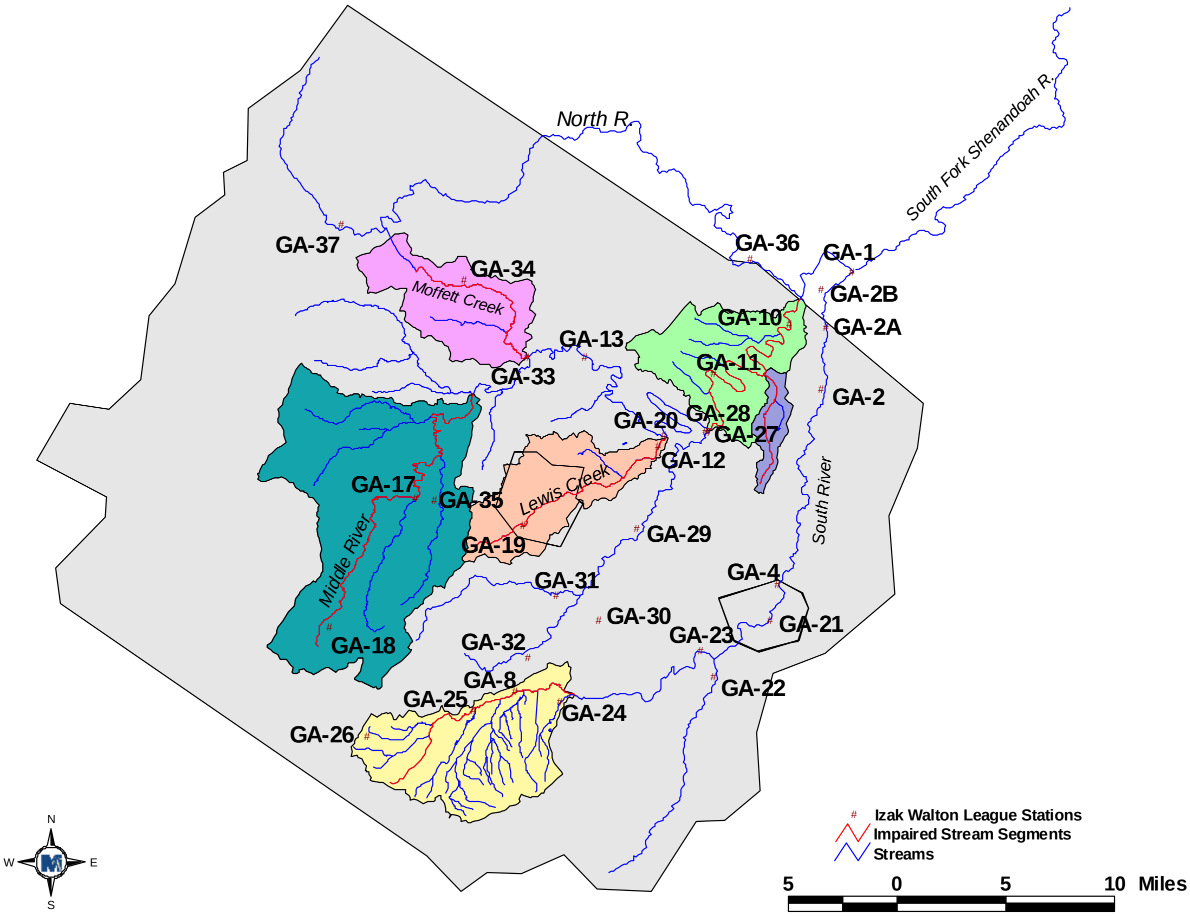

Figure 2.11 Location of stations monitored by the Izaak Walton League.

Table 2.4 Summary of fecal coliform monitoring conducted by the Izaak Walton League.

Impairment	Station	Count (#)	Minimum (cfu/100ml)	Maximum (cfu/100ml)	Mean (cfu/100ml)	Median (cfu/100ml)
South River	GA-1	6	20	300	170	180
South River	GA-2	6	20	300	180	200
South River	GA-2A	6	70	1,700	497	300
South River	GA-2B	6	80	800	277	175
South River	GA-4	6	20	1,300	357	200
South River	GA-8	6	500	2,200	1,200	1,200
South River	GA-23	6	70	500	233	130
Jones Hollow	GA-21	6	80	16,000	5,047	2,350
Back Creek	GA-22	5	70	2,400	670	300
Stony Run	GA-24	4	40	2,800	890	360
Poor Creek	GA-25	6	40	500	195	80
Broadhead Creek	GA-26	6	20	3,000	1,133	650
Christians Creek	GA-32	6	500	16,000	5,300	2,700
Christians Creek	GA-29	6	40	1,300	553	400
Christians Creek	GA-28	6	40	2,200	502	100
Lewis Creek	GA-19	6	300	2,200	967	700
Lewis Creek	GA-20	6	130	5,000	3,305	4,000
Middle River	GA-10	6	110	300	192	190
Middle River	GA-11	6	40	800	270	105
Middle River	GA-12	6	80	500	313	285
Middle River	GA-13	5	40	300	137	80
Middle River	GA-17	6	800	16,000	6,143	2,400
Middle River	GA-18	6	230	16,000	230	2,250
Meadow Run	GA-27	6	20	500	200	150
Moffett Creek	GA-33	5	70	3,000	230	800
Barterbrook Branch	GA-30	7	800	16,000	5,367	4,000
Folly Mills Creek	GA-31	6	230	9,000	2,888	1,200
Eidson Creek	GA-35	7	500	16,000	5,214	1,100
Jennings Branch	GA-34	6	20	3,000	1,003	235
North River	GA-36	6	230	5,000	1,255	500
North River	GA-37	7	20	230	90	20

2.2.2 Analysis of Monitoring Data

A wide range of fecal coliform concentrations have been recorded in the watershed. The data collected by VADEQ were analyzed for frequency of violations, patterns in fecal source identification, and seasonal impacts. Results of the analyses are presented in the following sections.

2.2.2.1 Summary of Frequency of Violations at the Monitoring Stations

All water quality data were collected at least monthly. The former state standard of 1,000 cfu/100 ml and the interim standard of 400 cfu/100ml were used to test for violations.

All stations show some level of violations when compared to the interim standard. Only two stations (*i.e.*, 1BJEN002.46 and 1BMDL051.36) had less than 10 % violations when compared to the interim standard. A distribution of fecal coliform concentrations at each sampling station in the watershed can be found in Appendix A.

2.2.2.2 Bacterial Source Tracking

James Madison University was contracted by VADCR to do in-stream sampling and analysis of fecal coliform concentrations as well as bacterial source tracking (BST). BST is intended to aid in identifying sources (*i.e.*, human, pet, livestock, or wildlife) of fecal contamination in water bodies. While the short available time-frame and the small number of observations taken in this case made drawing conclusions difficult, the data collected provided insight into likely sources of fecal contamination, aided in distributing fecal loads from different sources during model calibration, and should improve the chances for success in implementing the appropriate control measures.

Several BST methods are currently under development. For this project, the Antibiotic Resistance Analysis (ARA) method was used to indicate the potential sources of fecal contamination in streams. This method was selected because it has been demonstrated to be a reliable procedure for indicating the presence of human, livestock, and wildlife sources in watersheds in Virginia. The results of sampling were reported as the percentage of isolates acquired from the sample. These isolates were identified as originating from human, livestock, or wildlife sources.

The results show some general patterns across the stations, as well as some station-specific patterns. In general, domestic animals (*e.g.*, livestock) appear to be the major contributors of fecal bacteria to the stream, followed by wildlife and human sources. However, in samples collected from Lewis Creek (*i.e.*, stations 12 and 34), there is a significant and consistent contribution from human sources. A similar situation is evident in sampling from Back Creek (*i.e.*, station 28) in the Upper Middle River watershed. The statistical significance was determined through two tests. The first was based on the sample size. A z-test was used to determine if the proportion was significantly different from zero (alpha = 0.10). Second, the rate of false positives was calculated for each source category in each library, and a proportion was not considered significantly different from zero unless it was greater than the false-positive rate plus three standard deviations.

2.2.2.3 Trend and Seasonal Analyses

In order to improve TMDL allocation scenarios and, therefore, the success of implementation strategies, trend and seasonal analyses were performed on precipitation, discharge, and fecal coliform concentrations. A Seasonal Kendall Test was used to examine long-term trends. The Seasonal Kendall Test ignores seasonal cycles when looking for long-term trends. This improves the chances of finding existing trends in data that are likely to have seasonal patterns. Additionally, trends for specific seasons can be analyzed. For instance, the Seasonal Kendall Test can identify the trend (over many years) in discharge levels during a particular season or month.

A seasonal analysis of precipitation, discharge, and fecal coliform concentration data was conducted using the Mood Median Test. This test was used to compare median values of precipitation, discharge, and fecal coliform concentrations in each month. Significant differences between months within years were reported.

2.2.2.4 Precipitation

Total monthly precipitation measured at Station #448062 in Augusta County, Virginia from January 1980 to January 2003 was analyzed, and no overall, long-term trend was found. Differences in mean monthly precipitation at station #448062 are indicated in Table 2.5. Precipitations in months with a different median group letter are significantly different from each other at the 95% significance level. For example, February is in median group "A", while May and July are in median group "B"; therefore precipitation in February is significantly different than the amount of precipitation in May and July. Precipitation values in months that fall into multiple median groups are not significantly different from any of the groups that those months are classified under. For example, January is in both median group "A" and median group "B"; therefore, precipitation in January is not significantly different than precipitation in months that fall into either median group "A" or median group "B". In general, precipitation in the spring to summer months tends to be higher than precipitation in the fall to winter months.

2.2.2.5 Discharge

Total monthly flow measured at Station #01625000 in Rockingham County, Virginia (Middle River at Grottoes) from January 1970 to December 2000, was analyzed and no overall, long-term trend was found. Differences in mean monthly flow at Station #01625000 (Middle River at Grottoes) are indicated in Table 2.6. Flows in months with the same median group letter are not significantly different from each other at the 95% significance level. For example, September, October, and November are all in median group "A"; therefore September, October, and November are not significantly different from each other. In general, flow in the winter to spring months tends to be higher than flow in the summer to fall months.

Table 2.5 Summary of the Mood Median Test on mean monthly precipitation at Station 448062.

Month	Mean (in)	Minimum (in)	Maximum (in)	Median Groups	
January	2.78	0.12	7.21	A	B
February	2.42	0.23	10.37	A	
March	3.16	0.73	7.57	A	B
April	2.92	0.93	8.68	A	B
May	3.71	1.42	8.21		B
June	3.44	0.76	13.40	A	B
July	3.77	1.27	8.94		B
August	3.45	0.57	9.24	A	B
September	3.66	0.04	12.82	A	B
October	3.44	0.02	9.65	A	B
November	2.99	0.24	11.85	A	B
December	2.54	0.31	6.28	A	B

Table 2.6 Summary of the Mood Median Test on mean monthly flow at USGS Station 01625000.

Month	Mean (cfs)	Minimum (cfs)	Maximum (cfs)	Median Groups			
January	475.63	66.94	1,435.58			C	D
February	532.65	118.32	2,287.86			C	D
March	634.04	106.48	1,595.58				D
April	497.88	95.83	1,674.27			C	D
May	383.74	124.61	962.97			C	D
June	293.45	76.33	992.93			C	
July	187.85	61.26	704.52		B		
August	169.39	55.65	449.68	A	B		
September	236.71	65.80	1,886.90	A			
October	261.85	77.61	1,138.48	A	B		
November	296.55	90.03	2,018.67	A	B	C	
December	336.93	79.81	968.61			C	

2.2.2.6 Fecal Coliform Concentrations

Water quality monitoring data collected by VADEQ were described in section 2.2.1.1. The trend analysis was conducted on data collected at stations used in TMDL assessment, when a sufficient amount of data (*i.e.*, a minimum of 3 years of data for each month reported) was available. An overall trend in fecal coliform concentrations was detected at station 1BLEW002.91. The slope of this decrease was estimated at -125.00 cfu/100 ml/year. Remaining stations had no overall trend (Table 2.7). Differences in monthly fecal coliform concentration for stations 1BLEW002.91 (Lewis Creek), 1BMDL001.83

(Middle River), 1BMDL036.08 (Middle River), and 1BSTH041.68 (South River) are indicated in Table 2.8 through Table 2.11. The remaining stations had no seasonality effect. Fecal coliform concentrations in months with the same median group letter are not significantly different from each other at the 95% significance level. For example, in Table 2.8, January, February, and March are in median group “A”; therefore January, February and March are not significantly different from each other.

Table 2.7 Summary of trend analysis on fecal coliform (cfu/100 ml).

Station	Mean	Median	Max	Min	SD[1]	N[2]	Significant Trend[3]
1BAKK001.74	944.44	500	3,800	100	1,147.95	9	--
1BEDN003.67	1,471.43	600	3,900	100	1,657.02	7	--
1BEKR000.25	371.43	200	1,700	100	587.97	7	--
1BLEW002.91	2,108.36	1,225	8,000	100	2,275.33	122	-125.00
1BLEW006.95	1,500.00	1,500	2,000	1,000	707.11	2	--
1BMDL001.83	782.98	200	8,000	100	1,575.49	119	No Trend
1BMDL026.58	180.00	180	180	180	--	1	--
1BMDL036.08	351.60	100	4,400	100	742.11	125	No Trend
1BMDL047.90	157.14	100	500	100	151.19	7	--
1BMDL060.48	1,572.96	568	8,000	25	2,370.90	23	--
1BMDL061.07	1,605.39	800	8,000	51	2,024.74	28	--
1BMFT001.43	342.86	100	1,600	100	556.35	7	--
1BMFT006.20	1,100	200	8,000	100	1,834.53	41	--
1BPCD001.03	2,193.83	1,200	8,000	100	2,387.33	82	No Trend
1BPNE000.04	257.14	100	1,100	100	373.53	7	--
1BSTH041.68	1,082.52	600	8,000	100	1,640.98	103	No Trend
1BSTH044.90	257.14	200	600	100	207.02	7	--

[1]SD: standard deviation, [2]N: number of sample measurements, [3]A number in the significant trend column represents the Seasonal-Kendall estimated slope, “--” insufficient data

Table 2.8 Summary of Mood Median Test on mean monthly fecal coliform at 1BLEW002.91 on Lewis Creek.

Month	Mean (cfu/100 ml)	Minimum (cfu/100 ml)	Maximum (cfu/100ml)	Median Groups	
January	560.00	100	1,500	A	
February	773.64	100	3,600	A	
March	895.00	100	3,100	A	B
April	1,020.46	100	5,100	A	
May	2,460.00	8,000	8,000		B
June	3,320.00	100	8,000		B
July	3,860.00	600	8,000		B
August	3,513.89	625	7,300		B
September	3,301.82	1,250	8,000		B
October	2,362.00	100	8,000	A	B
November	1,885.00	200	8,000	A	B
December	1,616.00	200	8,000	A	B

Table 2.9 Summary of Mood Median Test on mean monthly fecal coliform at 1BMDL001.83 on Middle River.

Month	Mean (cfu/100 ml)	Minimum (cfu/100 ml)	Maximum (cfu/100ml)	Median Groups	
January	1,155.56	100	5,800		B
February	145.45	100	300	A	B
March	170.00	100	700	A	
April	618.18	100	3,500	A	B
May	1,760.00	100	8,000		B
June	1,854.55	100	8,000	A	B
July	908.33	100	5,400	A	B
August	288.89	100	600	A	B
September	1,011.11	100	4,900	A	B
October	544.44	100	1,300	A	B
November	618.18	100	5,000	A	B
December	310.00	100	1,200	A	B

Table 2.10 Summary of Mood Median Test on mean monthly fecal coliform at 1BMDL036.08 on Middle River.

Month	Mean (cfu/100 ml)	Minimum (cfu/100 ml)	Maximum (cfu/100ml)	Median Groups	
January	800.00	100	4,300		B
February	125.00	100	400	A	
March	427.78	100	1,950	A	B
April	127.27	100	300	A	
May	1,570.00	100	4,400		B
June	236.36	100	1,000	A	B
July	127.27	100	400	A	
August	187.50	100	500	A	B
September	236.36	100	1,300	A	
October	170.00	100	700	A	
November	100.00	100	100	A	
December	172.73	100	800	A	

Table 2.11 Summary of Mood Median Test on mean monthly fecal coliform at 1BSTH041.68 on South River.

Month	Mean (cfu/100 ml)	Minimum (cfu/100 ml)	Maximum (cfu/100ml)	Median Groups	
January	660.00	100	1,400	A	B
February	310.00	100	1,800	A	
March	250.00	100	600	A	
April	1,266.67	200	5,100	A	B
May	1,662.50	100	6,000	A	B
June	2,920.00	100	8,000		B
July	922.22	100	1,400	A	B
August	1,200.00	100	2,700		B
September	2,200.00	100	8,000	A	B
October	562.50	100	1,000	A	B
November	444.44	100	2,100	A	B
December	500.00	100	2,100	A	B

3. FECAL COLIFORM SOURCE ASSESSMENT

The TMDL development described in this report includes examination of all potential significant sources of fecal coliform in the Middle and South River watersheds. The source assessment was used as the basis of water quality model development and ultimate analysis of TMDL allocation options. In evaluation of the sources, loads were characterized by the best available information, landowner input, literature values, and local, state, and federal management agencies. This section documents the available information and interpretation for the TMDL analysis. The source assessment chapter is organized into point and nonpoint sections. The representation of the following sources in the model is discussed in Section 4.

3.1 Assessment of Point Sources

Point sources permitted to discharge in the Middle and South River watersheds through the Virginia Pollutant Discharge Elimination System (VPDES) are listed in Table 3.1. Of these point sources, those that are permitted for control of fecal bacteria are shown in Figure 3.1. There are currently no MS4 permitted storm sewer discharges in the watershed. Permitted point discharges that may contain pathogens associated with fecal matter are required to maintain a fecal coliform concentration below 200 cfu/100 ml. One method for achieving this goal is chlorination. Chlorine is added to the discharge stream at levels intended to kill off any pathogens and fecal coliform bacteria. The monitoring method for ensuring the goal is to measure the concentration of total residual chlorine (TRC) in the effluent. If the concentration is high enough, pathogen concentrations, including fecal coliform bacteria concentrations, are considered reduced to acceptable levels. Typically, if minimum TRC levels are met, fecal coliform concentrations are reduced to levels well below the 200 cfu/100 ml limit.

Table 3.1 Permitted Point Sources in the Middle and South River Watersheds.

Facility	VPDES #	Receiving Stream	Permitted for Fecal Control
American Safety Razor	VA0002194	Middle River	No
American Safety Razor 002	VA0002194	Middle River	No
Snyder General Corp.	VA0002437	Middle River	Expired
Riverheads High School STP	VA0020427	Christians Creek	Expired
Brookwood STP	VA0022292	Christians Creek	Expired
ACSA-Staunton Plaza STP	VA0022306	Christians Creek	Expired
ACSA; Mt. Sidney, Ft. Defiance STP	VA0022322	Middle River	Yes
Cold Spring Correctional Unit 10	VA0023400	South River	Yes
ACSA-Fishersville STP	VA0025291	Christians Creek	Yes
Staunton WTP	VA0030716	Middle River	Expired
Greenville Car Wash	VA0054771	South River	Expired
Camp Shenandoah STP	VA0060917	Middle River	Yes
ACSA-New Hope STP	VA0062481	Middle River	Yes
Verona STP	VA0064637	Lewis & Middle	Expired
Middle River Regional STP	VA0064793	Middle River	Yes
Charles W. Surface	VA0077640	Lewis Creek	Transferred to VAG401072
ACSA-Churchville WTP	VA0084212	Jennings Branch	Yes
Petroleum Coop-Aug. Co.	VA0086738	Christians Creek	No
ACSA-Verona Water System	VA0088170	Middle River	No
Woodlawn Village M.H. Park	VA0089061	Christians Creek	Yes
Greenville STP	VA0089362	Christians Creek	Transferred to VA0090417
White Way Lunch	VA0089419	Jennings Branch	Expired
Churchville STP	VA0089851	Middle River	Expired
Greenville STP	VA0090417	Christians Creek	Yes
Casta Line Trout Farms	VA0091219	Middle River	No
WNLR Radio Station	VAG401064	Middle River	Yes
Private Residence	VAG401072	Lewis Creek	Yes
Private Residence	VAG401082	Christians Creek	Yes
Private Residence	VAG401195	Christians Creek	Yes
Private Residence	VAG401312	Middle River	Yes
Private Residence	VAG401359	Middle River	Yes
Private Residence	VAG401443	Christians Creek	Yes
Private Residence	VAG401449	Christians Creek	Yes
Private Residence	VAG401498	Middle River	Yes
Private Residence	VAG401664	Middle River	Yes
Weaver's Garage	VAG401882	Poague Run (Lewis Cr. watershed)	Yes
Victory Worship Center STP	VAG401896	Christians Creek	Yes
Jake's Convenience Store	VAG401915	Bell Creek (Middle R. watershed)	Yes
Private Residence	VAG401959	Barterbrook Branch (Christians Cr. watershed)	Yes
Private Residence	VAG401960	Barterbrook Branch (Christians Cr. watershed)	Yes
Amoco/Deno's Food Mart	VAG401967	Christians Creek	Yes
Private Residence	VAG401969	Christians Creek	Yes
Private Residence	VAG401979	Poor Farm Draft (Christians Cr. watershed)	Yes

Table 3.1 Permitted Point Sources in the Middle and South River Watersheds (cont.).

Facility	VPDES #	DEQ Permit #	Receiving Stream	Permitted for Fecal Control
Royston LLC--Lofton Plant	VAG401981		Poor Creek (South R. watershed)	Yes
Private Residence	VAG408038		Christians Creek	Yes
Belmont Quarry Company	VAG841010		Lewis Creek	No
Belmont Quarry Company	VAG841010		Christians Creek	No
Luck Stone-Augusta Plant	VAG841015		Middle River	No
Brett Aggregates Inc - Stuarts Draft Plant	VAG841025		Loves Run (South R. watershed)	No
Riverside Plaza Car Wash	VAG750047		Jennings Branch	No
Riverside Plaza Car Wash	VAG751001		Jennings Branch	Expired
Transit Mixed Concrete	VAG110071		Lewis Creek	No
Augusta Block Inc	VAG110073		Lewis Creek	No
Transit Mixed Concrete	VAG111002		Lewis Creek	No
Augusta Block Inc	VAG111011		Lewis Creek	No
Shenandoah Valley Regional Airport	VAR101716	VAR560054	Broad Run (Middle R. watershed)	No
Pilot Travel Center 96	VAR100595	VAR460232	Christians Creek	No
Project #U000-132-105,C501,B602	VAR100580	VAR460212	Poor Farm Draft (Christians Cr. watershed)	No
Project #0871-007-317,M502,D686,B697	VAR100583	VAR460217	Folly Mills Creek (Christians Cr. watershed)	No
Project #0728-007-P79,N501	VAR100622	VAR460231	Elk Run (Moffett Cr. watershed)	No
Project #0262-007-101,C502	VAR100570	VAR460154	Lewis Creek	No
Project #0642-007-293,M502 et al	VAR100635	VAR460243	Goose Creek (Christians Cr. watershed)	No
Project #0732-007-315,M501,D680,D681,D682	VAR100574	VAR460198	Middle River	No
Countryside Development Co LC - Windward Pointe	VAR102392		Meadow Run (Christians Cr. watershed)	No
Disposal Area 1 - VDOT NFO 0262 007 101 C503	VAR101645		Bell Creek (Middle R. watershed)	No
Shields Construction Company	VAR101656		Goose Creek (Christians Cr. watershed)	No
Teaberry Green	VAR101657		Meadow Run (Christians Cr. watershed)	No
Project #0262-007-101,C504,B610,B611	VAR101702		Bell Creek (Middle R. watershed)	No

Table 3.1 Permitted Point Sources in the Middle and South River Watersheds (cont.).

Facility	VPDES #	DEQ Permit #	Receiving Stream	Permitted for Fecal Control
Project #0262-007-101,C503,B609,B614,B615	VAR101703		Lewis Creek	No
VDOT Verona - 0262 007 101 L801	VAR101710		Christians Creek	No
Augusta County Commercial Center - Phase I	VAR101719		Christians Creek	No
Harley Crossing	VAR101725		Christians Creek	No
Mill Place Commerce Park - Phase II	VAR101737		Middle River	No
VDOT Verona - 0635 007 S83 N501	VAR101780		Barterbrook Branch (Christians Cr. watershed)	No
VDOT Verona - 0254 007 105 M600	VAR101778		Buffalo Branch (Middle R. watershed)	No
VDOT Verona - 0616 007 348 M501	VAR101913		Middle River	No
Disposal Area 2 - VDOT NFO 02262 007 101 C503	VAR102097		Lewis Creek	No
Middle River Regional Jail	VAR102801		Middle River	No
Augusta Regional Landfill	VAR051405	VAR560238	Christians Creek	No
FedEx Freight East, Inc.-STN	VAR051334	VAR560166	Goose Creek (Christians Cr. watershed)	No
Ord's Auto Parts, LLC	VAR051333	VAR560226	Lewis Creek	No
Augusta Block Inc	VAR050778	VAR560082	Lewis Creek	No
OMS #12	VAR050502	VAR560006	Lewis Creek	No
Staunton Metal Recyclers Inc	VAR050504	VAR560091	Lewis Creek	No
Unifi - Staunton	VAR050823	VAR560075	Lewis Creek	No
B & S Contracting Inc - Staunton Plant	VAR050924	VAR560010	Lewis Creek	No
Dixie Gas & Oil Corp Bulk Plant	VAR050826	VAR560080	Lewis Creek	No
Crosby Trucking Service Inc	VAR050788	VAR560005	Middle River	No
McQuay International Inc	VAR050946	VAR560121	Middle River	No

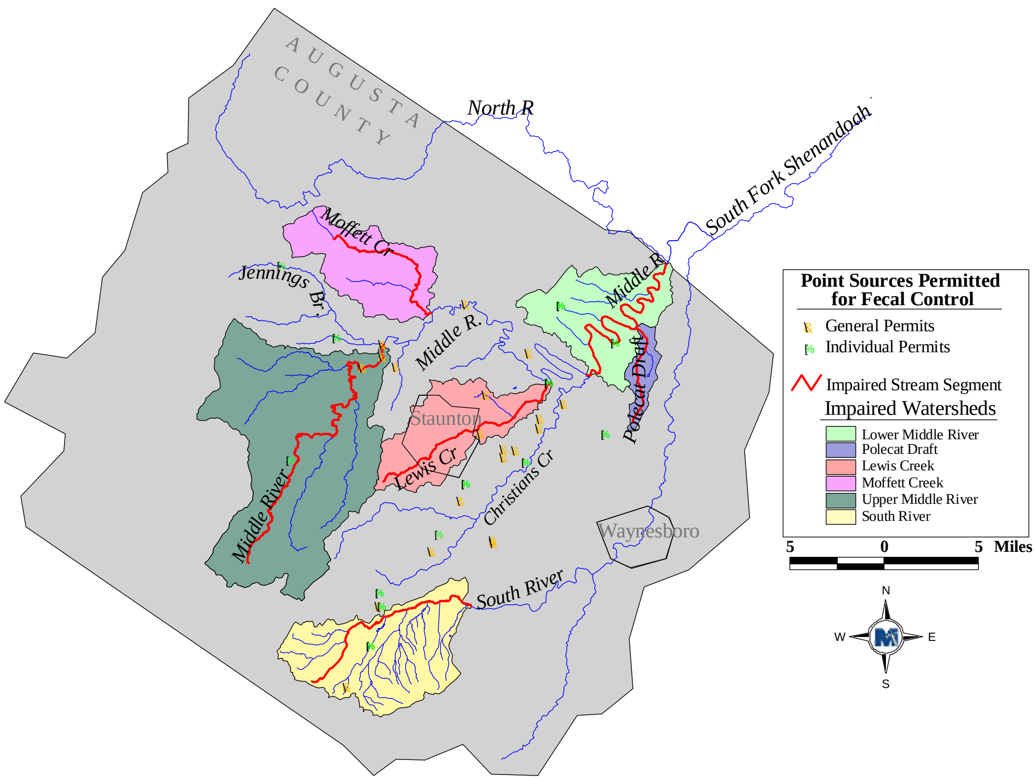

Figure 3.1 Location of VPDES permitted point sources in the Middle and South Rivers watersheds.

3.2 Assessment of Nonpoint Sources

In the Middle and South River watersheds, both urban and rural nonpoint sources of fecal coliform bacteria were considered. Sources include exfiltration and overflows from municipal sewage systems, residential sewage treatment systems, land application of waste (livestock and biosolids), livestock, wildlife, and pets. Sources were identified and enumerated. Where appropriate, spatial distribution of sources throughout the watersheds was also determined.

3.2.1 Private Residential Sewage Treatment

Typical private residential sewage treatment systems (septic systems) consist of a septic tank, distribution box, and a drainage field. Waste from the household flows first to the septic tank, where solids settle out and should be periodically removed by a septic tank pump-out. The liquid portion of the waste (effluent) flows to the distribution box, where it is distributed among several buried absorption trenches consisting of perforated pipes enclosed in beds of gravel. This combination of pipe and trenches comprise the drainage field. Once in the soil, the effluent may potentially flow downward to groundwater, laterally to surface water, and/or upward to the soil surface. Removal of fecal coliform is accomplished primarily by filtration by the soil matrix and die-off during the time between introduction to the septic system and eventual introduction to naturally occurring waters (ground and surface water). Properly designed, installed, and functioning septic systems that are more than 50 feet from a stream are considered to contribute virtually no fecal coliform to surface waters. Reneau (2000) reported that a very small portion of fecal coliform can survive in the soil system for over 50 days. This number might be higher or lower depending on soil moisture, temperature, and physical characteristics such as soil structure and texture.

A septic failure occurs when a drain field has inadequate drainage or a "break", such that effluent flows directly to the soil surface, bypassing travel through the soil profile. In this situation, the effluent is either available to be washed into waterways during runoff events or is directly deposited in-stream due to proximity. A permit from the Virginia Department of Health (VDH) is required for installing or repairing a septic system. VDH personnel were contacted, but had no information regarding the failure rates in Augusta County. A survey of septic pump-out contractors performed by MapTech showed that failures were more likely to occur in the winter to spring months than in the summer to fall months, and that a higher percentage of system failures were reported because of a back-up to the household than because of a failure noticed on the surface of the yard.

Table 3.2 indicates the human population contributing to each impairment, projected to current numbers based on 1990 and 2000 Census data. Due to the aggregation of census data from geographical units developed for the census (*i.e.*, census blocks) to subwatersheds, some slight errors occurred (*e.g.*, small numbers of homes with sewer service indicated in subwatersheds where no service is available). These slight errors were controlled based on validation with public review and cross-referencing with other data sources (*e.g.*, public service authorities). The number of households that reported in the 1990 Census a system other than sewer or septic are an indicator of the potential number of households depositing sewage directly to the stream. VDH personnel were contacted to provide guidance as to the number of illicit discharges (straight pipes) in the study area, but were hesitant to provide estimates. The population in the Christians Creek drainage is not included in this study, because a fecal bacteria TMDL has already been developed for that area and the loads modeled during that study will be used as input to the current modeling effort.

MapTech sampled waste from septic tank pump-outs and found an average fecal coliform density of 1,040,000 cfu/100 ml. An average fecal coliform density for human waste of 13,000,000 cfu/g was reported by Geldreich (1978) and a total wastewater load of 75 gal/day/person for households utilizing septic systems (VDH 2000), with typical septic tank effluent having fecal coliform concentrations of 10,000 cfu/100 ml (Metcalf and Eddy 1991).

Table 3.2 Estimated human populations by watershed (2003)[1].

Watershed	Population	Households	Sewer (Homes)	Septic (Homes)	Other (Homes)
Upper Middle River	3,817	1,577	22	1,464	91
Jennings Branch [2]	1,695	730	6	689	35
Moffett Creek	1,055	427	2	406	19
Middle River [2]	6,753	2,871	1,369	1,442	60
Lewis Creek	24,822	11,075	10,326	680	69
Lower Middle River	2,372	949	375	556	18
Polecat Draft	517	193	17	170	6
TOTAL Middle River	41,030	17,822	12,117	5,408	297
South River	4,528	1,593	161	1,389	43

[1] Disaggregated data from 1990 and 2000 Census projected to 2003.
[2] Non-impaired areas.

3.2.2 Public Sewage Treatment

Where residents have access to public sewer systems, sewage is collected and transported through a system of pipelines to the treatment facility, where it is treated (*e.g.*, removal of solids, and chlorination/de-chlorination) and discharged. Fecal bacteria remaining in the waste stream after treatment are accounted for as a point source (Section 3.1). However, failure of the collection system can occur through exfiltration (*e.g.*, leaking sewer lines), or overflows (*e.g.*, capacity of system exceeded due to blockage in line, system malfunction, or infiltration). As indicated in Table 3.2, a significant portion of the population in the impaired drainages is serviced by a public sewage system. Figure 3.2 shows the service area of the public sewer system. These data were used to refine estimated numbers presented in Table 3.2 (*i.e.*, the Upper Middle River, Moffett Creek, Polecat Draft, and South River impairments have no sewer service available). The revised numbers are presented in Table 3.3. Occurrence of exfiltration and overflows were modeled based on density, size, and location of sewer lines, as well as historic records of overflow events.

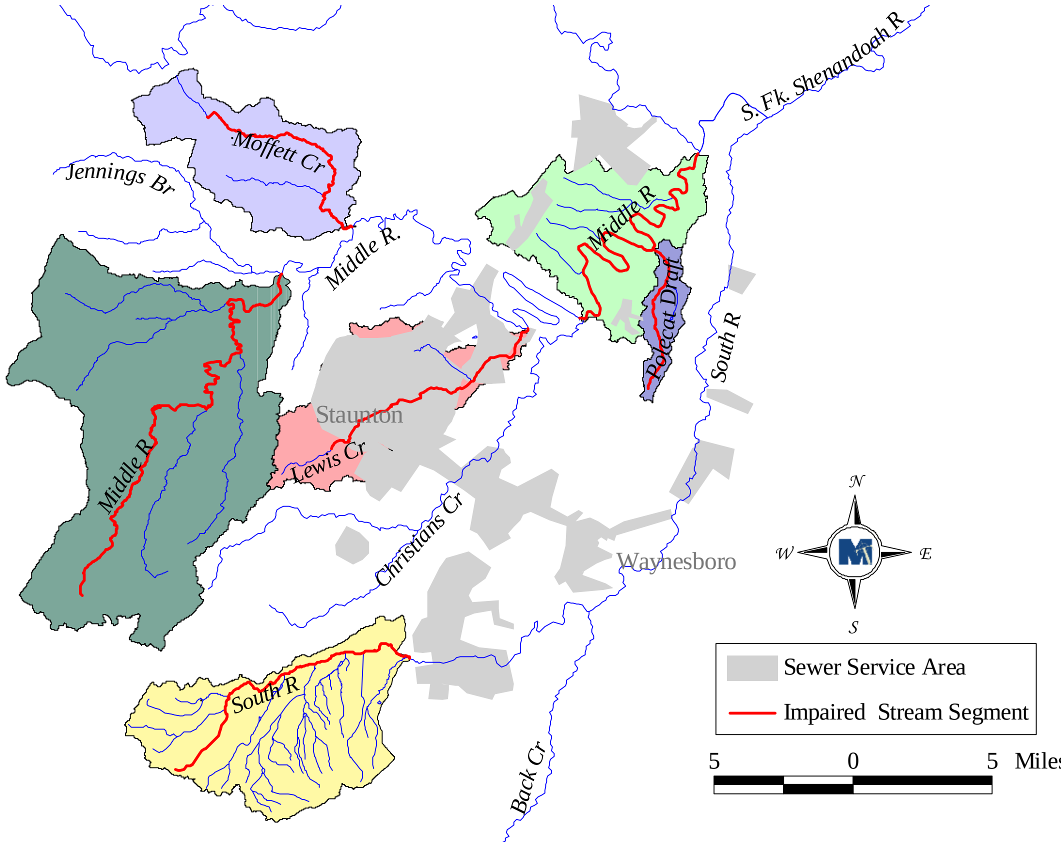

Figure 3.2 Sewer service area in the Middle and South River drainages.

Table 3.3 Estimated human populations by watershed (2003)[1], adjusted based on sewer service area.

Watershed	Population	Households	Sewer (Homes)	Septic (Homes)	Other (Homes)
Upper Middle River	3,817	1,577	0	1,486	91
Jennings Branch [2]	1,695	730	0	695	35
Moffett Creek	1,055	427	0	408	19
Middle River [2]	6,753	2,871	1,369	1,442	60
Lewis Creek	24,822	11,075	10,326	680	69
Lower Middle River	2,372	949	375	556	18
Polecat Draft	517	193	0	187	6
TOTAL Middle River	41,030	17,822	12,070	5,454	297
South River	4,528	1,593	0	1,550	43

[1] Disaggregated data from 1990 and 2000 Census projected to 2003.
[2] Non-impaired areas.

3.2.3 Livestock

The predominant types of livestock in the Middle and South River watersheds are poultry (chickens and turkeys), beef and dairy cattle, sheep, and horses, although all types of livestock identified were considered in modeling the watershed. Animal populations were based on communication with Virginia Cooperative Extension Service (VCE), Natural Resources Conservation Service (NRCS), Headwaters Soil and Water Conservation District (HSWCD), VADCR, watershed visits, verbal communication with farmers, and review of all publicly available information on animal type and approximate numbers known to exist within Augusta County and the TMDL project areas. Table 3.4 and Table 3.5 give estimates of livestock and poultry populations, respectively, in the Middle and South River watersheds. The population in the Christians Creek drainage is not included in this study, because a fecal bacteria TMDL has already been developed for this area and the loads modeled during this effort will be used as input to the current modeling effort. Values of fecal coliform density for livestock sources were based on sampling performed by MapTech. Reported manure production rates for livestock were taken from ASAE, 1998. A summary of fecal coliform density values and manure production rates is presented in Table 3.6.

Table 3.4 Estimated livestock populations in the Middle and South River watersheds.

Watershed	Beef Cattle	Dairy Cattle	Horse	Swine	Sheep	Goat
Upper Middle River	9,591	1,700	649	80	1,000	0
Jennings Branch [1]	1,090	0	112	0	172	0
Moffett Creek	1,016	1,090	164	0	253	0
Middle River [1]	3,305	967	402	0	620	22
Lewis Creek	220	756	213	0	629	0
Lower Middle River	4,160	1,096	277	0	426	0
Polecat Draft	716	188	48	0	73	0
TOTAL Middle River	20,098	5,797	1,865	80	3,172	22
South River	3,291	415	228	0	351	30

[1] Non-impaired areas

Table 3.5 Estimated poultry populations in the Middle and South River watersheds (total birds per year).

Watershed	Broilers	Pullets	Turkey: Breeders	Finished Hens	Finished Toms	2-Stage Toms
Upper Middle River	0	0	15,000	522,800	19,500	0
Jennings Branch [1]	672,000	0	0	160,000	0	672,000
Moffett Creek	336,000	0	31,700	225,600	222,000	336,000
Middle River [1]	312,000	224,000	0	108,800	0	312,000
Lewis Creek	0	0	0	91,200	0	0
Lower Middle River	1,389,000	0	0	624,000	225,000	1,389,000
Polecat Draft	504,000	0	0	0	25,500	504,000
TOTAL Middle River	3,213,000	224,000	46,700	1,732,400	492,000	3,213,000
South River	0	0	20000	291200	0	0

[1] Non-impaired areas

Table 3.6 Average fecal coliform densities and waste loads associated with livestock and poultry.

Type	Waste Load (lb/d/an)	FC Density (cfu/g)
Dairy (1,400 lb)	120.4	258,000
Beef (800 lb)	46.4	101,000
Horse (1,000 lb)	51.0	94,000
Swine (135 lb)	11.3	400,000
Swine Lagoon	N/A	95,300[1]
Sheep (60 lb)	2.4	43,000
Goat (140 lb)	5.7	15,500
Dairy Separator	N/A	32,000[1]
Dairy Storage Pit	N/A	1,200[1]
Layer	0.26	586,000
Broiler	0.17	586,000
Pullet	0.34	586,000
Turkey Breeder	2.00	289,000
Finished Hen	0.71	289,000
Finished Tom	1.18	289,000
2-stage Tom	0.39	289,000
Brood to Move	0.30	289,000

[1]Units are cfu/100ml.

Fecal coliform produced by livestock can enter surface waters through four pathways. First, waste produced by animals in confinement is typically collected, stored, and applied to the landscape (*e.g.*, pasture and cropland), where it is available for wash-off during a runoff-producing rainfall event. Second, grazing livestock deposit manure directly on the land, where it is available for wash-off during a runoff-producing rainfall event. Third, livestock with access to streams occasionally deposit manure directly in streams. Fourth, some animal confinement facilities have illegal drainage systems that divert wash-water and waste directly to drainage ways or streams.

Poultry is one of the major livestock commodities in the Middle and South Rivers watersheds and poultry litter is a primary source of land-applied livestock waste. Timing of applications throughout the year was based on data reported by SWCD, NRCS, VADCR, and VCE personnel (Table 3.7). All grazing livestock were expected to deposit some portion of waste on pasture land areas. The percentage of time spent on pasture for dairy and beef cattle was reported by SWCD, NRCS, VADCR, and VCE personnel (Table 3.8 through Table 3.10). Horses, sheep, beef cattle and goats were assumed to be in pasture 100% of the time. The average amount of time spent by dairy and beef cattle in stream access areas (*i.e.*, within 100 feet of the stream) for each month is given in Table 3.8 through Table 3.10.

Table 3.7 Estimated average percentage of collected livestock waste applied throughout year.

Month	Applied % of Total			Landuse
	Beef and Swine	*Dairy*	*Poultry*	
January	0.00	0.00	0.00	Cropland
February	0.00	0.00	0.00	Cropland
March	15.00	10.00	20.00	Cropland
April	20.00	20.00	20.00	Cropland
May	20.00	20.00	7.50	Cropland
June	0.00	0.00	7.50	Pasture
July	2.50	2.50	7.50	Pasture
August	2.50	2.50	7.50	Pasture
September	15.00	15.00	15.00	Cropland
October	20.00	25.00	15.00	Cropland
November	5.00	5.00	0.00	Cropland
December	0.00	0.00	0.00	Cropland

Table 3.8 Estimated average time dairy milking cows spend in different areas per day.

Month	Pasture (hr)	Stream (hr)	Loafing Lot (hr)
January	2.54	0.06	21.4
February	2.54	0.06	21.4
March	3.71	0.09	20.2
April	5.71	0.09	18.2
May	6.61	0.09	17.3
June	7.18	0.12	16.7
July	7.88	0.12	16
August	7.88	0.12	16
September	7.91	0.09	16
October	7.51	0.09	16.4
November	6.61	0.09	17.3
December	4.84	0.06	19.1

Table 3.9 Estimated average time dry cows and replacement heifers spend in different areas per day.

Month	Pasture (hr)	Stream (hr)	Loafing Lot (hr)
January	23.79	0.21	0
February	23.79	0.21	0
March	23.58	0.42	0
April	23.34	0.66	0
May	23.34	0.66	0
June	23.13	0.87	0
July	23.13	0.87	0
August	23.13	0.87	0
September	23.34	0.66	0
October	23.58	0.42	0
November	23.58	0.42	0
December	23.79	0.21	0

Table 3.10 Estimated average time beef cows spend in different areas per day.

Month	Pasture (hr)	Stream (hr)	Feed Lot (hr)
January	23.79	0.21	0
February	23.79	0.21	0
March	23.70	0.30	0
April	23.58	0.42	0
May	23.58	0.42	0
June	23.49	0.51	0
July	23.49	0.51	0
August	23.49	0.51	0
September	23.58	0.42	0
October	23.70	0.30	0
November	23.70	0.30	0
December	23.79	0.21	0

3.2.4 Biosolids

The rate of biosolids application in the Middle and South River watersheds is relatively small. The four sources include the Augusta County Service Authority--Fishersville (ACSA-F), the Augusta County Service Authority—Middle River (ACSA-MR), the Harrisonburg Service Authority (HRRSA), and Hershey Chocolate-Stuarts Draft (HC-SD). Table 3.11 shows the amount of biosolids produced and distributed in the affected watersheds by source and year. Table 3.12 shows acreages permitted for biosolids application and the actual application information. The sensitivity analysis for this study will include modeling application of the maximum permitted level on permitted sites in the watershed.

Table 3.11 Sources of biosolids spread (dry tons) in the Middle and South River watersheds.

Source	2000	2001	2002
ACSA-F		80	
ACSA-MR	107	326	172
HRRSA		164	134
HERSHEY	55	67	36
TOTAL	162	636	342

Table 3.12 Acreages permitted for biosolids applications and actual applications by impairment area in the Middle and South River watersheds.

Impairment	Acres Permitted	Acres Applied (2000-2002)	Dry Tons Applied (2000-2002)
Upper Middle	0.0	0.0	0.0
Moffett Creek	0.0	0.0	0.0
Lewis Creek	0.0	0.0	0.0
Polecat Draft	0.0	0.0	0.0
Lower Middle	528.3	26.4	415
South River	192.7	89.2	725

3.2.5 Wildlife

The predominant wildlife species in the watershed were determined through consultation with wildlife biologists from the Virginia Department of Game and Inland Fisheries (VDGIF), citizens from the watershed, source sampling, and site visits. Population densities were provided by VDGIF and are listed in Table 3.13. The estimated numbers of animals in the Middle and South River watersheds are reported in Table 3.14. Habitat and seasonal food preferences were determined based on information obtained from The Fire Effects Information System (1999) and VDGIF (Costanzo, 2002; Norman, 1999; Rose and Cranford, 1987; and VDGIF, 1999). Waste loads were comprised from literature values and discussion with VDGIF personnel (ASAE, 1998; Costanzo, 2002; Weiskel et al., 1996, and Yagow, 1999). Table 3.15 summarizes the habitat and fecal production information that was obtained. Where available, fecal coliform densities were based on wildlife waste sampling performed by MapTech. The fecal coliform density of beaver waste was taken from sampling done for the Mountain Run TMDL development (Yagow, 1999). Percentage of waste directly deposited to streams was based on habitat information and location of feces during source sampling for other projects. Fecal coliform densities and estimated percentages of time spent in stream access areas (*i.e.*, within 100 feet of stream) are reported in Table 3.16.

Table 3.13 Wildlife population density.

Wildlife	Augusta County Density	Density Unit
Raccoon	0.0703	an/ac of habitat
Muskrat	2.75	an/ac of habitat
Beaver	4.8	an/mi of stream
Deer	0.033	an/ac of habitat
Turkey	0.008	an/ac of forest
Goose	0.003	an/ac
Duck	0.007	an/ac

Table 3.14 Estimated wildlife populations in the Middle and South River watersheds.

Watershed	Deer	Turkey	Goose	Duck	Muskrat	Raccoon	Beaver
Upper Middle River	1,913	213	176	1,027	4,005	856	299
Jennings Branch [1]	740	136	60	131	1,700	379	116
Moffett Creek	555	69	51	296	1,207	258	79
Middle River [1]	984	82	94	203	2,612	560	142
Lewis Creek	465	35	53	116	1,272	286	58
Lower Middle River	620	26	58	125	1,832	401	111
Polecat Draft	115	8	11	23	376	87	0
TOTAL Middle River	5,392	569	503	1,921	13,004	2,827	805
South River	835	112	244	492	2,473	511	230

[1] Non-impaired areas

Table 3.15 Wildlife fecal production rates and habitat.

Animal	Waste Load (g/an-day)	Habitat
Raccoon	450	Primary = region within 600 ft of continuous streams Infrequent = region between 601 and 7,920 ft from continuous streams
Muskrat	100	Primary = region within 66 ft from continuous streams Less frequent = region between 67 and 308 ft
Beaver[1]	200	Continuous stream below 500 ft elevation (defined as distance in feet)
Deer	772	Primary = forested, harvested forest land, orchards, grazed woodland, open urban, cropland, pasture Infrequent = low density residential, medium density residential Seldom/None = rest of landuse codes
Turkey[2]	320	Primary = forested, harvested forest land, grazed woodland Infrequent = open urban, orchards, cropland, pasture Seldom/None = Rest of landuse codes
Goose[3]	225	Primary = region within 0-66 ft from ponds and continuous streams Infrequent = region between 67 and 308 ft from ponds and continuous streams
Duck	150	Primary = region within 0-66 ft from ponds and continuous streams Infrequent = region between 67 and 308 ft from ponds and continuous streams

1 Beaver waste load was calculated as twice that of muskrat, based on field observations.
2 Waste load for domestic turkey (ASAE, 1998).
3 Goose waste load was calculated as 50% greater than that of duck, based on field observations and conversation with Gary Costanzo (Costanzo, 2000).

Table 3.16 Average fecal coliform densities and estimated percentage of fecal matter directly deposited in stream for wildlife.

Animal Type	Fecal Coliform Density (cfu/g)	Portion of Day in Stream Access Areas (%)
Raccoon	2,100,000	0.25
Muskrat	1,900,000	4.5
Beaver	1,000	100
Deer	380,000	.007
Turkey	1,332	.007
Goose	250,000	2.5
Duck	3,500	3.75

3.2.6 Pets

Among pets, cats and dogs are the predominant contributors of fecal coliform in the watershed and were the only pets considered in this analysis. Dog waste load was reported by Weiskel et al. (1996), while cat waste load was measured during the Blackwater River TMDL study conducted by MapTech. Fecal coliform density for dogs and cats was measured from samples collected throughout Virginia by MapTech. A summary of the data collected is given in Table 3.17. Table 3.18 lists the domestic animal populations for the six impairments.

Table 3.17 Domestic animal population density, waste load, and fecal coliform density.

Type	Population Density (an/house)	Waste load (g/an-day)	FC Density (cfu/g)
Dog	0.534	450	480,000
Cat	0.598	19.4	9

Table 3.18 Estimated domestic animal populations in the Middle and South Rivers watersheds.

Watershed	Dog	Cat
Upper Middle River	842	943
Jennings Branch [1]	390	437
Moffett Creek	228	255
Middle River [1]	1,533	1,717
Lewis Creek	5,914	6,623
Lower Middle River	507	568
Polecat Draft	103	115
TOTAL Middle River	9,517	10,658
South River	851	953

1 Non-impaired areas

4. MODELING PROCEDURE: LINKING THE SOURCES TO THE ENDPOINT

Establishing the relationship between in-stream water quality and the source loadings is a critical component of TMDL development. It allows for the evaluation of management options that will achieve the desired water quality endpoint. In the development of TMDLs for the Middle and Upper South River watersheds, the relationship was defined through computer modeling based on data collected throughout the study area. Monitored flow and water quality data were then used to verify that the relationships developed through modeling were accurate. In this section, the selection of modeling tools, parameter development, calibration/validation, and model application are discussed.

4.1 Modeling Framework Selection

The USGS Hydrologic Simulation Program - Fortran (HSPF) water quality model was selected as the modeling framework to simulate existing conditions and to perform TMDL allocations. The HSPF model is a continuous simulation model that can account for NPS pollutants in runoff, as well as pollutants entering the flow channel from point sources. In establishing the existing and allocation conditions, seasonal variations in hydrology, climatic conditions, and watershed activities were explicitly accounted for in the model. The use of HSPF allowed consideration of seasonal aspects of precipitation patterns within the watershed.

The HSPF model simulates a watershed by dividing it up into a network of stream segments (referred to in the model as RCHRES), impervious land areas (IMPLND) and pervious land areas (PERLND). Each subwatershed contains a single RCHRES, modeled as an open channel, and numerous PERLNDs and IMPLNDs, representing the various landuses in that subwatershed. Water and pollutants from the land segments in a given subwatershed flow into the RCHRES in that subwatershed. Point discharges and withdrawals of water and pollutants are simulated as flowing directly to or withdrawing from a particular RCHRES as well. Water and pollutants from a given RCHRES flow into the next downstream RCHRES. The network of RCHRESs is constructed to mirror the configuration of the stream segments found in the physical world. Therefore, activities simulated in one impaired stream segment affect the water quality downstream in the model.

4.2 Model Setup

To adequately represent the spatial variation in the watershed, the Middle and Upper South River drainage areas were divided into forty-eight subwatersheds (Figure 4.1). The rationale for choosing these subwatersheds was based on the availability of water quality data and the limitations of the HSPF model. Water quality data (*i.e.*, fecal coliform concentrations) are available at specific locations throughout the watershed. Subwatershed outlets were chosen to coincide with these monitoring stations, since output from the model can only be obtained at the modeled subwatershed outlets (Figure 4.1 and Table 4.1). The HSPF model requires that the travel time through any RCHRES be greater than the time-step being used for the model. Given this modeling constraint and the desire to maintain a spatial distribution of watershed characteristics and associated parameters, a 30-minute modeling time-step was determined to be required. The spatial division of the watershed allowed for a more refined representation of pollutant sources, and a more realistic description of hydrologic factors in the watershed.

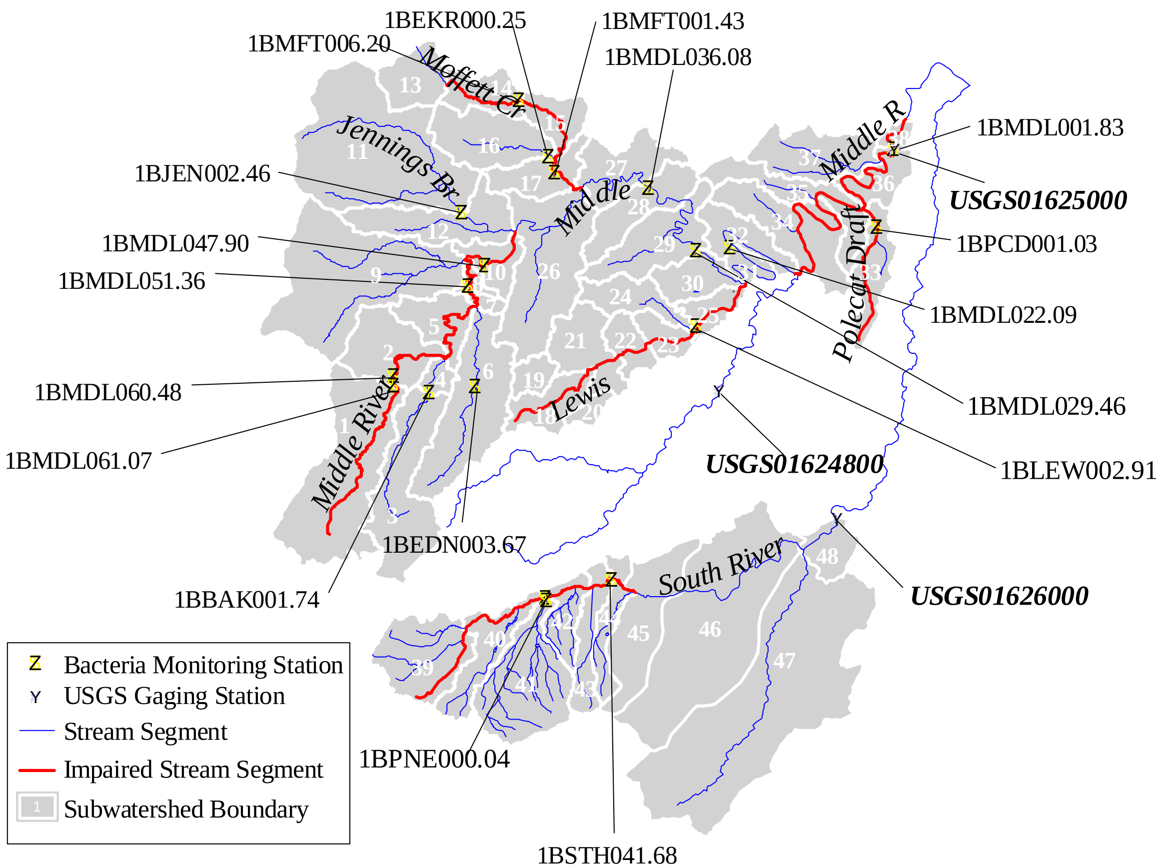

Figure 4.1 **Subwatersheds delineated for modeling and location of VADEQ water quality monitoring stations and USGS Gaging Stations in the Middle and Upper South River watersheds.**

Table 4.1 VADEQ monitoring stations and corresponding reaches in the Middle and Upper South River watersheds.

Station Number	Reach Number
1BMDL061.07	1
1BMDL060.48	2
1BBAK001.74	3
1BEDN003.67	6
1BMDL051.36	7
1BMDL047.90	10
1BJEN002.46	11
1BMFT006.20	14
1BEKR000.25	16
1BMFT001.43	17
1BLEW002.91	23
1BMDL036.08	27
1BMDL022.09	31
1BPCD001.03	33
1BMDL001.83	36
1BPNE000.04	41
1BSTH044.90	40
1BSTH041.68	43

Using the VADCR-provided landuse data layer, described in section 1.1, twenty-two landuse types were identified in the watershed. The twenty-two landuse types were consolidated into 10 categories based on similarities in hydrologic and waste application/production features (Table 4.2). Within each subwatershed, up to the ten landuse categories were represented. Each landuse had parameters associated with it that described the hydrology of the area (*e.g.,* average slope length) and the behavior of pollutants (*e.g.,* fecal coliform accumulation rate). Table 4.3 shows the consolidated landuse types and the area existing in each impairment. These landuse types are represented in HSPF as PERLNDs and IMPLNDs. Impervious areas in the watershed are represented in two IMPLND types, while there are ten PERLND types, each with parameters describing a particular landuse (Table 4.2). Some IMPLND and PERLND parameters (*e.g.,* slope length) vary with the particular subwatershed in which they are located. Others vary with season (*e.g.*, upper zone storage) to account for plant growth, die-off, and removal.

Table 4.2 Consolidation of MRLC landuse categories for the Middle and South River watersheds.

TMDL Landuse Categories	Pervious / Impervious (Percentage)	VADCR Landuse Classifications
Water	Impervious (100%)	Open Water
Residential	Pervious (93%) Impervious (7%)	Low Intensity Residential Open Urban Land Medium Intensity Residential Mobile Home Park Wooded Residential
Commercial and Services	Pervious (93%) Impervious (7%)	Commercial and services Industrial Transportation Mixed Urban or Built-Land Barren
Woodland	Pervious (100%)	Forested Orchards Harvested Forest Land
Unimproved Pasture	Pervious (100%)	Unimproved Pasture Grazed Woodland
Improved Pasture	Pervious (100%)	Improved Pasture
Cropland	Pervious (100%)	Cropland
Livestock Access	Pervious (100%)	Pasture/bordering streams
Livestock Operations	Pervious (100%)	Cattle Operations Poultry Operations Other Feeding Operations
Farmstead	Pervious (100%)	Farmstead

Table 4.3 Spatial distribution of landuse types in the Middle and Upper South River drainage areas.

Landuse	Upper Middle River Acreage	Moffett Creek Acreage	Lewis Creek Acreage	Polecat Draft Acreage	Lower Middle River Acreage	Upper South River Acreage
Water	54	0	27	0	27	109
Residential	263	64	2,706	0	272	708
Commercial & Services	64	9	781	0	145	499
Woodland	26,786	8,690	4,531	1,081	3,396	13,847
Unimproved Pasture	999	699	64	0	218	209
Improved Pasture	26,341	6,111	8,907	1,970	11,541	9,298
Cropland	2,497	763	390	327	2,924	1,208
Livestock Access	1,407	463	463	136	481	581
Livestock Operations	73	82	0	18	73	45
Farmstead	191	118	64	9	227	173

Die-off of fecal coliform can be handled implicitly or explicitly. For land-applied fecal matter (mechanically applied and deposited directly), die-off was addressed implicitly through monitoring and modeling. Samples of collected waste prior to land application (*i.e.,* dairy waste from loafing areas) were collected and analyzed by MapTech. Therefore, die-off is implicitly accounted for through the sample analysis. Die-off occurring in the field was represented implicitly through model parameters such as the maximum accumulation and the 90% wash off rate, which were adjusted during the calibration of the model. These parameters were assumed to represent not only the delivery mechanisms, but the bacteria die-off as well. Once the fecal coliform entered the stream, the general decay module of HSPF was incorporated, thereby explicitly addressing the die-off rate. The general decay module uses a first order decay function to simulate die-off.

4.3 Source Representation

Both point and nonpoint sources can be represented in the model. In general, point sources are added to the model as a time-series of pollutant and flow inputs to the stream. Land-based nonpoint sources are represented as an accumulation of pollutants on land, where some portion is available for transport in runoff. The amount of accumulation and availability for transport vary with landuse type and season. The model allows for a maximum accumulation to be specified. The maximum accumulation was adjusted seasonally to account for changes in die-off rates, which are dependent on temperature and moisture conditions. Some nonpoint sources, rather than being land-based, are represented as being deposited directly to the stream (*e.g.,* animal defecation in stream). These sources are modeled similarly to point sources, as they do not require a runoff event for delivery to the stream. These sources are primarily due to animal activity, which varies with the time of day. Direct depositions by nocturnal animals were modeled as being deposited from 6:00 PM to 6:00 AM, and direct depositions by diurnal animals were modeled as being deposited from 6:00 AM to 6:00 PM. Once in stream, die-off is represented by a first-order exponential equation.

Much of the data used to develop the model inputs for modeling water quality is time-dependent (*e.g.*, population). Depending on the timeframe of the simulation being run, different numbers should be used. Data representing 1995 were used for the water quality calibration and validation period (1992-2002). Data representing 2003 were used for the allocation runs in order to represent current conditions. Additionally, data projected to 2008 were analyzed to assess the impact of changing populations.

4.3.1 Point Sources

For permitted point dischargers, design flow capacities were used for allocation runs. This flow rate was combined with a fecal coliform concentration of 200 cfu/100 ml, where discharges were permitted for fecal control, to ensure that compliance with state water quality standards could be met even if permitted loads were at maximum levels. For calibration and current condition runs, a lower value of fecal coliform concentration was used, based upon a regression analysis relating Total Residual Chlorine (TRC) levels and fecal coliform concentrations (VADEQ/VADCR, 2000). Nonpoint sources of pollution that were not driven by runoff (*e.g.*, direct deposition of fecal matter to the the stream by wildlife) were modeled similarly to point sources. These sources, as well as land-based sources, are identified in the following sections.

4.3.2 Private Residential Sewage Treatment

The number of septic systems in the subwatersheds modeled for the Middle and Upper South River watersheds was calculated by overlaying U.S. Census Bureau data (USCB, 1990; USCB, 2000) with the watershed to enumerate the septic systems. Households were then distributed among residential and farmstead landuse types. Septic divisions between residential and farmstead were based on GIS analysis. Each landuse area was assigned a number of septic systems based on census data. A total of 5,901 septic systems were estimated in the Middle and Upper South River watersheds in 1995. During allocation runs, the number of households was projected to 2003, based on current Augusta County growth rates (USCB, 2000) resulting in 7,082 septic systems (Table 4.4). The number of septic systems was projected to increase to 7,820 by 2008.

Table 4.4 Estimated failing septic systems (2003).

Impaired Segment	Total Septic Systems	Failing Septic Systems	Straight Pipes
Upper Middle River	1,540	345	16
Jennings Branch*	715	166	9
Moffett Creek	421	87	3
Middle River*	1,493	359	9
Lewis Creek	744	192	6
Polecat Draft	175	40	1
Lower Middle River	572	140	2
South River	1,423	289	9
TOTAL	7,082	1,617	55

*non-impaired watersheds

4.3.2.1 Failing Septic Systems

Failing septic systems were assumed to deliver all effluent to the soil surface where it was available for wash-off during a runoff event. In accordance with estimates from Raymond B. Reneau, Jr. of the Crop and Soil Environmental Sciences Department at Virginia Tech, a 40% failure rate for systems designed and installed prior to 1964, a 20% failure rate for systems designed and installed between 1964 and 1984, and a 5% failure rate on all systems designed and installed after 1984 was used in development of the TMDLs for the Middle and Upper South River watersheds. Total septic systems in each category were calculated using U.S. Census Bureau block demographics. The applicable failure rate was multiplied by each total and summed to get the total failed septic systems per subwatershed. The fecal coliform density for septic system effluent was multiplied by the average design load for the septic systems in the subwatershed to determine the total load from each failing system. Additionally, the loads were distributed seasonally based on a survey of septic pump-out contractors (VADEQ/VADCR, 2000) to account for more frequent failures during wet months.

4.3.2.2 Uncontrolled Discharges

Uncontrolled discharges were estimated using 1990 U.S. Census Bureau block demographics. Houses listed in the Census sewage disposal category “other means” were assumed to be disposing of sewage via uncontrolled discharges if located within 200 feet of a stream. Corresponding block data and subwatershed boundaries were intersected to determine an estimate of uncontrolled discharges in each subwatershed. A 200-foot buffer was created from the stream segments. The corresponding buffer and subwatershed areas were intersected resulting in uncontrolled discharges within 200 feet of the stream per subwatershed. Fecal coliform loads for each discharge were calculated based on the fecal density of human waste and the waste load for the average size household in the subwatershed. The loadings from uncontrolled discharges were applied directly to the stream in the same manner that point sources are handled in the model.

4.3.2.3 Sewer System Overflows

During the model calibration/validation period, October 1992 to September 2002, there were 25 reported sewer overflows, leading to a significant input of fecal bacteria into the watershed. It was assumed that additional occurrences of sewer overflows were likely undetected, and a procedure was determined to estimate the quantity of unreported overflows. Overflows were considered to occur during sufficiently wet periods, as based on the average rainfall over a three day period encompassing a reported overflow event. Additional three day wet periods exceeding this average value were considered to contain an unreported sewer overflow. The concentration of fecal bacteria discharged was considered to be equivalent to the concentration of septic tank effluent, and the magnitude of the discharge was estimated as the average discharge volume of reported sewer overflow events. This estimate of concentration is conservative because some biodegradation occurs in a septic system.

4.3.3 Livestock

Fecal coliform produced by livestock can enter surface waters through four pathways: land application of stored waste, deposition on land, direct deposition to streams, and diversion of wash-water and waste directly to streams. Each of these pathways is accounted for in the model. The number of fecal coliform directed through each pathway was calculated by multiplying the fecal coliform density with the amount of waste expected through that pathway. Livestock numbers determined for 2003 were used for the allocation runs, while these numbers were projected back to 1995 for the calibration and validation runs. The numbers are based on data provided by HSWCD, and NRCS, as well as taking into account growth rates in Augusta County (as determined from data reported by the Virginia Agricultural Statistics Service -- VASS, 1995 and VASS, 2003). Similarly, when growth was analyzed, livestock numbers were projected to 2008. For land-applied waste, the fecal coliform density measured from stored waste was used, while the density in as-excreted manure was used to calculate the load for deposition on land and to streams (Table 3.7). The use of fecal coliform densities measured in stored manure accounts for any die-off that occurs in storage. The modeling of fecal coliform entering the stream through diversion of wash-water was accounted for by the direct deposition of fecal matter to streams by cattle.

4.3.3.1 Land Application of Collected Manure

Significant collection of livestock manure occurs on dairy farms. For dairy farms in the drainage area, the average daily waste production per month was calculated using the number of animal units, weight of animal, and waste production rate as reported in Section 3.2.2. The amount of waste collected was first based on proportion of milking cows, as the milking herd represented the only cows subject to confinement and, therefore, waste collection. Second, the total amount of waste produced in confinement was calculated based on the proportion of time spent in confinement. Finally, values for the percentage of loafing lot waste collected were used to calculate the amount of waste available to be spread on pasture and cropland (Table 3.8). Stored waste was spread on pastureland. It was assumed that 100% of land-applied waste is available for transport in surface runoff transport unless the waste is incorporated in the soil by plowing during seedbed preparation. Percentage of cropland plowed and amount of waste incorporated was adjusted using calibration for the months of planting.

4.3.3.2 Deposition on Land

For cattle, the amount of waste deposited on land per day was a proportion of the total waste produced per day. The proportion was calculated based on the study entitled "Modeling Cattle Stream Access" conducted by the Biological Systems Engineering Department at Virginia Tech and MapTech, Inc. for VADCR. The proportion was based on the amount of time spent in pasture, but not in close proximity to accessible streams, and was calculated as follows:

Proportion = [(24 hr) – (time in confinement) – (time in stream access areas)]/(24 hr)

All other livestock (horse and goat) were assumed to deposit all feces on pasture. The total amount of fecal matter deposited on the pasture land-use type was area-weighted.

4.3.3.3 Direct Deposition to Streams

Beef and dairy cattle are the primary sources of direct deposition by livestock in the Middle and Upper South River watersheds. The amount of waste deposited in streams each day was a proportion of the total waste produced per day by cattle. First, the proportion of manure deposited in “stream access” areas was calculated based on the “Modeling Cattle Stream Access” study. The proportion was calculated as follows:

Proportion = (time in stream access areas)/(24 hr)

For the waste produced on the “stream access” landuse, 30% of the waste was modeled as being directly deposited in the stream and 70% remained on the land segment adjacent to the stream. The 70% remaining was treated as manure deposited on land. However, applying it in a separate land-use area (stream access) allows the model to consider the proximity of the deposition to the stream. The 30% that was directly deposited to the stream was modeled in the same way that point sources are handled in the model.

4.3.4 Biosolids

Investigation of VDH data indicated that biosolids applications have occurred within the Middle and Upper South River watersheds. Applications occurred only in the Lower Middle and Upper South River impairments. For model calibration (Section 4.7 of this document), biosolids were modeled at the average reported load, and average fecal coliform density. With urban populations growing, the disposal of biosolids will take on increasing importance. Class B biosolids have been measured with 68,467 cfu/g-dry and are permitted to contain up to 1,995,262 cfu/g-dry, as compared with approximately 240 cfu/g-dry for dairy waste. The sensitivity analysis (Section 4.6 of this document) provided insight into the effects that increased applications of biosolids could have on water quality. During allocation runs, biosolids applications were modeled at the highest permittable loading rate (*i.e.*, 15 dry tons/ac at 1,995,262 cfu/g) applied to all permitted acreages in the month of May each year.

4.3.5 Wildlife

For each species, a GIS habitat layer was developed based on the habitat descriptions that were obtained (Section 3.2.5). An example of one of these layers is shown in Figure 4.2. This layer was overlaid with the landuse layer and the resulting area was calculated for each landuse in each subwatershed. The number of animals per land segment was determined by multiplying the area by the population density. Fecal coliform loads for each land segment were calculated by multiplying the waste load, fecal coliform densities, and number of animals for each species.

Seasonal distribution of waste was determined using seasonal food preferences for deer and turkey. Goose and duck populations were varied based on migration patterns, but the load available for delivery to the stream was never reduced below 40% of the maximum to account for the resident population of birds. No seasonal variation was assumed for the remaining species. For each species, a portion of the total waste load was considered to be land-based, with the remaining portion being directly deposited to streams. The portion being deposited to streams was based on the amount of time spent in stream access areas (Table 3.15). It was estimated, for all animals other than beaver, that 5% of fecal matter produced while in stream access areas was directly deposited to the stream. For beaver, it was estimated that 100% of fecal matter would be directly deposited to streams. No long-term (1995–2008) projections were made to wildlife populations, as there was no available data to support such adjustments.

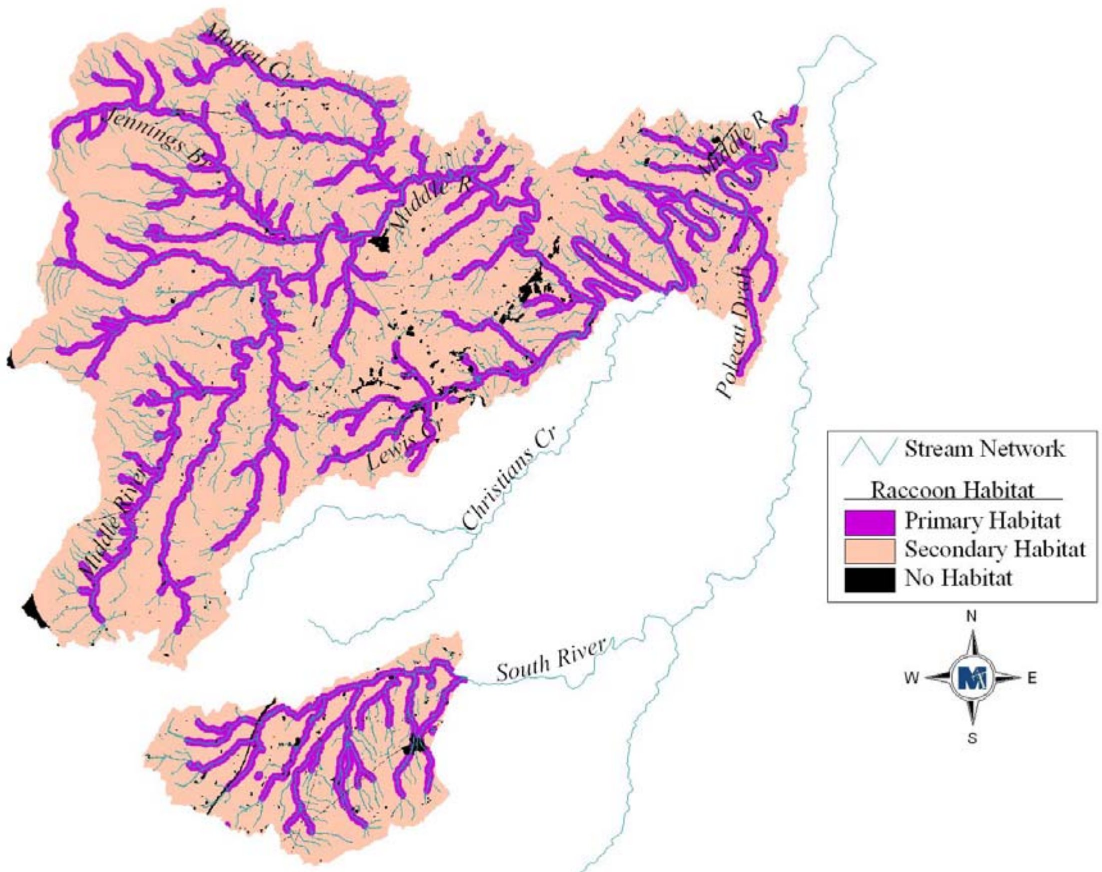

Figure 4.2 Example of raccoon habitat layer developed by MapTech in the Middle River watershed.

4.3.6 Pets

Cats and dogs were the only pets considered in this analysis. Population density (animals/house), waste load, and fecal coliform density are reported in Section 3.2.6. Waste from pets was distributed in the low and high residential landuses. The locations of households were taken from the 1990 and 2000 Census (USCB, 1990, 2000). The landuse and household layers were overlaid, which resulted in number of households per landuse. The number of animals per landuse was determined by multiplying the number of households by the population density. The amount of fecal coliform deposited daily by pets in each landuse segment was calculated by multiplying the waste load, fecal coliform density, and number of animals for both cats and dogs. The waste load was assumed not to vary seasonally. The populations of cats and dogs were projected from 1990 data to 1995, 2003, and 2008 based on housing growth rates.

4.4 Stream Characteristics

HSPF requires that each stream reach be represented by constant characteristics (*e.g.*, stream geometry and resistance to flow). A representative stream profile for each cross-section was developed and consisted of a trapezoidal channel with pitch breaks at the beginning of the flood plain (Figure 4.3). With this approach, the flood plain can be represented differently from the streambed.

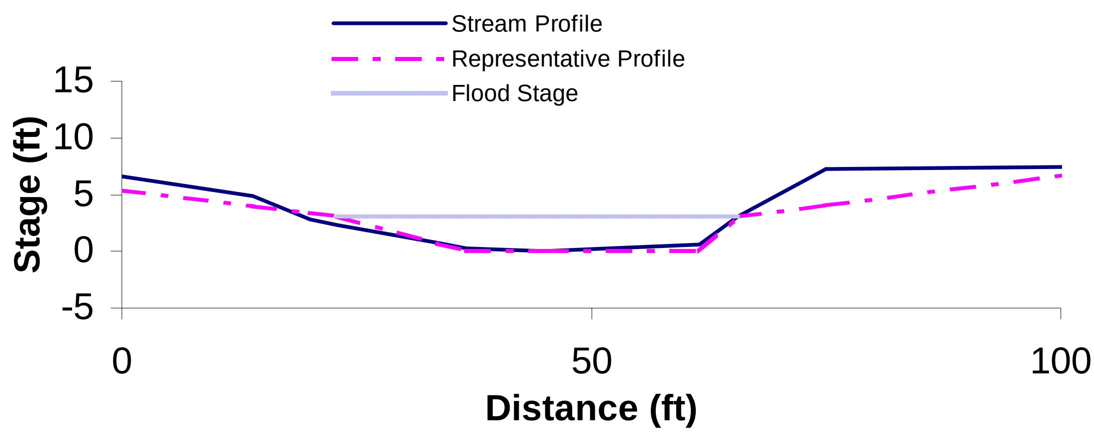

Figure 4.3 Stream profile representation in HSPF.

These data were used to derive the Hydraulic Function Tables (F-tables) used by the HSPF model (Table 4.5). The F-tables developed consist of four columns: depth (ft), area (ac), volume (ac-ft), and outflow (ft^3/s). The depth represents the possible range of flow, with a maximum value beyond what would be expected for the reach. The area listed is the surface area of the flow in acres. The volume corresponds to the total volume of the flow in the reach, and is reported in acre-feet. The outflow is simply the stream discharge, in cubic feet per second.

Table 4.5 Example of an "F-table" calculated for the HSPF model.

Depth (ft)	Area (ac)	Volume (ac-ft)	Outflow (ft^3/s)
0.0	0.00	0.00	0.00
0.2	21.96	4.37	10.87
0.4	22.16	8.78	34.54
0.6	22.36	13.23	67.92
0.8	22.56	17.73	109.75
1.0	22.77	22.26	159.29
1.3	23.07	29.14	246.88
1.7	23.48	38.44	386.59
2.0	23.78	45.53	507.43
2.3	24.08	52.71	641.30
2.7	24.49	62.43	839.20
3.0	24.79	69.82	1,001.68
6.0	29.42	149.62	3,222.35
9.0	37.08	249.37	6,254.60
12.0	44.73	372.08	10,078.05
15.0	52.38	517.75	14,818.37
25.0	77.32	1,163.48	38,629.43
50.0	92.02	2,796.19	103,246.75

4.5 Selection of Representative Modeling Period

Selection of the calibration/validation periods was based on two factors: availability of data (discharge and water-quality) and the need to represent critical hydrological conditions. Mean daily discharge at USGS Gaging Station #01625000 (Middle River at Grottoes) was available from October 1970 to September 2000. The modeling period was selected to include the VADEQ assessment period from July 1992 through June 1997 that led to the inclusion of the Middle and South River segments on the 1998 303(d) Total Maximum Daily Load Priority List and Report. In addition, the fecal concentration data from this period were evaluated for use during calibration and validation of the model.

The mean daily flow and precipitation for each season were calculated for the period October 1970 through September 2000. This resulted in 30 observations of mean flow and precipitation for each season. The mean and variance of these observations were calculated. Next, a representative period for modeling was chosen and compared to the historical data. The initial period was chosen based on the availability of discharge data closest to the fecal coliform assessment period. The representative period was chosen such that the mean and variance of each season in the modeled period was not significantly different from the historical data (Table 4.6, Figure 4.4 and Figure 4.5).

Therefore, the period was selected as representing the hydrologic regime of the study area, accounting for critical conditions associated with all potential sources within the watershed. The resulting period for hydrologic calibration/validation was:

- Calibration: 1993-1997 (Comparison to 30-minute flow data)
- Validation: 1986-1990 (Comparison to daily flow data)

Table 4.6 Comparison of modeled period to historical records.

	Mean Flow (cfs)				Precipitation (in/day)			
	Fall	**Winter**	**Spring**	**Summer**	**Fall**	**Winter**	**Spring**	**Summer**
	Historical Record (1971-2000)				**Historical Record (1971-2000)**			
Mean	304	548	392	198	0.096	0.093	0.111	0.118
Variance	47,275	86,384	31,314	18,500	0.002	0.002	0.001	0.002
	Calibration & Validation Period (10/85-9/90, 10/92-9/97)							
Mean	310	548	404	241	0.095	0.096	0.117	0.130
Variance	58,657	74,969	36,029	41,205	0.001	0.002	0.002	0.003
	P-Values							
Mean	0.470	0.499	0.426	0.264	0.477	0.418	0.359	0.272
Variance	0.310	0.437	0.360	0.048	0.380	0.435	0.127	0.111

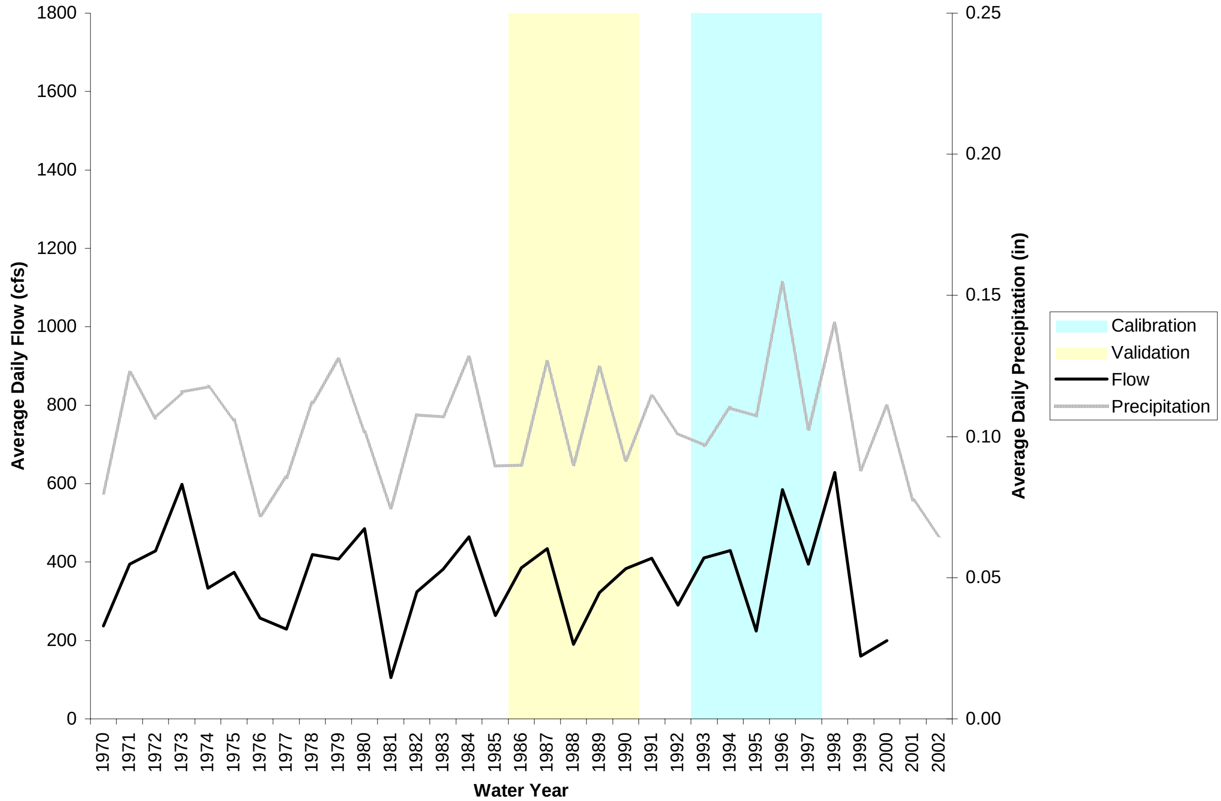

Figure 4.4 Hydrologic calibration and validation periods compared to annual flow and precipitation records.

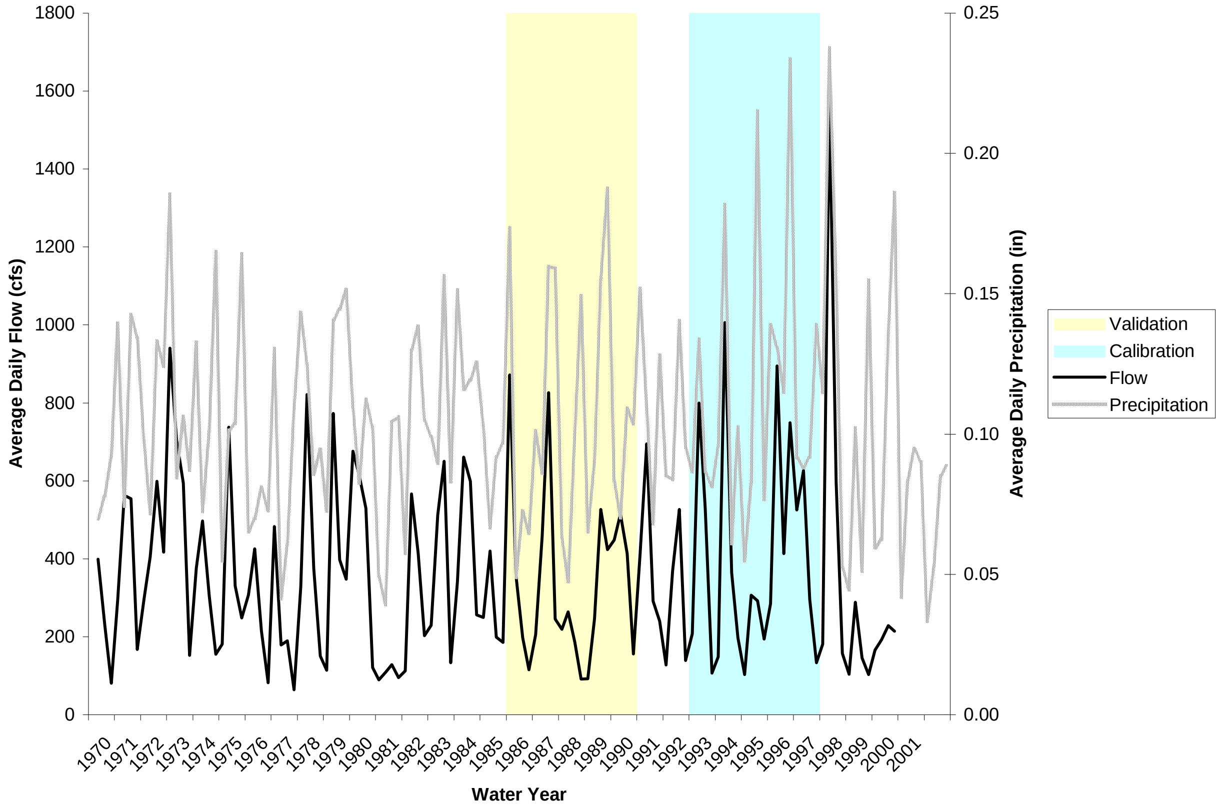

Figure 4.5 Hydrologic calibration and validation periods compared to seasonal flow and precipitation records.

4.6 Sensitivity Analysis

Sensitivity analyses were conducted to assess the sensitivity of the model to changes in hydrologic and water quality parameters as well as to assess the impact of unknown variability in source allocation (*e.g.* seasonal and spatial variability of waste production rates for wildlife, livestock, septic system failures, uncontrolled discharges, background loads, and point source loads). Additional analyses were performed to define the sensitivity of the modeled system to growth or technology changes that impact waste production rates.

Sensitivity analyses were run on both hydrologic and water quality parameters. The parameters adjusted for the hydrologic sensitivity analysis are presented in Table 4.7, with base values for the model runs given. The parameters were adjusted to -50%, -10%, 10%, and 50% of the base value, and the model was run for water years 1993 through

1997. Where an increase of 50% exceeded the maximum value for the parameter, the maximum value was used and the parameters increased over the base value were reported. The hydrologic quantities of greatest interest in a fecal coliform model are those that govern peak flows and low flows. Peak flows, being a function of runoff, are important because they are directly related to the transport of fecal coliforms from the land surface to the stream. Peak flows were most sensitive to changes in the parameters governing infiltration such as INFILT (Infiltration) and UZSN (Upper Zone Storage) which govern surface transport, and by LZETP (Lower Zone Evapotranspiration) which affects soil moisture. To a lesser extent, the model was affected by LZSN (Lower Zone Storage) which also affects soil moisture. Low flows are important in a water quality model because they control the level of dilution during dry periods. Parameters with the greatest influence on low flows (as evidenced by their influence in the *Low Flows* and *Summer Flow Volume* statistics) were AGWRC (Groundwater Recession Rate), INFILT, CEPSC (interception), BASETP (Evapotranspiration from Base Flow), and, to a lesser extent DEEPFR (Losses to Deep Aquifers). The response of pertinent hydrologic outputs was recorded, and is reported in Table 4.8.

For the water quality sensitivity analysis, an initial base run was performed using precipitation data from water years 1993 through 1999 and model parameters established for 1995 conditions. The four parameters impacting the model's water quality response (Table 4.9) were increased and decreased by amounts that were consistent with the range of values for the parameter.

Since the water quality standard for fecal coliform bacteria is based on concentrations rather than loadings, it was considered necessary to analyze the effect of source changes on the monthly geometric-mean fecal coliform concentration. A monthly geometric mean was calculated for all months during the simulation period, and the value for each month was averaged. Deviations from the base run are given in Table 4.10 and plotted by month in Figure 4.6 through Figure 4.9.

In addition to analyzing the sensitivity of the model response to changes in model parameters, the response of the model to changes in land-based and direct loads was analyzed. The impacts of land-based and direct load changes on the annual load are presented in Figure 4.10, while impacts on the monthly geometric mean are presented in Figure 4.11 and Figure .

Table 4.7 Base parameter values used to determine hydrologic model response.

Parameter	Description	Units	Base Value
AGWRC	Active Groundwater Coefficient	1/day	0.98
BASETP	Base Flow Evapotranspiration	---	0.032
CEPSC	Interception Storage Capacity	in	0.1
DEEPFR	Fraction of Deep Groundwater	---	0.1
INFILT	Soil Infiltration Capacity	in/hr	0.052 – 0.1
INTFW	Interflow Inflow	---	0.75
KVARY	Groundwater Recession Coefficient	1/day	0.0
LZSN	Lower Zone Nominal Storage	in	6.5
MON-LZETPARM	Monthly Lower Zone Evapotranspiration	---	0.2 – 0.4
NSUR	Manning's *n* for Overland Flow	---	0.05 – 0.2
UZSN	Upper Zone Storage Capacity	in	1.128

Table 4.8 Sensitivity analysis results for hydrologic model parameters.

Model Parameter	Parameter Change (%)	% Change in Total Flow	High Flows	Low Flows	Winter Flow Volume	Spring Flow Volume	Summer Flow Volume	Fall Flow Volume	Total Storm Volume
AGWRC	-50	2.38	32.41	-48.26	13.97	-13.38	-0.86	6.70	10.45
AGWRC	-10	1.38	14.74	-29.88	11.05	-11.21	-2.20	5.32	6.87
AGWRC	1.5[1]	-3.32	-7.60	18.15	-10.65	-6.42	5.61	6.17	2.76
BASETP	-50	1.26	-0.74	6.06	-0.13	2.12	3.03	0.46	1.43
BASETP	-10	0.25	-.015	1.21	-0.03	0.42	0.61	0.07	0.28
BASETP	10	-0.24	0.15	-1.20	0.03	-0.42	0.61	0.07	-0.28
BASETP	50	-1.15	0.74	-5.58	0.11	-2.09	-2.74	-0.16	-1.34
CEPSC	-50	3.01	0.09	9.22	1.37	3.71	4.21	3.95	3.20
CEPSC	-10	0.61	-0.19	2.23	0.21	0.74	0.99	0.76	0.63
CEPSC	10	-0.28	-0.13	-0.57	-0.17	-0.37	-0.31	-0.33	-0.31
CEPSC	50	-1.41	-0.50	-3.22	-0.83	-1.84	-1.63	-1.71	-1.56
DEEPFR	-50	2.65	1.25	4.26	2.30	3.04	2.57	2.89	3.04
DEEPFR	-10	0.53	0.25	0.85	0.46	0.61	0.51	0.58	0.61
DEEPFR	10	-0.53	-0.25	-0.85	-0.46	-0.61	-0.51	-0.58	-0.61
DEEPFR	50	-2.65	-1.25	-4.25	-2.30	-3.04	-2.57	-2.88	-3.04
INFILT	-50	-0.86	14.71	-17.72	4.23	-3.42	-4.68	-2.88	-0.17
INFILT	-10	-0.19	2.06	-2.81	0.55	-0.50	-0.71	-0.66	-0.23
INFILT	10	0.20	-1.79	2.58	-0.45	0.42	0.66	0.66	0.23
INFILT	50	0.98	-7.05	11.10	-1.54	1.63	2.81	3.14	1.15
INTFW	-50	-0.79	-0.53	1.39	-2.15	0.60	0.26	-1.52	-0.93
INTFW	-10	-0.15	-0.05	0.22	-0.31	0.07	0.00	-0.36	-0.18
INTFW	10	0.14	0.08	-0.23	0.28	-0.05	0.00	0.33	0.17
INTFW	50	0.57	0.65	-1.13	1.20	-0.22	-0.05	1.36	0.65
KVARY	+2.5[1]	1.06	16.16	-27.87	12.77	-12.82	-2.36	2.19	5.29
KVARY	+5.0[1]	1.36	20.02	-32.89	13.46	-13.85	-2.46	4.40	6.58
LZSN	-50	3.79	7.77	-1.23	10.10	3.70	-4.31	0.93	4.07
LZSN	-10	0.66	1.12	0.13	1.45	0.85	-0.38	-0.01	0.57
LZSN	10	-0.64	-1.00	-0.25	-1.27	-0.88	0.21	0.04	-0.61
LZSN	50	-2.99	-4.14	-2.28	-5.04	-4.41	0.08	-0.25	-3.00
MON-LZETP	-50	9.03	14.28	5.13	10.17	4.67	6.81	17.05	10.47
MON-LZETP	-10	2.01	2.36	2.45	1.89	1.02	2.01	3.99	2.31
MON-LZETP	10	-2.11	-2.27	-3.02	-1.88	-1.08	-2.35	-4.07	-2.45
MON-LZETP	50	-7.73	-7.75	-11.93	-7.06	-4.43	-8.41	-13.94	-7.68
NSUR	-50	0.46	2.64	-1.47	0.64	0.68	0.04	0.25	0.54
NSUR	-10	0.07	0.41	-0.21	0.09	0.09	0.02	0.04	0.08
NSUR	10	-0.06	-0.37	0.20	-0.08	-0.09	-0.01	-0.04	-0.07
NSUR	50	-0.27	-1.63	0.84	-0.36	-0.37	-0.08	-0.14	-0.32
UZSN	-50	5.91	14.86	-1.47	5.14	6.61	5.65	6.94	6.87
UZSN	-10	0.92	2.20	-0.10	0.89	0.91	0.90	1.02	1.06
UZSN	10	-0.83	-1.94	0.03	-0.84	-0.79	-0.82	-0.89	-0.96
UZSN	50	-3.54	-7.99	-0.27	-3.78	-3.15	-3.62	-3.48	-4.09

[1]Maximum value used corresponds to the maximum allowable value for the parameter.

Table 4.9 Base parameter values used to determine water quality model response.

Parameter	Description	Units	Base Value
MON-SQOLIM	Maximum FC Accumulation on Land	FC/ac	0.00E+00 – 1.10E
WSQOP	Wash-off Rate for FC on Land Surface	in/hr	1.00E-02 – 3.2E+0
MON-IFLW-CONC	FC Interflow Concentration	FC/ft^3	0 – 1.8E+06
FSTDEC	In-stream First Order Decay Rate	1/day	0.01 - 10

Table 4.10 Percent change in average monthly FC geometric mean for the years 1993-1998.

Model Parameter	Parameter Change (%)	Percent Change in Average Monthly FC Geometric Mean for the Years 1993 -1998											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
FSTDEC	-50	20.8	20.9	20.8	20.7	20.3	20.5	19.4	18.8	18.0	15.8	18.0	19.9
FSTDEC	-10	3.5	3.6	3.5	3.5	3.5	3.5	3.3	3.1	3.0	2.6	3.0	3.4
FSTDEC	10	-3.3	-3.3	-3.3	-3.3	-3.2	-3.2	-3.0	-2.9	-2.8	-2.4	-2.8	-3.1
FSTDEC	50	-14.5	-14.7	-14.5	-14.3	-14.1	-14.2	-13.3	-12.7	-12.2	-10.5	-12.0	-13.6
MON-IFLW CONC	-100	-76.2	-78.1	-64.7	-42.7	-45.7	-43.1	-19.9	-24.7	-22.6	-7.5	-22.8	-51.9
MON-IFLW CONC	-50	-31.4	-34.6	-27.1	-18.6	-19.9	-17.9	-8.0	-9.9	-9.8	-3.3	-9.0	-22.5
MON-IFLW CONC	50	22.4	26.8	20.6	14.3	17.9	18.4	8.5	8.5	7.5	2.8	6.4	16.8
MON-IFLW CONC	100	64.5	70.1	51.4	35.0	39.3	34.6	13.6	16.8	18.0	5.4	15.6	45.8
SQOLIM	-50	-5.7	-2.5	-2.7	-2.1	-3.2	-6.1	-2.0	-2.4	-2.8	-1.5	-5.3	-5.6
SQOLIM	-25	-2.6	-1.0	-1.0	-0.9	-1.4	-2.6	-0.8	-0.9	-1.2	-0.5	-2.3	-2.7
SQOLIM	50	5.5	2.0	1.3	1.0	1.6	3.5	1.0	1.2	1.9	0.8	4.0	4.8
SQOLIM	100	10.4	3.7	2.2	1.6	2.7	5.8	1.6	2.0	3.3	1.3	6.6	8.2
WSQOP	-50	7.0	5.7	6.3	6.0	7.5	7.9	3.9	2.8	3.8	3.0	8.4	8.1
WSQOP	-10	1.0	0.8	0.9	0.8	1.0	1.1	0.5	0.4	0.6	0.4	1.2	1.2
WSQOP	10	-0.9	-0.8	-0.8	-0.7	-0.9	-1.0	-0.5	-0.4	-0.5	-0.4	-1.0	-1.0
WSQOP	50	-3.7	-3.1	-3.1	-2.9	-3.7	-4.0	-2.0	-1.6	-2.0	-1.5	-4.1	-4.1

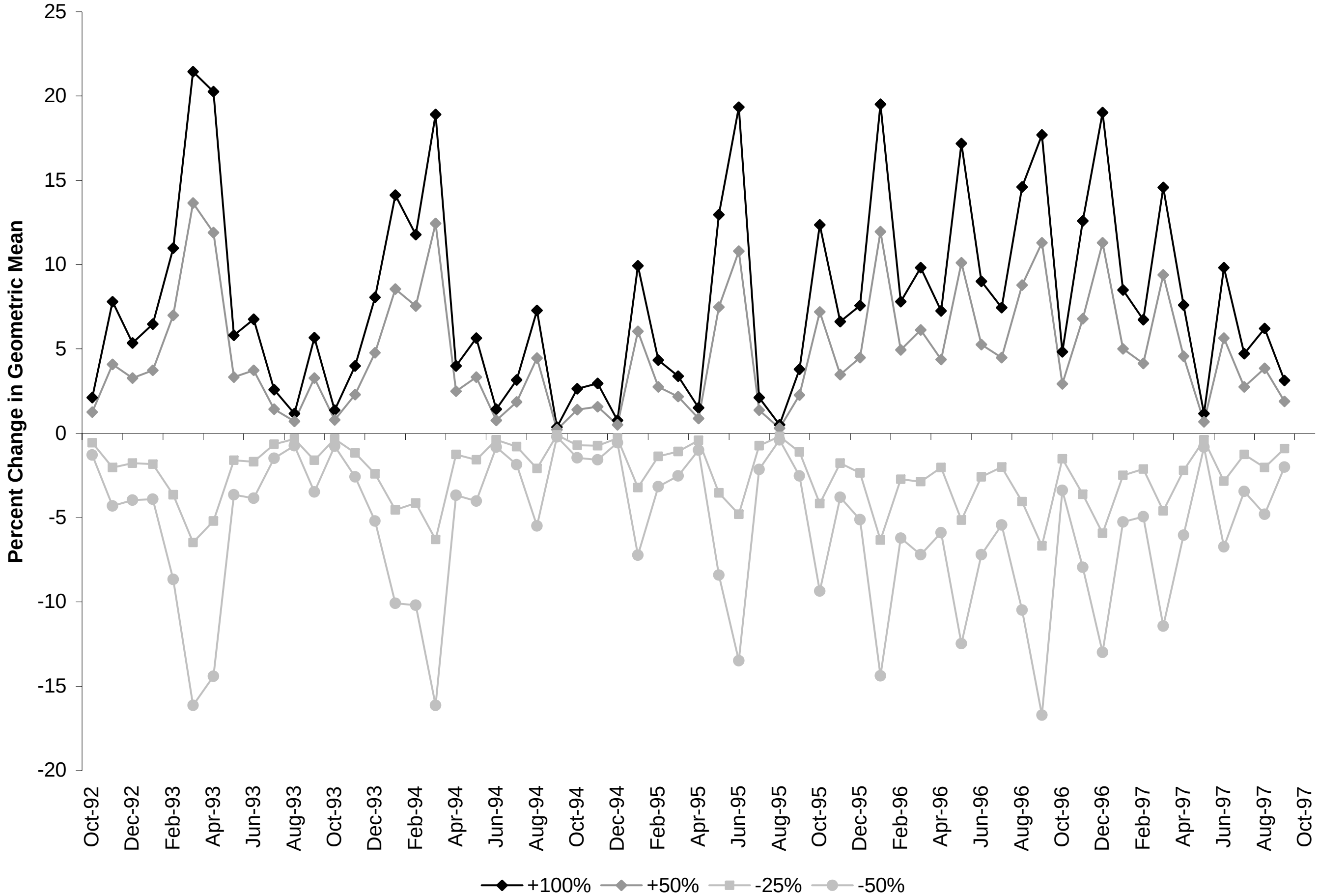

Figure 4.6 **Results of sensitivity analysis on monthly geometric-mean concentrations in the Middle River watershed, as affected by changes in maximum FC accumulation on land (MON-SQOLIM).**

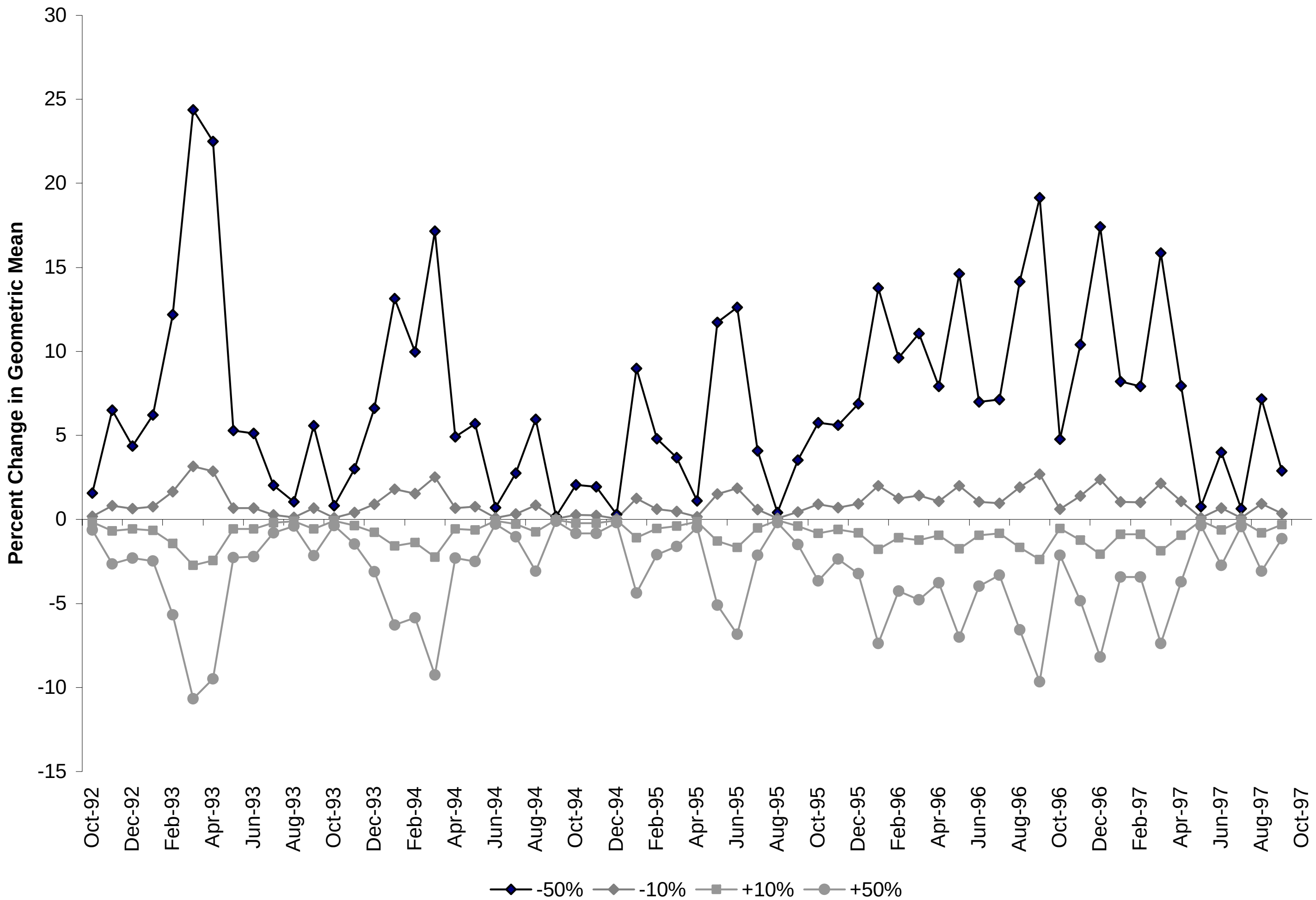

Figure 4.7 **Results of sensitivity analysis on monthly geometric-mean concentrations in the Middle River watershed, as affected by changes in the wash-off rate for FC fecal coliform on land surfaces (WSQOP).**

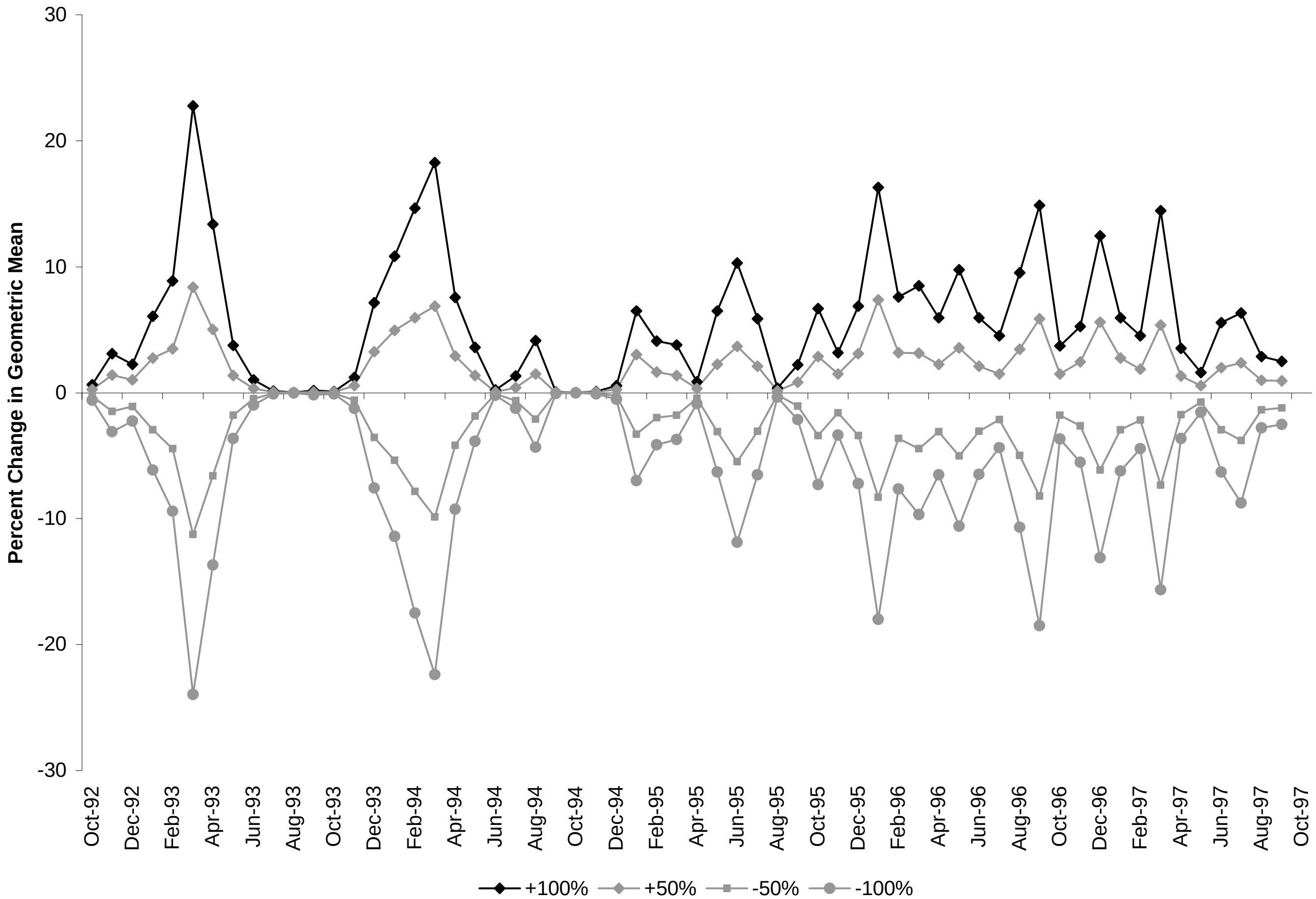

Figure 4.8 **Results of sensitivity analysis on monthly geometric-mean concentrations in the Middle River watershed, as affected by changes in the concentration of fecal coliform in interflow (IFLW).**

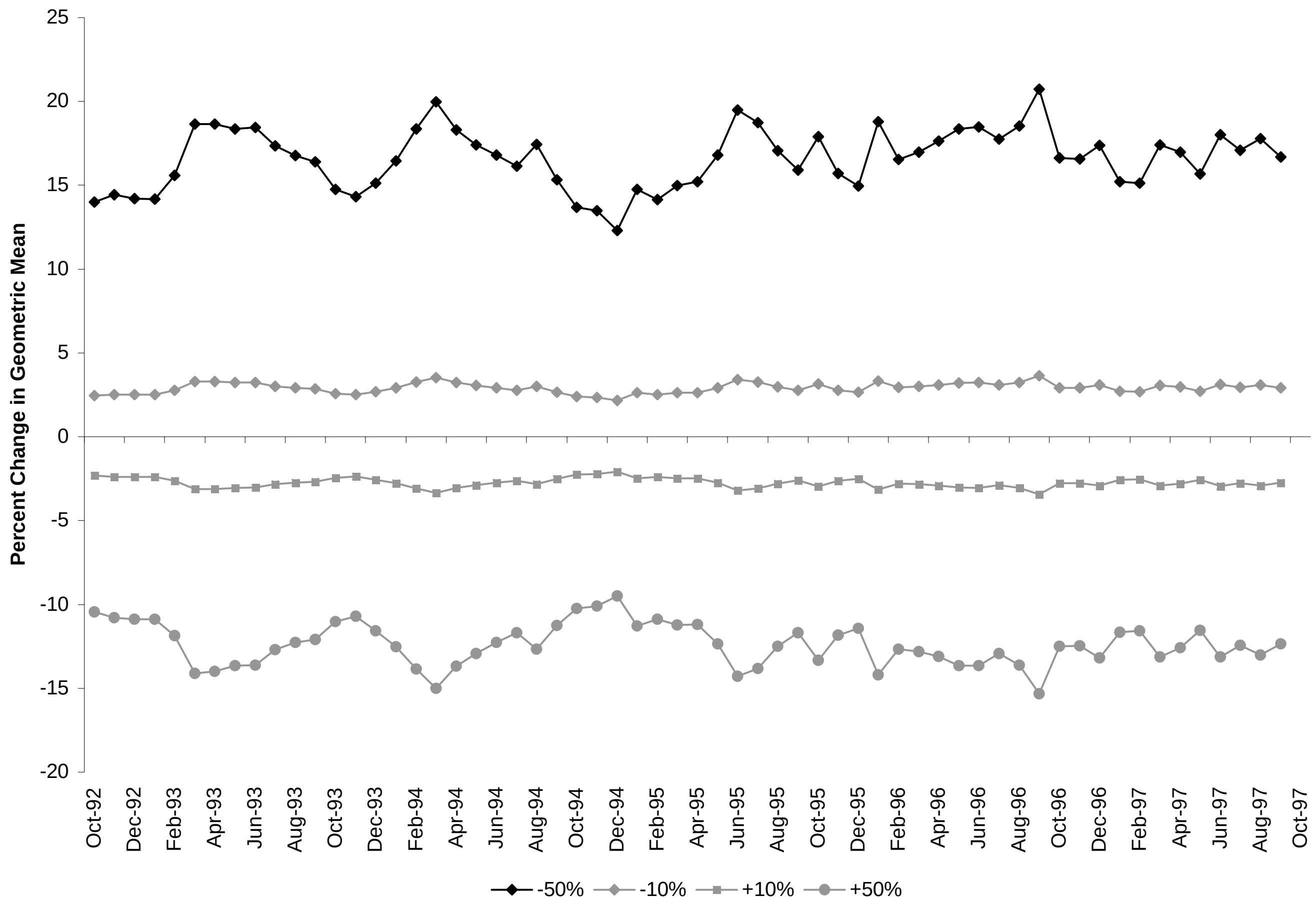

Figure 4.9 Results of sensitivity analysis on monthly geometric-mean concentrations in the Middle River watershed, as affected by changes in the in-stream first-order decay rate (FSTDEC).

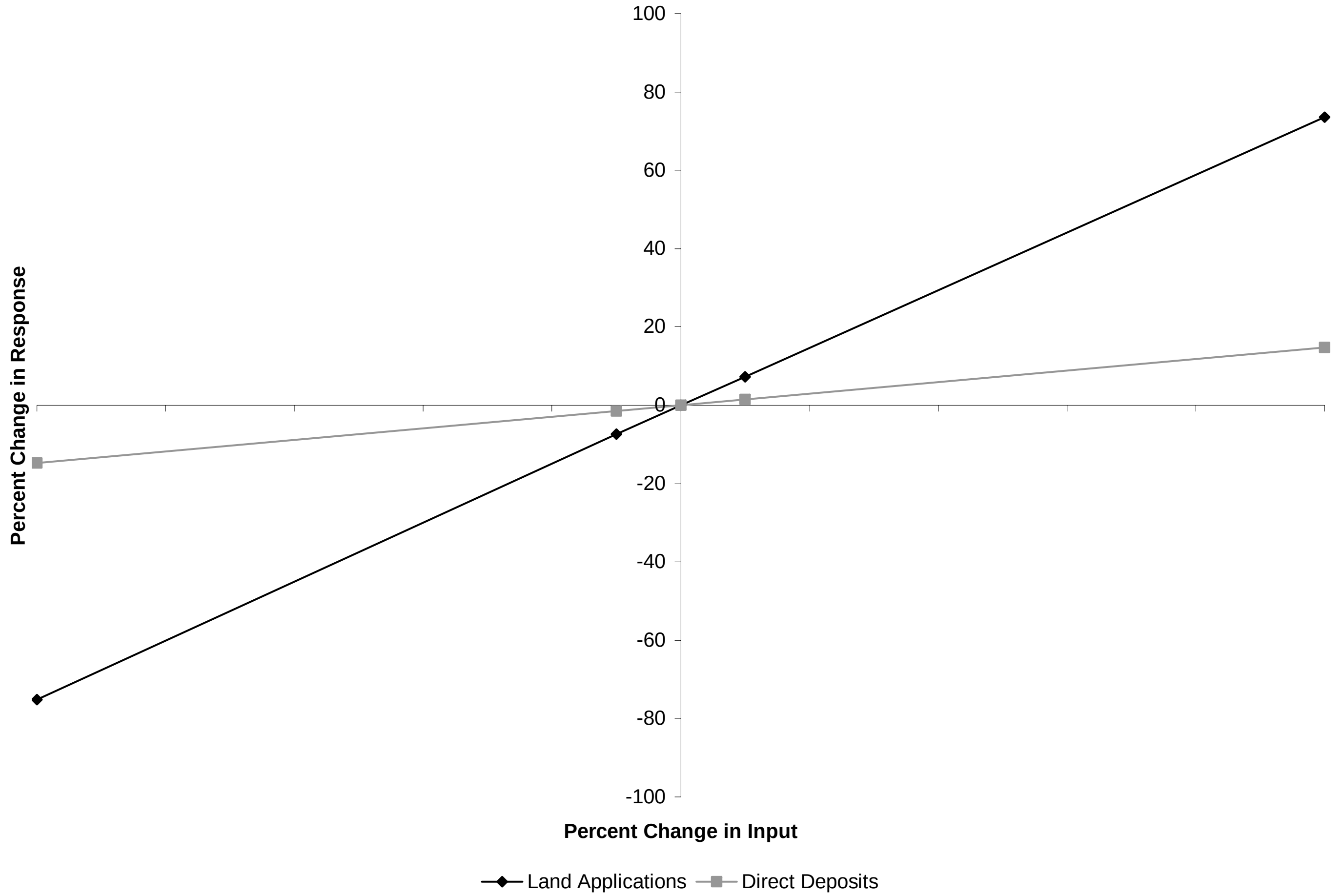

Figure 4.10 Total loading sensitivity to changes in direct and land-based loads for the Middle River watershed.

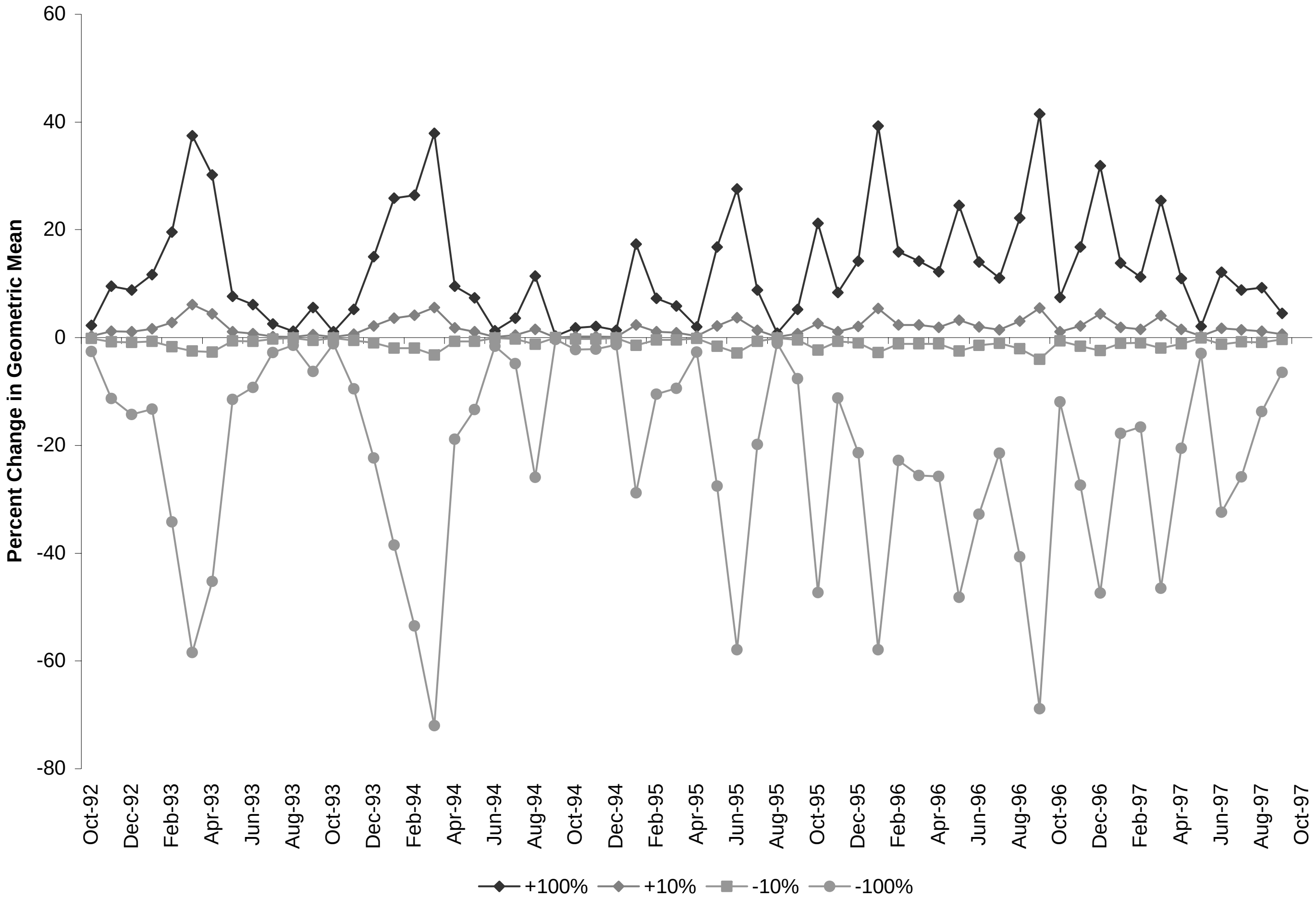

Figure 4.11 Results of sensitivity analysis on monthly geometric-mean concentrations in the Middle River watershed, as affected by changes in land-based loadings.

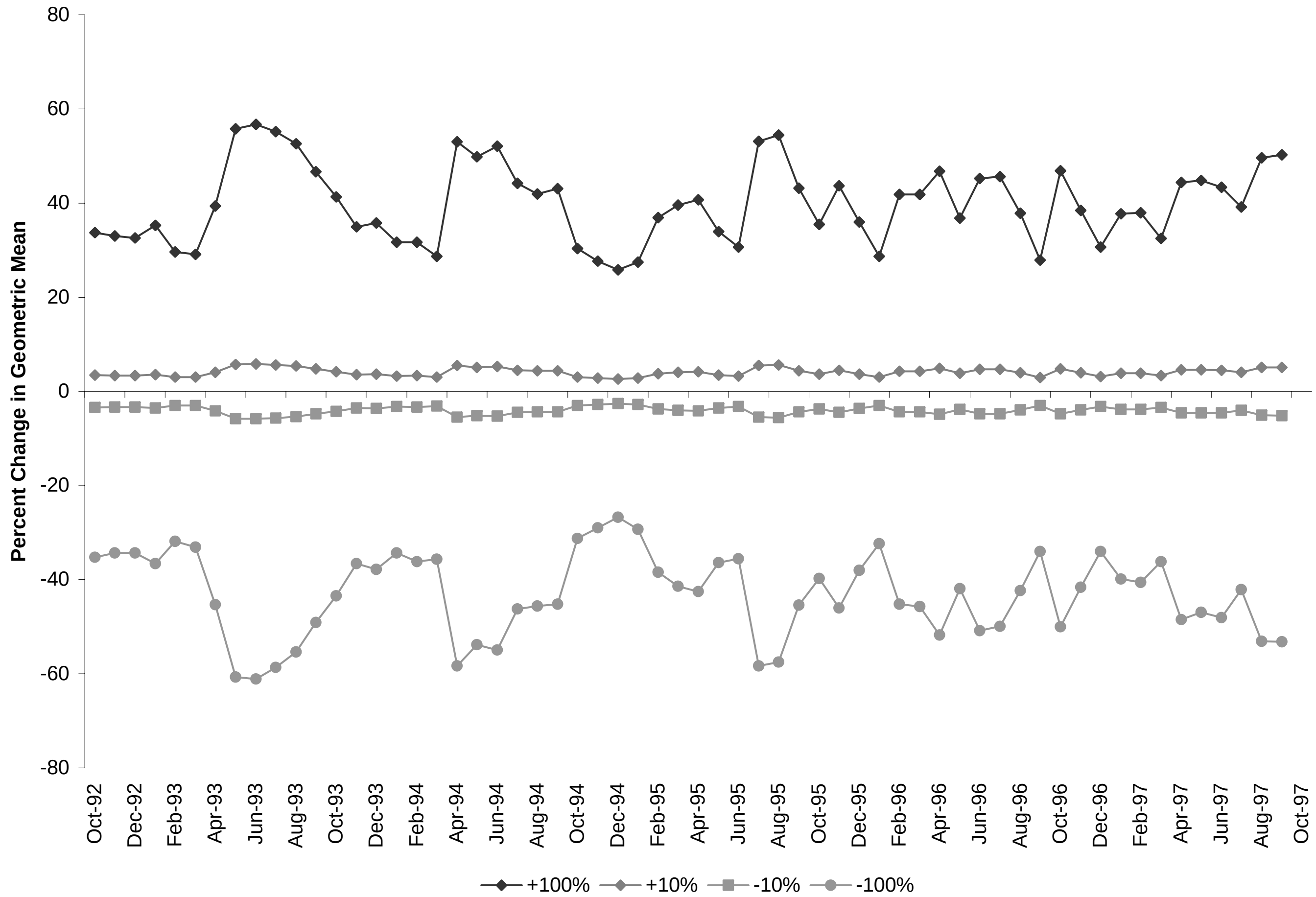

Figure 4.12 Results of sensitivity analysis on monthly geometric-mean concentrations in the Middle River watershed, as affected by changes in loadings from direct nonpoint sources.

4.7 Model Calibration and Validation Processes

Calibration and validation are performed in order to ensure that the model accurately represents the hydrologic and water quality processes in the watershed. The model's hydrologic parameters were set based on available soils, landuse, and topographic data. Qualities of fecal coliform sources were modeled as described in chapters 3 and 4. Through calibration, these parameters were adjusted within appropriate ranges until the model performance was deemed acceptable.

Calibration is the process of comparing modeled data to observed data and making appropriate adjustments to model parameters to minimize the error between observed and simulated events. Using observed data that is reported at a shorter time-step improves this process and, subsequently, the performance of a time-dependent model. Validation is the process of comparing modeled data to observed data during a period other than that used for calibration. During validation, no adjustments are made to model parameters. The goal of validation is to assess the capability of the model in hydrologic conditions other than those used during calibration.

4.7.1 Hydrologic Calibration and Validation

Parameters that were adjusted during the hydrologic calibration represented the amount of evapotranspiration from the root zone (MON-LZE), the recession rates for groundwater (AGWRC), the amount of soil moisture storage in the upper zone (MON-UZS) and lower zone (MON-LZE), the infiltration capacity (INFILT), baseflow PET (BASETP), forest coverage (FOREST), and Manning's n for overland flow plane (MON-MAN). Table 4.11 contains the typical range for the above parameters along with the initial estimate and final calibrated value. Specific values for each calibrated parameter are given in the excerpt from the calibrated UCI in Appendix F.

The results of calibration and validation for Middle and South River are presented in Table 4.12 through Table 4.15 and Figure 4.13 through Figure 4.24. The model was calibrated/validated for hydrologic accuracy using 30-minute flow data from USGS Station #01625000 (Middle River at Grottoes) and USGS Station #01626000 (South

River near Waynesboro). The distribution of flow volume between surface runoff, interflow, and groundwater was 20%, 14%, and 66%, respectively, for Middle River; and 17%, 26%, and 57%, respectively, for South River. Acceptable values of error (%) vary with the parameter being assessed. Parameters that represent the long-term response of the model are held to a higher standard than parameters that are more temporally specific. For instance, the error associated with "Total In-stream Flow" is a measure of the long-term accuracy of the model and is expected to be less than 10%; however, the errors associated with seasonal "Storm Volumes" measure the accuracy of the model for specific storms within seasons and are expected to be less than 50%. The errors reported for calibration and validation are all within acceptable limits and the hydrologic model is considered to be an accurate representation of the system.

Table 4.11 Model parameters utilized for hydrologic calibration.

Parameter	Units	Typical Range of Parameter Value	Initial Parameter Estimate	Calibrated Parameter Value
FOREST	---	0.0 – 0.95	0.0	0.0-1.0
LZSN	in	2.0 – 15.0	1.5	6.5
INFILT	in/hr	0.001 – 0.50	0.01 – 0.354	0.052 – 0.1
LSUR	ft	100 – 700	100-3500	100 – 3500
SLSUR	---	0.001 – 0.30	0.001 –0.2849	0.001 – 0.2849
KVARY	1/in	0.0 – 5.0	0.0	0.0
AGWRC	1/day	0.85 – 0.999	0.97 – 0.98	0.98
PETMAX	deg F	32.0 – 48.0	40.0	40.0
PETMIN	deg F	30.0 – 40.0	35.0	35.0
INFEXP	---	1.0 – 3.0	2.0	2.0
INFILD	---	1.0 – 3.0	2.0	2.0
DEEPFR	---	0.0 – 0.50	0.1	0.1
BASETP	---	0.0 – 0.20	0.02	0.033
AGWETP	---	0.0 – 0.20	0.0	0.0
INTFW	---	1.0 – 10.0	0.75	0.75
IRC	1/day	0.30 – 0.85	0.5	0.5
MON-INT	in	0.01 - 0.40	0.1	0.1
MON-UZS	in	0.05 – 2.0	1.92 – 2.068	1.00-1.18
MON-LZE	---	0.1 – 0.9	0.2 – 0.65	0.2-0.4
MON-MAN		0.10 – 0.50	1.92 – 2.068	0.1
RETSC	in	0.0 – 1.0	0.1	0.1
KS	---	0.0 – 0.9	0.5	0.5

Table 4.12 Hydrology calibration criteria and model performance for Middle River for the period 9/30/92 through 9/30/97.

Criterion	Observed	Modeled	Error
Total In-stream Flow:	103.8201	97.9823	-5.62%
Upper 10% Flow Values:	45.1386	42.2267	-6.45%
Lower 50% Flow Values:	17.1719	17.4462	1.60%
Winter Flow Volume	45.7505	36.5536	-20.10%
Spring Flow Volume	24.0469	23.5158	-2.21%
Summer Flow Volume	17.7456	22.1090	24.59%
Fall Flow Volume	16.2771	15.8039	-2.91%
Total Storm Volume	82.1823	80.5467	-1.99%
Winter Storm Volume	40.4048	32.2458	-20.19%
Spring Storm Volume	18.6506	19.1661	2.76%
Summer Storm Volume	12.2981	17.7028	43.95%
Fall Storm Volume	10.8288	11.4320	5.57%

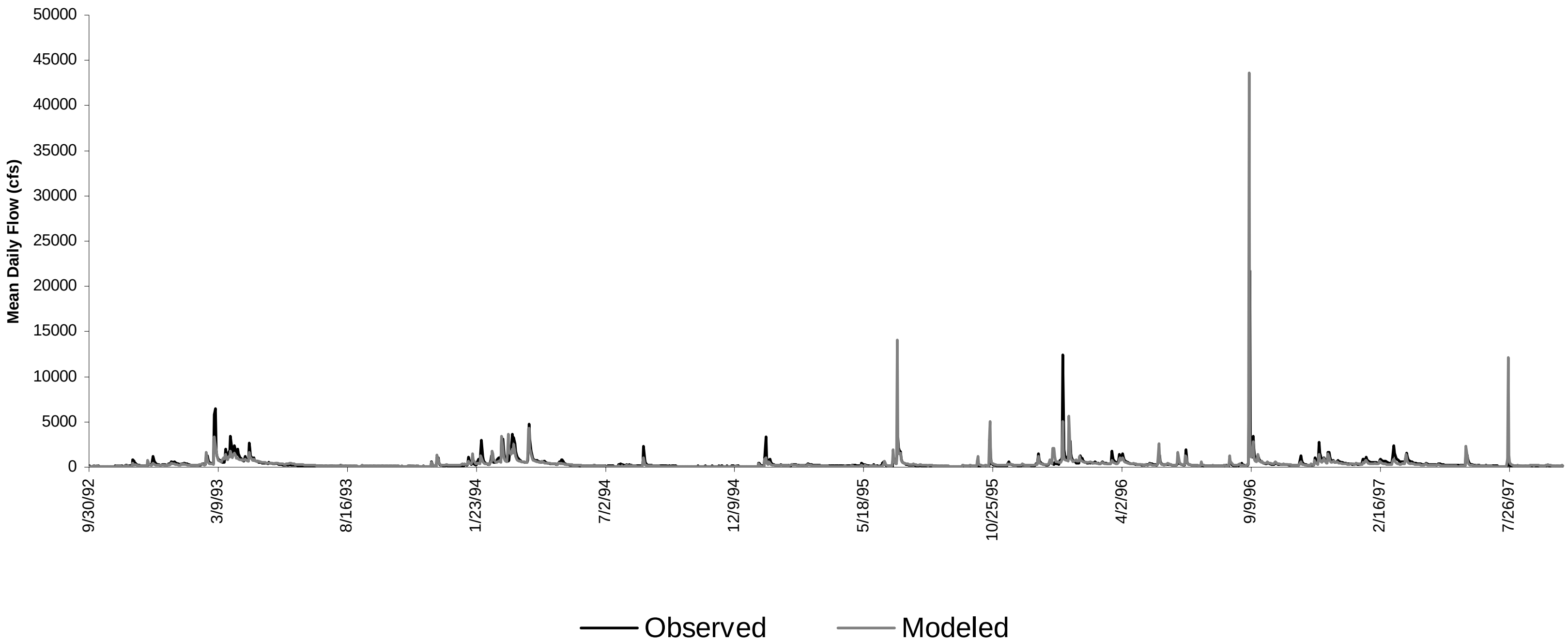

Figure 4.13 Calibration results for Middle River for the period 9/30/92 through 9/30/97.

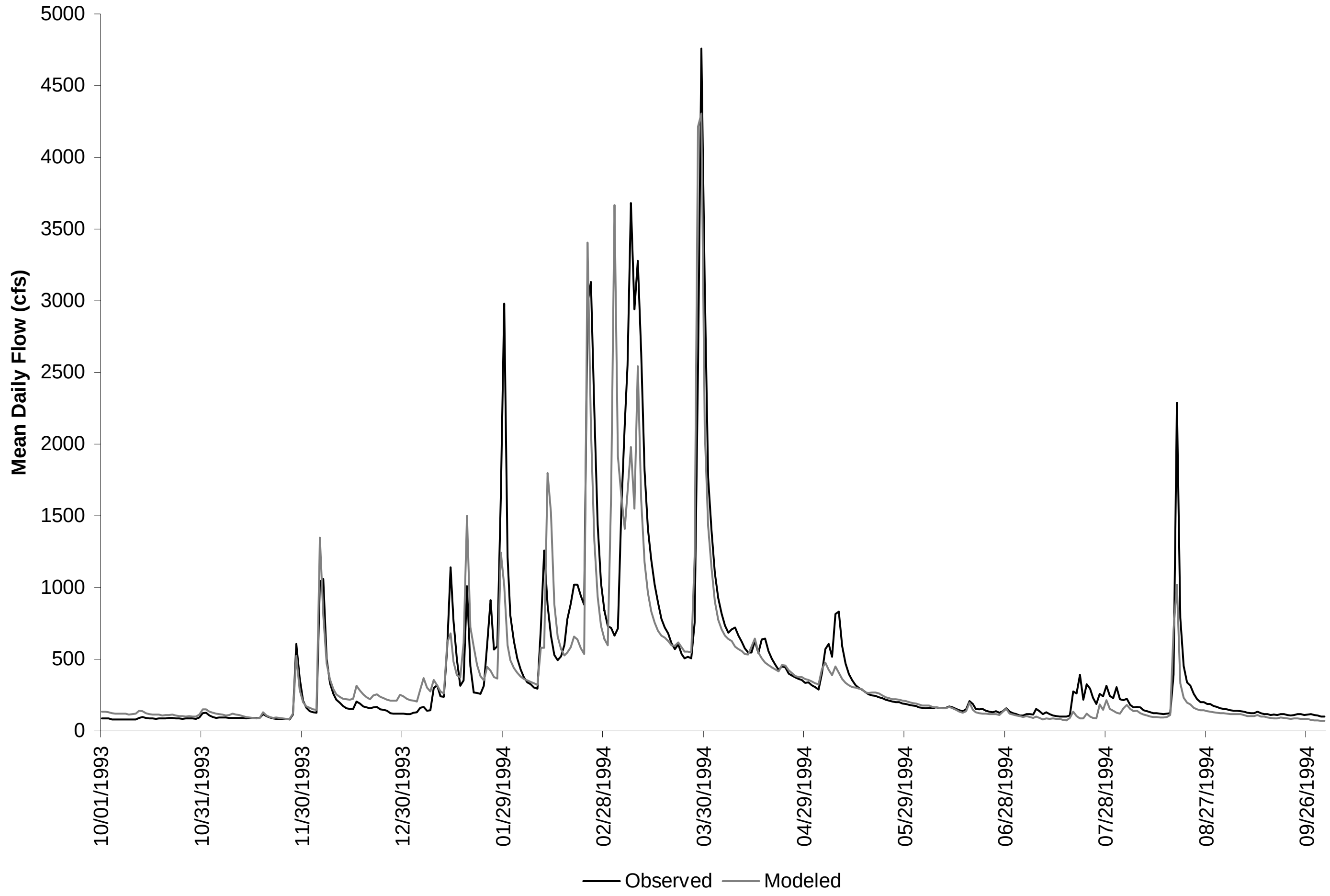

Figure 4.14 Calibration results for Middle River for the period 10/1/93 through 9/26/94.

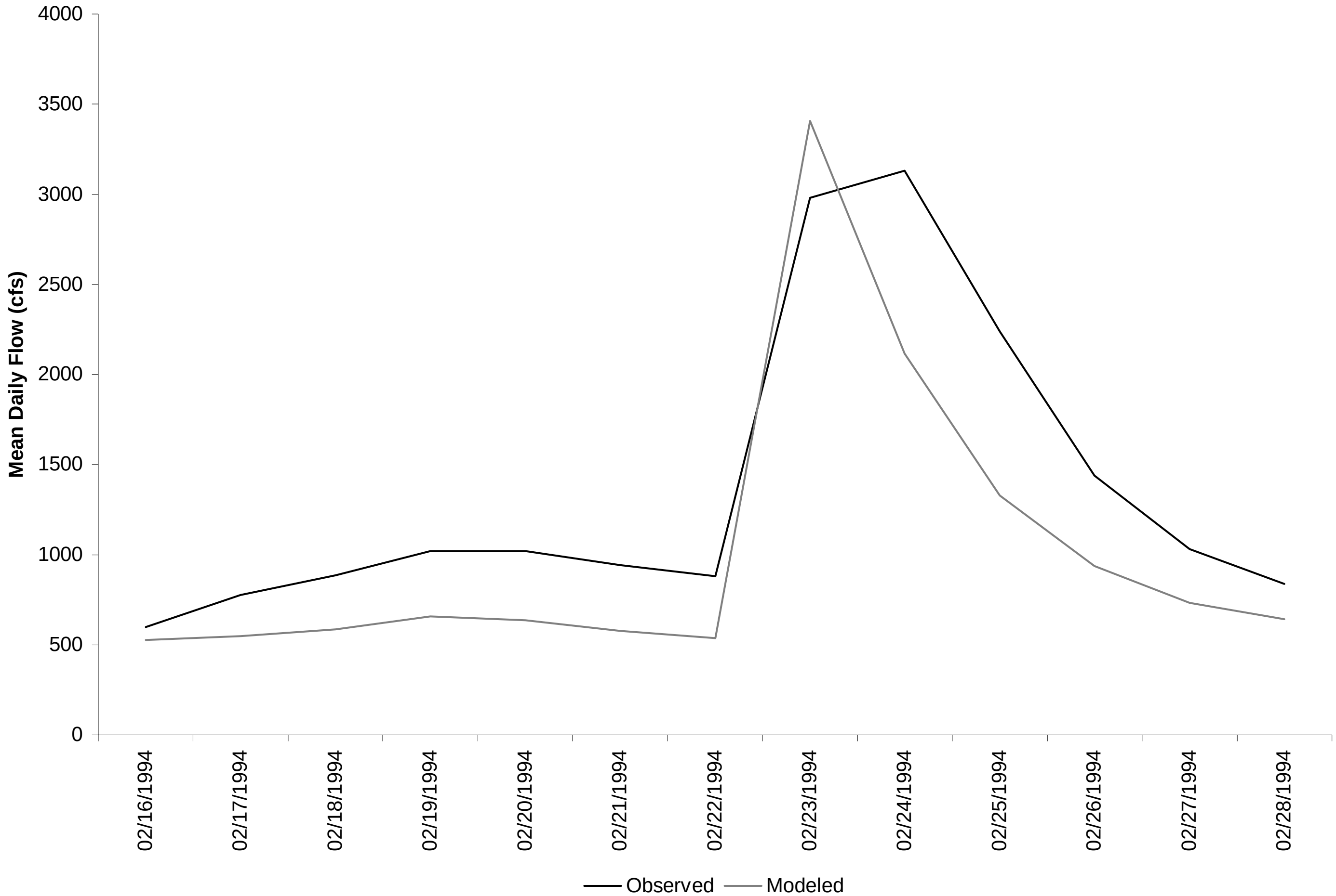

Figure 4.15 Calibration results for a single storm event for Middle River.

Table 4.13 Hydrology validation criteria and model performance for Middle River period 9/30/85 through 9/8/90.

Criterion	Observed	Modeled	Error
Total In-stream Flow:	87.3110	72.6406	-16.80%
Upper 10% Flow Values:	35.7036	23.2434	-34.90%
Lower 50% Flow Values:	16.6590	17.9655	7.84%
Winter Flow Volume	23.1849	18.1280	-21.81%
Spring Flow Volume	27.2861	20.0421	-26.55%
Summer Flow Volume	13.2657	16.4767	24.21%
Fall Flow Volume	23.5742	17.9938	-23.67%
Total Storm Volume	68.7272	57.1322	-16.87%
Winter Storm Volume	18.5912	14.2874	-23.15%
Spring Storm Volume	22.6516	16.1774	-28.58%
Summer Storm Volume	8.5891	12.5901	46.58%
Fall Storm Volume	18.8953	14.0773	-25.50%

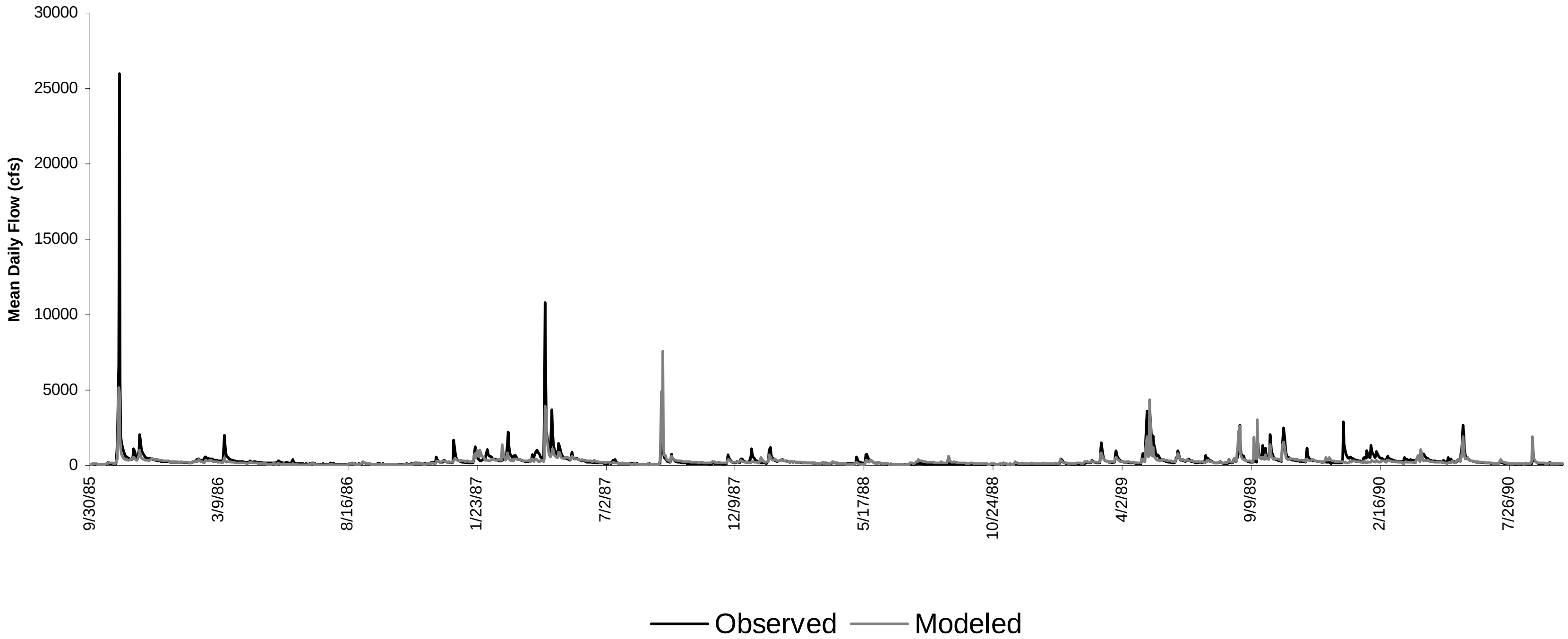

Figure 4.16 Validation results for Middle River for the period 9/30/85 through 9/30/90.

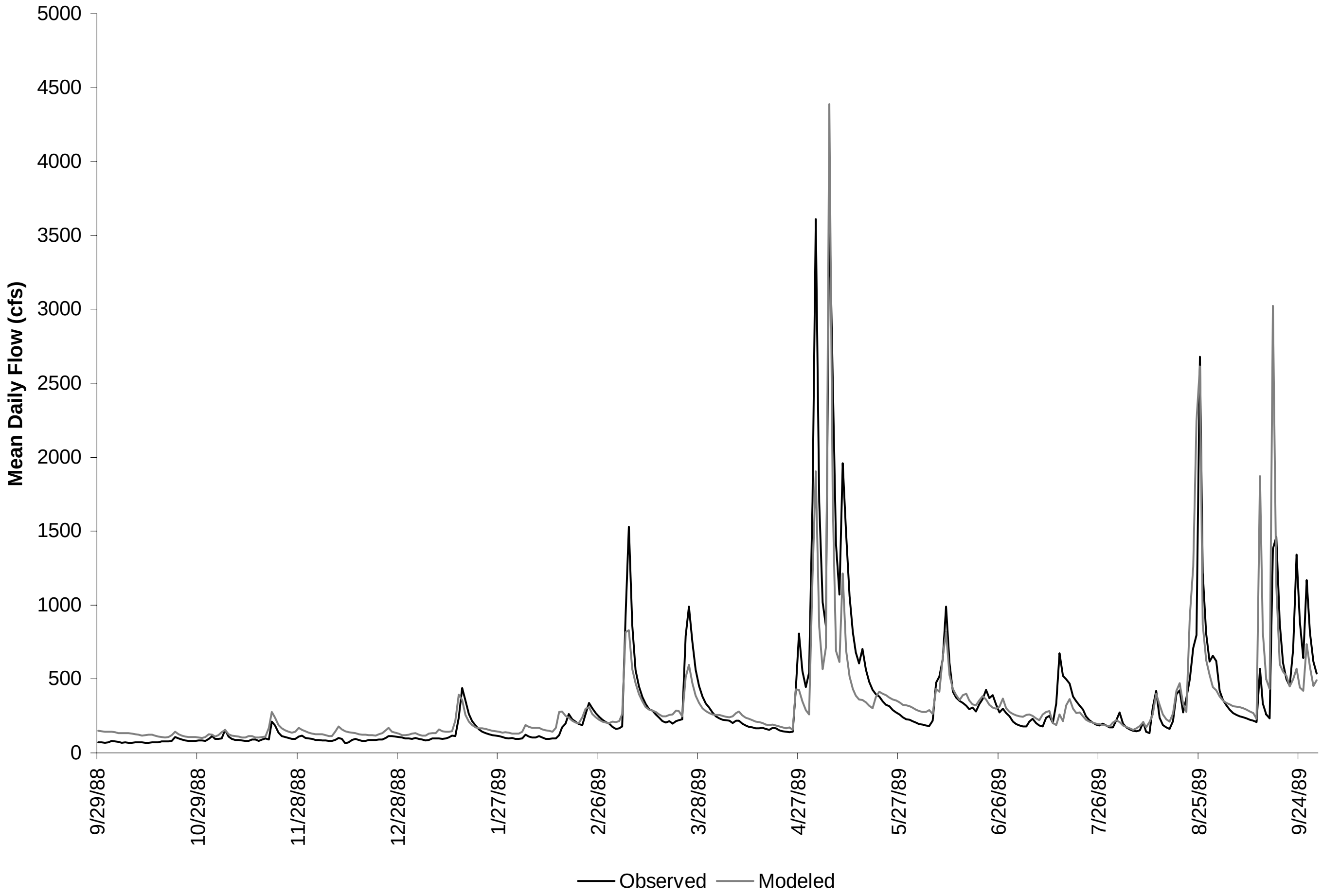

Figure 4.17 Validation results for Middle River for the period 9/29/88 through 9/30/89.

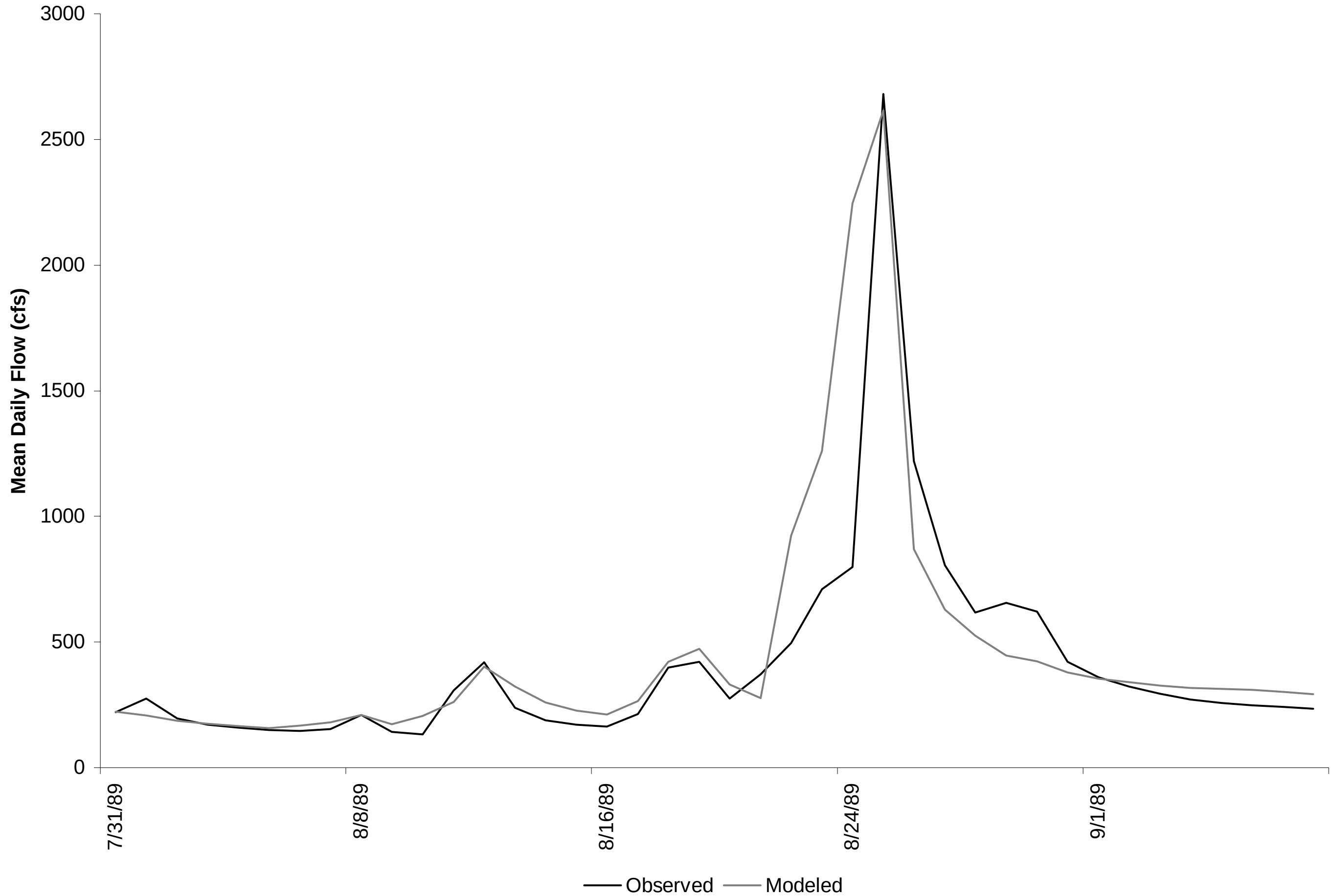

Figure 4.18 Validation results for a single storm for Middle River.

Table 4.14 Hydrology calibration criteria and model performance for South River for the period 9/30/93 through 9/30/97.

Criterion	Observed	Modeled	Error
Total In-stream Flow:	95.2180	85.6326	-10.07%
Upper 10% Flow Values:	41.5463	34.6300	-16.65%
Lower 50% Flow Values:	15.5484	17.7163	13.94%
Winter Flow Volume	39.7836	30.8535	-22.45%
Spring Flow Volume	23.8922	21.4487	-10.23%
Summer Flow Volume	13.5288	16.4569	21.64%
Fall Flow Volume	18.0135	16.8735	-6.33%
Total Storm Volume	77.5420	65.3787	-15.69%
Winter Storm Volume	35.4173	25.8380	-27.05%
Spring Storm Volume	19.4872	16.3912	-15.89%
Summer Storm Volume	9.0683	11.3814	25.51%
Fall Storm Volume	13.5692	11.7681	-13.27%

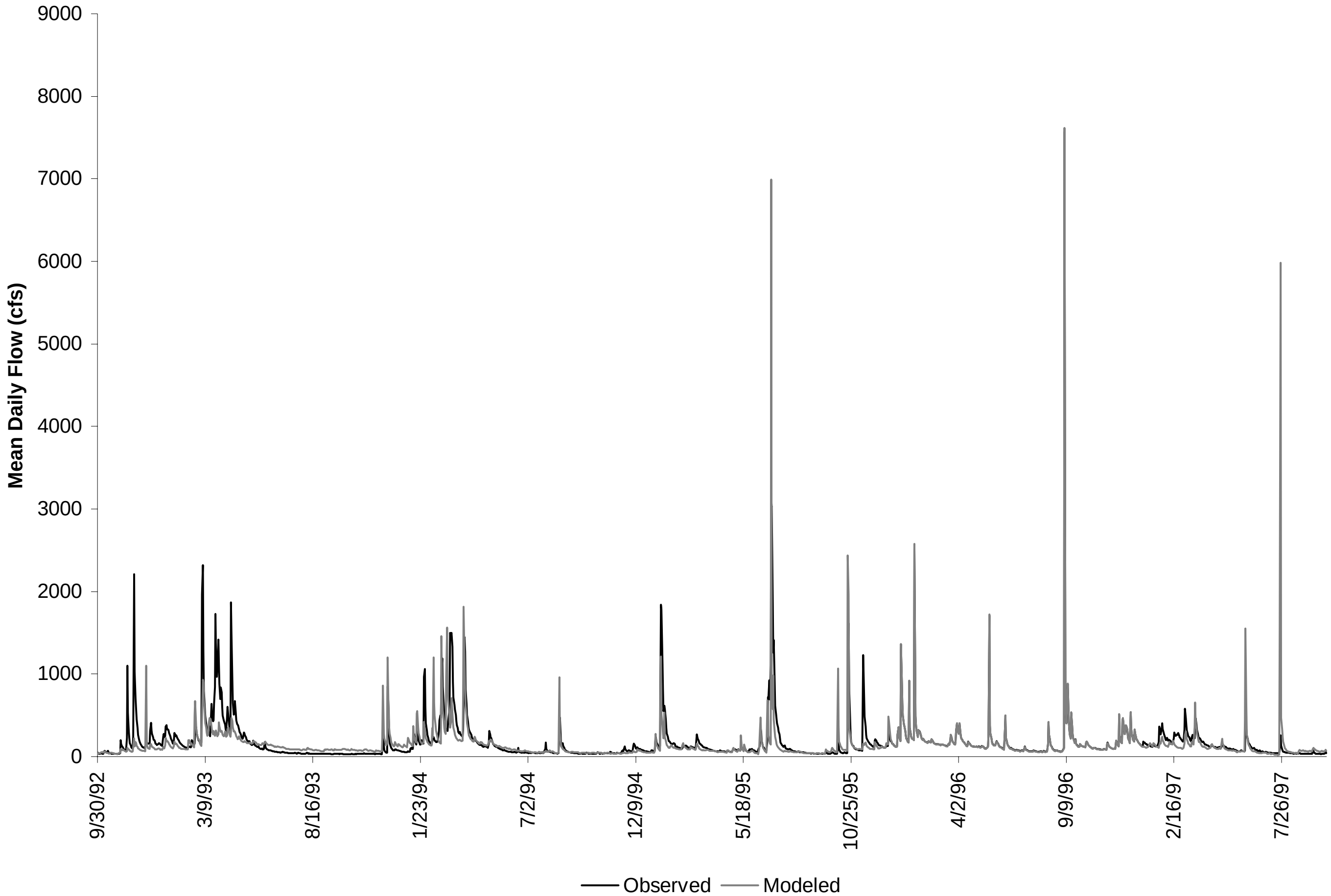

Figure 4.19 Calibration results for South River for the period 9/30/92 through 9/30/97.

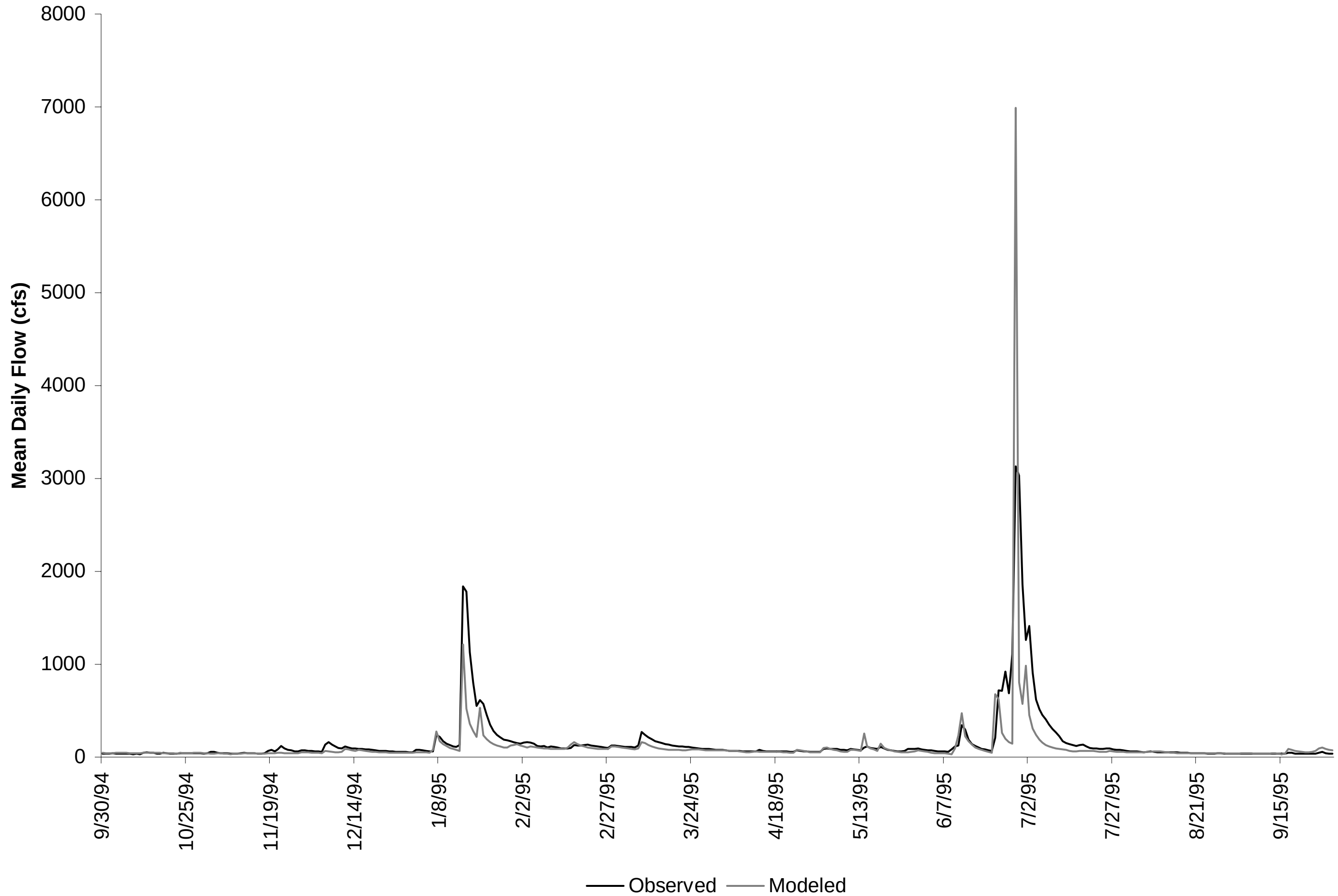

Figure 4.20 Calibration results for South River for the period 9/30/94 through 9/30/95.

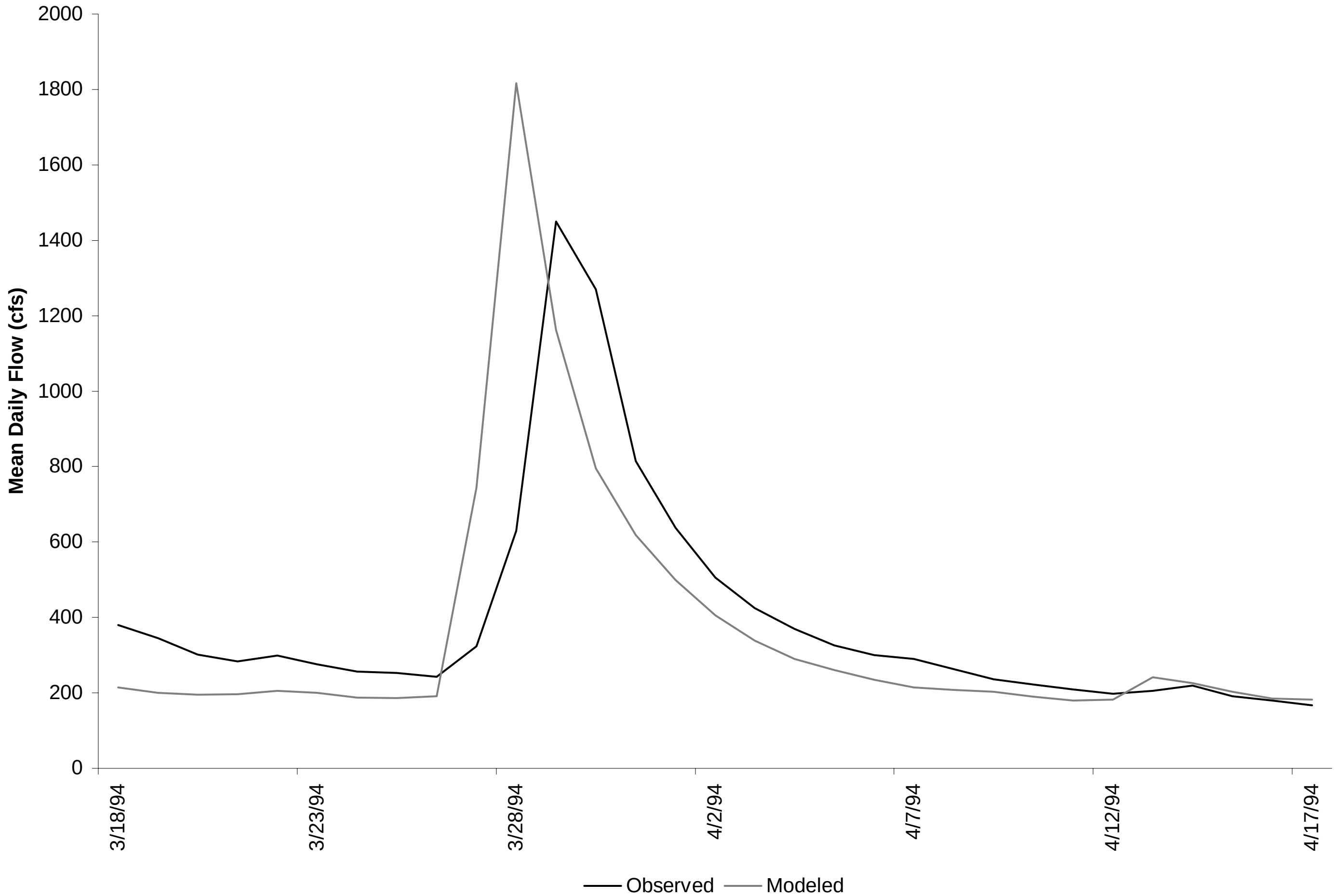

Figure 4.21 Calibration results for a single storm event for South River.

Table 4.15 Hydrology validation criteria and model performance for South River for the period 9/30/85 through 9/8/90.

Criterion	Observed	Modeled	Error
Total In-stream Flow:	41.5912	36.2925	-12.74%
Upper 10% Flow Values:	18.9966	13.3819	-29.56%
Lower 50% Flow Values:	6.8461	8.3186	21.51%
Winter Flow Volume	9.8902	9.7576	-1.34%
Spring Flow Volume	14.0497	10.2828	-26.81%
Summer Flow Volume	5.5692	7.1501	28.39%
Fall Flow Volume	12.0821	9.1019	-24.67%
Total Storm Volume	34.2077	30.7663	-10.06%
Winter Storm Volume	8.0653	8.3795	3.90%
Spring Storm Volume	12.2086	8.8925	-27.16%
Summer Storm Volume	3.7040	5.7976	56.52%
Fall Storm Volume	10.2298	7.6967	-24.76%

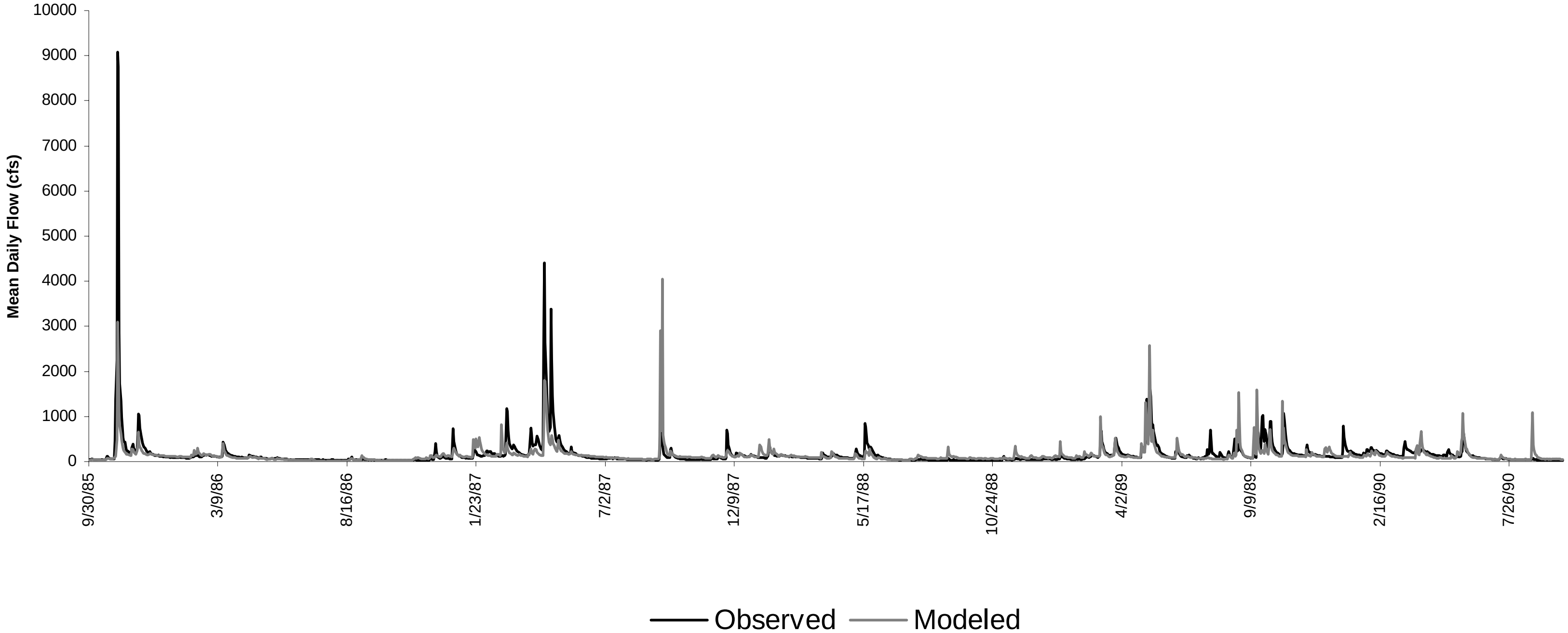

Figure 4.22 Validation results for South River for the period 9/30/85 through 9/8/90.

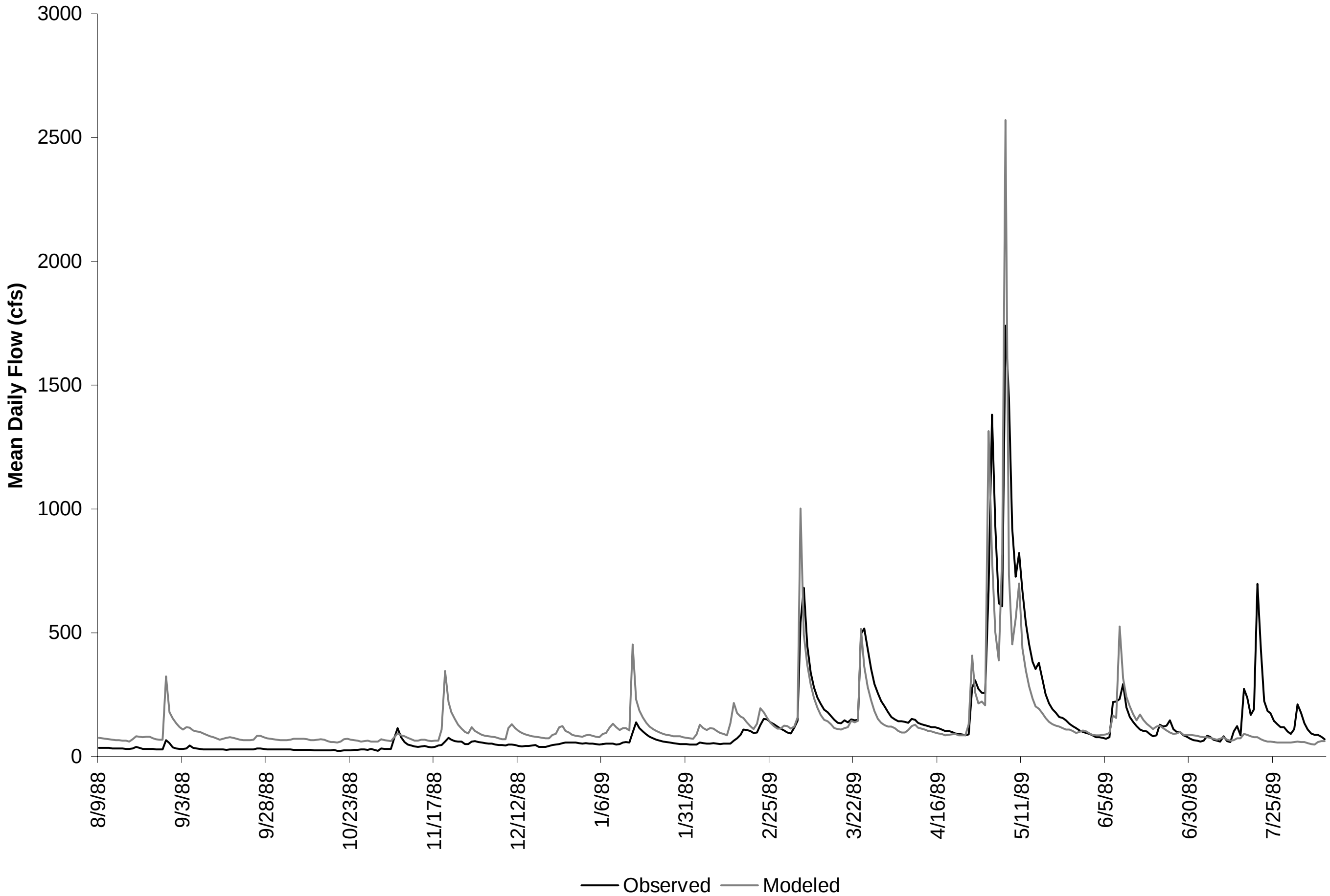

Figure 4.23 Validation results for South River for the period 9/30/88 through 9/30/89.

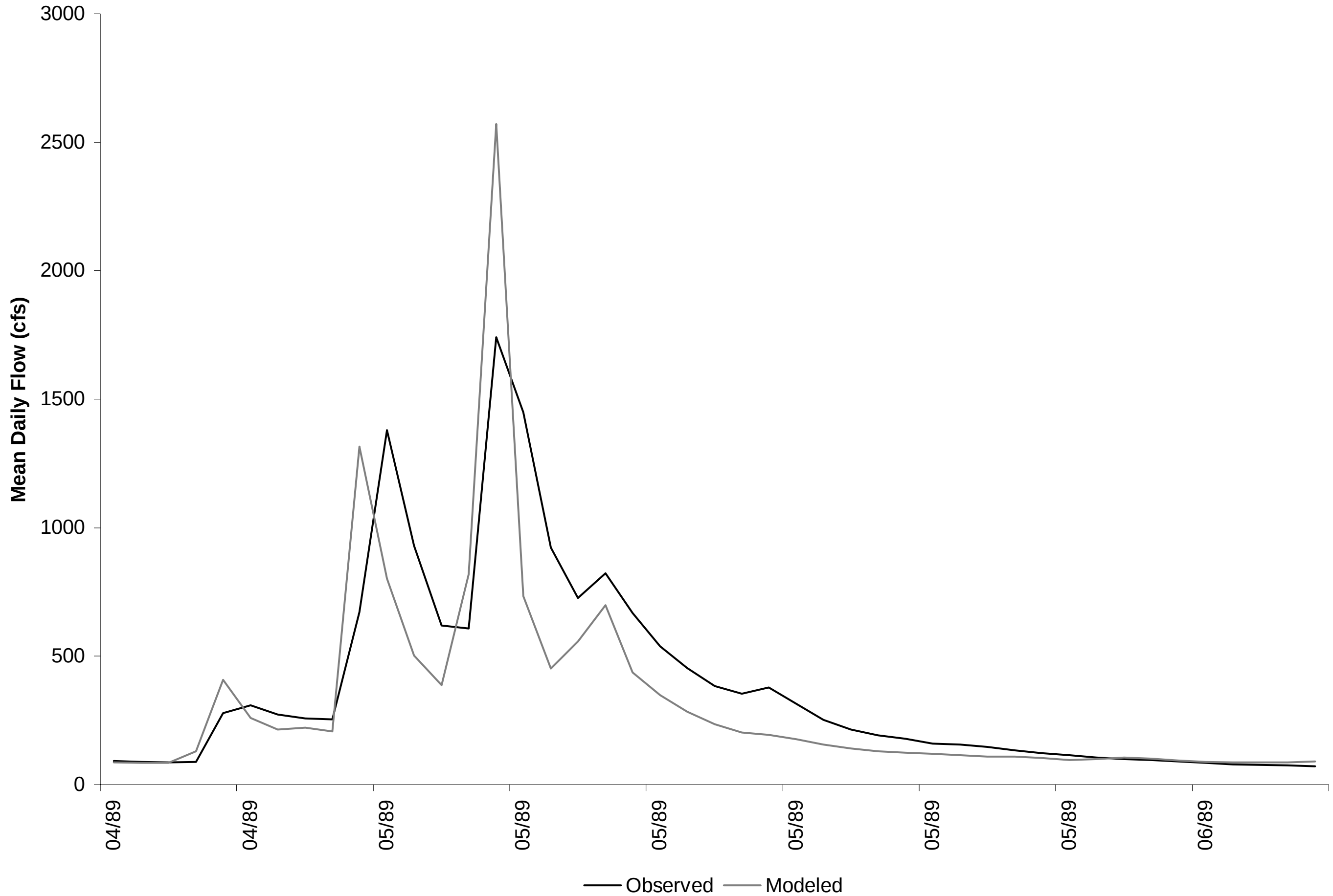

Figure 4.24 Validation results for a single storm for South River.

4.7.2 Water Quality Calibration and Validation

Water quality calibration is complicated by a number of factors, some of which are described here. First, water quality concentrations (*e.g.*, fecal coliform concentrations) are highly dependent on flow conditions. Any variability associated with the modeling of stream flow compounds the variability in modeling water quality parameters such as fecal coliform concentration. Second, the concentration of fecal coliform is particularly variable. Variability in location and timing of fecal deposition, variability in the density of fecal coliform bacteria in feces (among species and for an individual animal), environmental impacts on regrowth and die-off, and variability in delivery to the stream all lead to difficulty in measuring and modeling fecal coliform concentrations. Additionally, the limited amount of measured data for use in calibration and the practice of censoring both high (maximum values were at times censored at 8,000 cfu/100 ml and, at other times, 16,000 cfu/100 ml) and low (under 100 cfu/100 ml) concentrations impedes the calibration process.

The water quality calibration was conducted using monitored data from 10/1/92 through 9/30/97. Four parameters were utilized for model adjustment: in-stream first-order decay rate (FSTDEC), maximum accumulation on land (SQOLIM), rate of surface runoff that will remove 90% of stored fecal coliform per hour (WSQOP), and concentration of fecal coliform in interflow (IOQC). All of these parameters were initially set at expected levels for the watershed conditions and adjusted within reasonable limits until an acceptable match between measured and modeled fecal coliform concentrations was established (Table 4.16). Specific values for each calibrated parameter are given in the excerpt from the calibrated UCI in Appendix F. Figure 4.25 through Figure 4.30 show the results of water quality calibration. Short-period fluctuations in the modeled data denote the effective modeling of the variability within daily concentrations that was achieved through distributing direct depositions from wildlife, livestock, and uncontrolled discharges across each day (Section 4.3). Modeled coliform levels matched observed levels during a variety of flow conditions, indicating that the model was well calibrated.

Table 4.16 Model parameters utilized for water quality calibration.

Parameter	Units	Typical Range of Parameter Value	Initial Parameter Estimate	Calibrated Parameter Value
MON-ACCUM	FC/ac*day	0.0E+00 – 1.0E+20	0.0E+00 – 1.0E+12	0.0E+00 – 1.0E+12
MON-SQOLIM	FC/ac	1.0E-02 – 1.0E+30	0.0E+00 – 7.0E+12	0.0E+00 – 1.5E+13
WSQOP	in/hr	0.05 – 3.00	1.00	0.01- 2.4
IOQC	FC/ft^3	0.0E+00 – 1.0E+06	1.0E+03	0.0E+00-8.5E+05
AOQC	FC/ft^3	0 – 10	0	0
DQAL	FC/100ml	0 – 1,000	200	200
FSTDEC	1/day	0.01 – 10.00	1.00	0.5 – 5.0
THFST	---	1.0 – 2.0	1.07	1.07

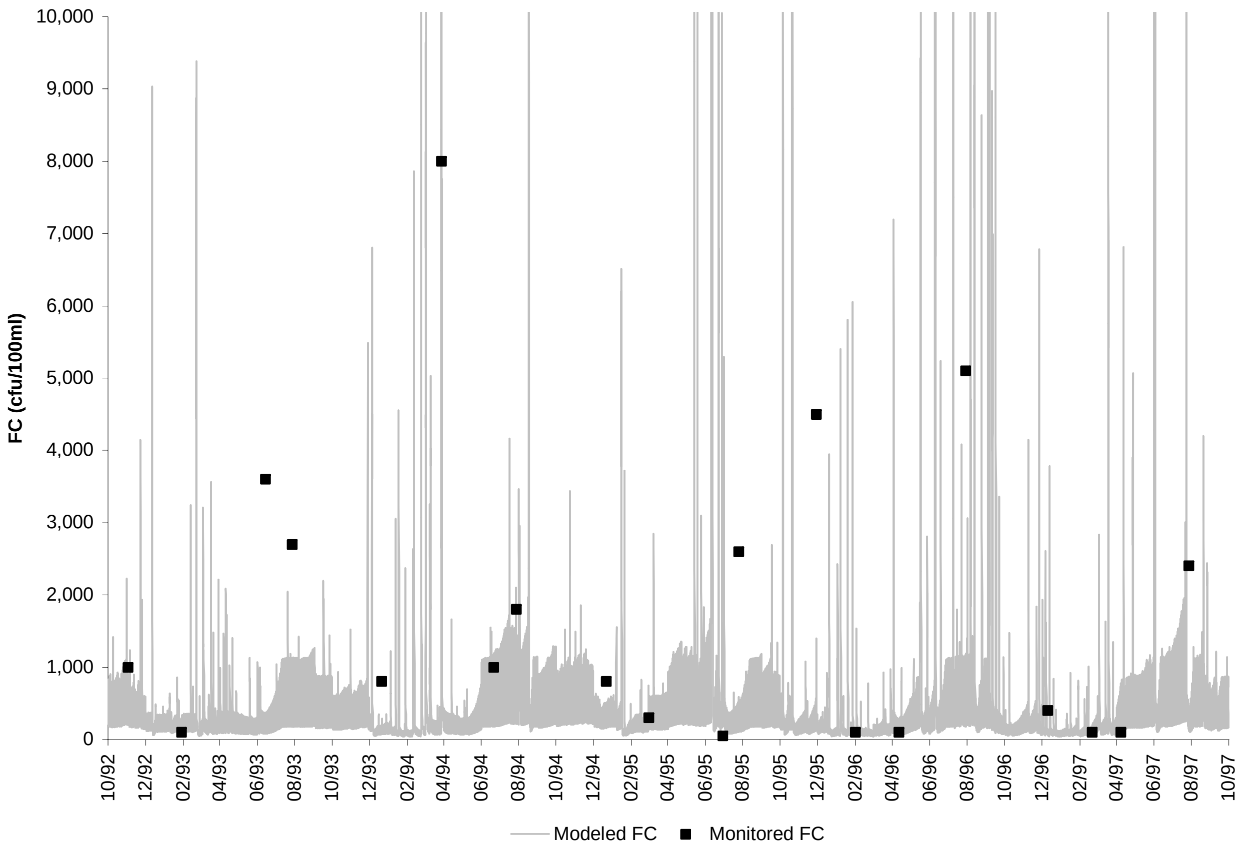

Figure 4.25 Quality Calibration for subwatershed 1 in the Lower Middle River impairment.

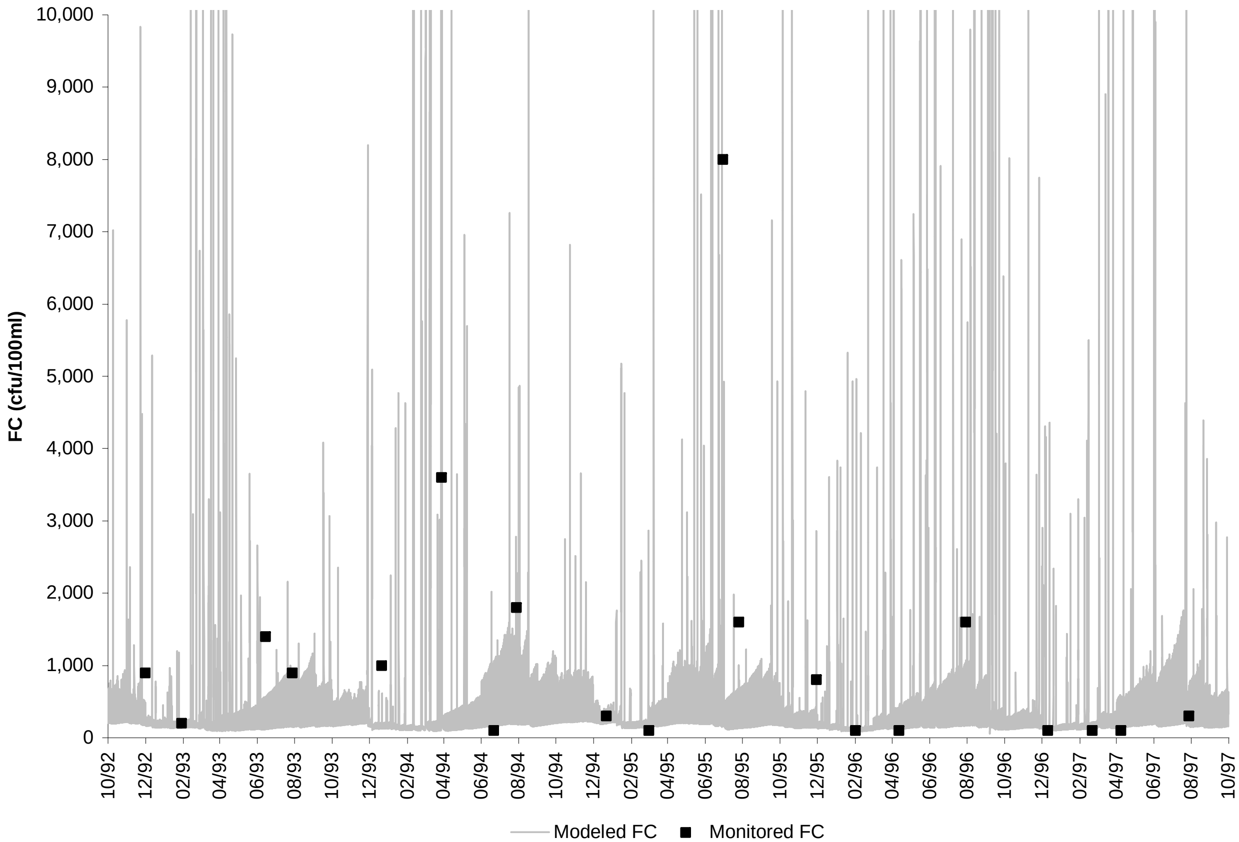

Figure 4.26 Quality Calibration for subwatershed 14 in the Moffett Creek impairment.

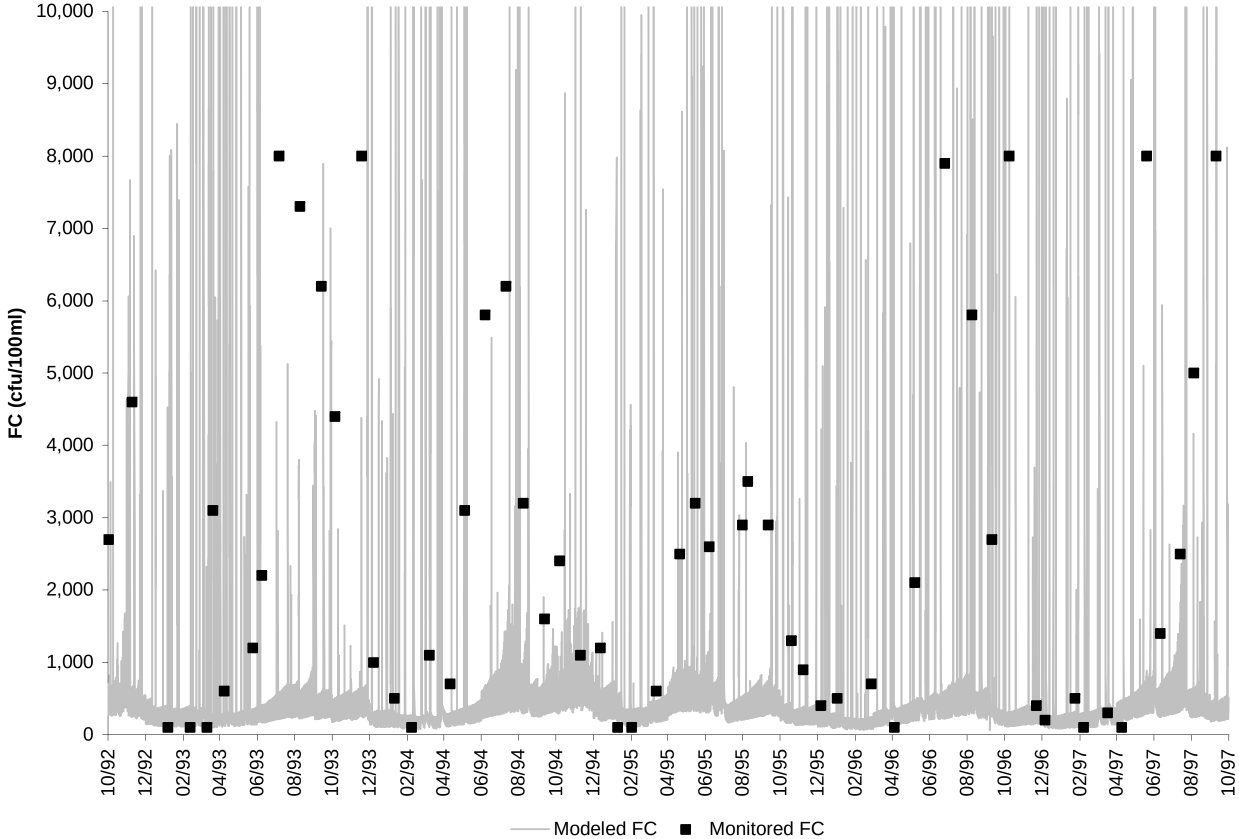

Figure 4.27 Quality Calibration for subwatershed 23 in the Lewis Creek impairment.

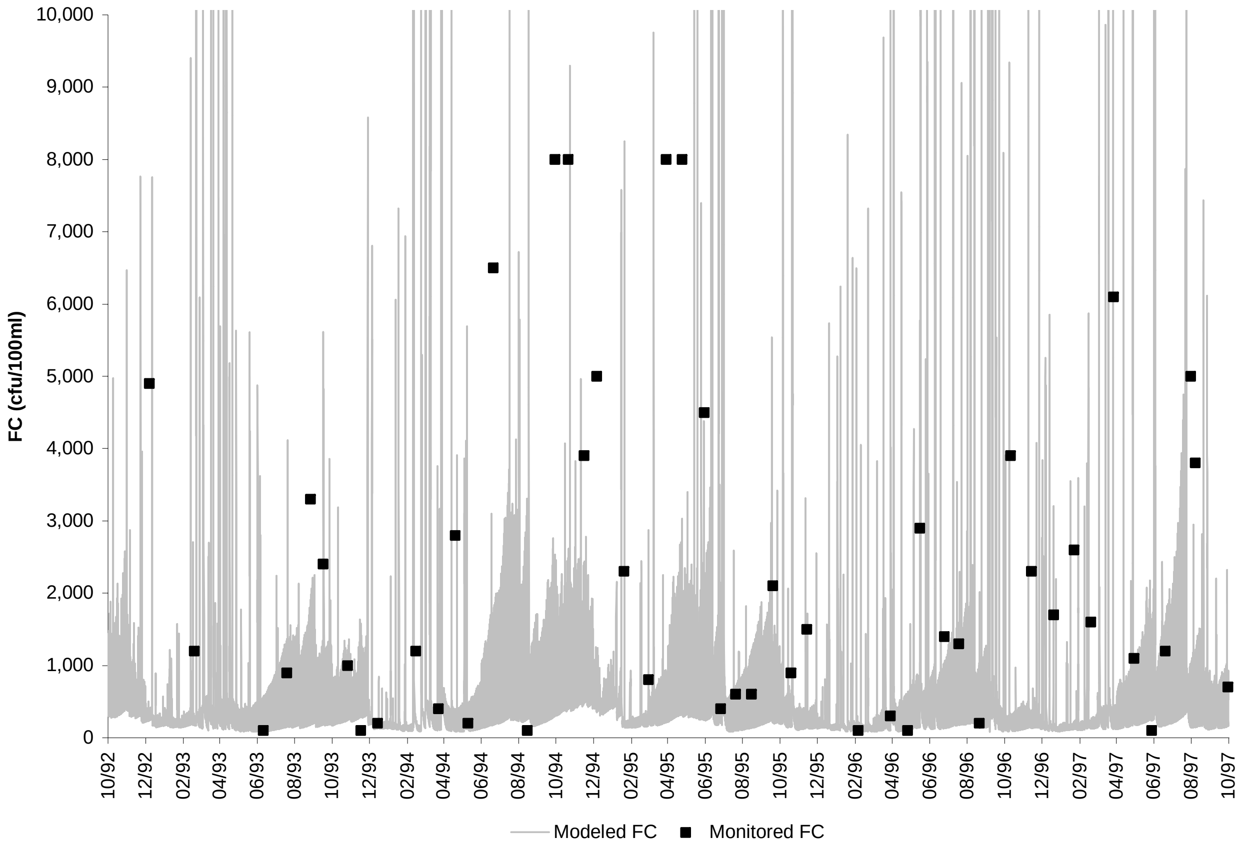

Figure 4.28 Quality Calibration for subwatershed 33 in the Polecat Draft impairment.

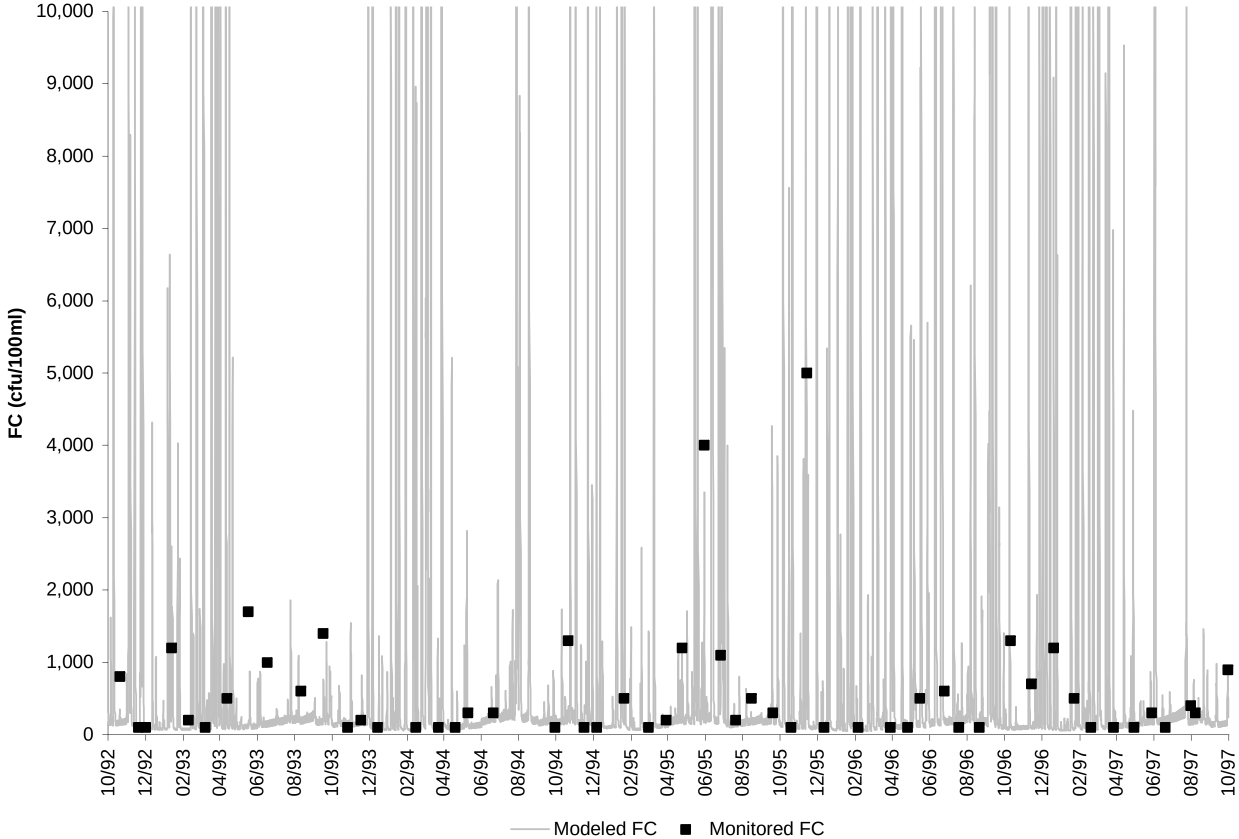

Figure 4.29 Quality Calibration for subwatershed 36 in the Lower Middle River impairment.

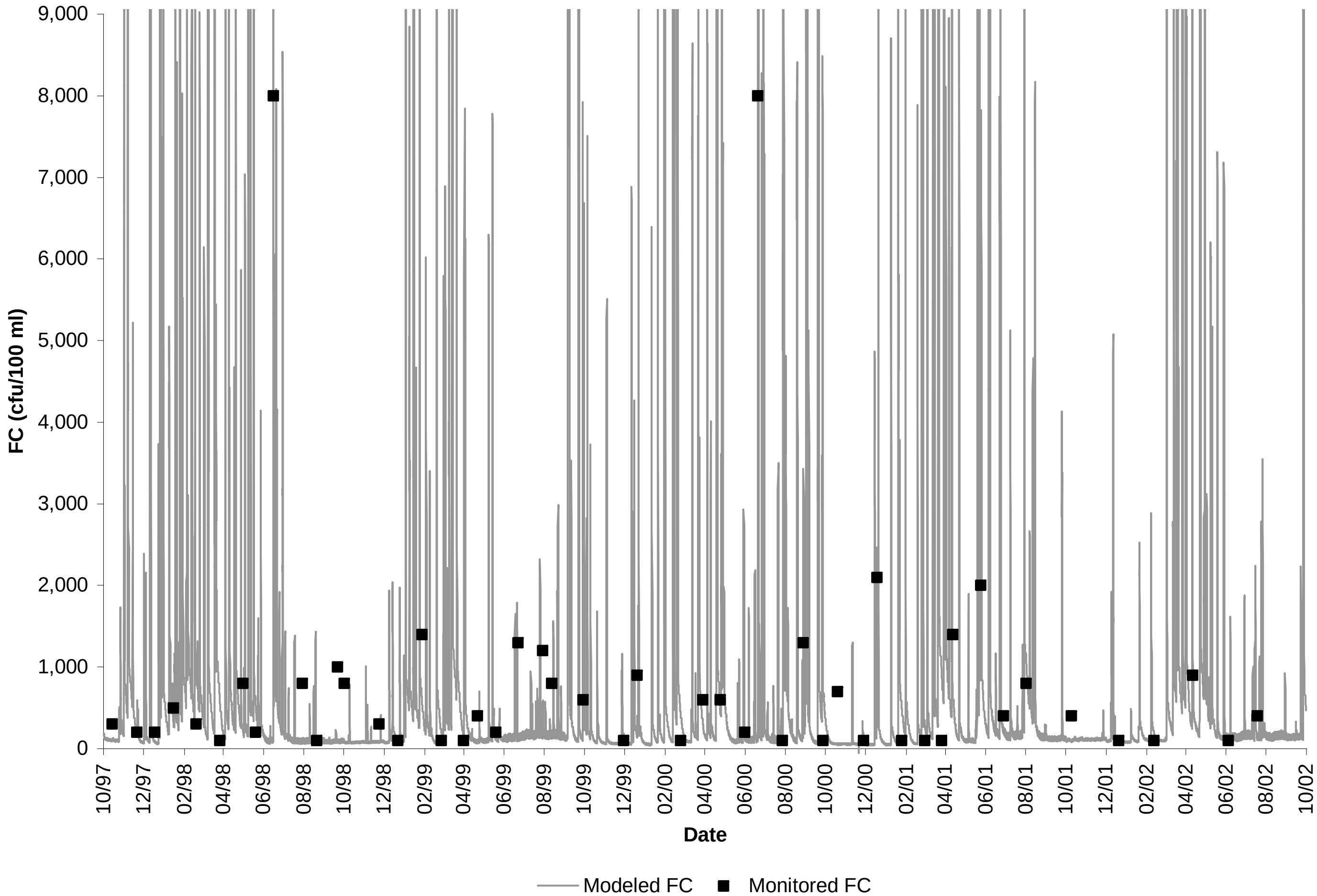

Figure 4.30 Quality Calibration for subwatershed 43 in the Upper South River impairment.

Careful inspection of graphical comparisons between continuous simulation results and limited observed points was the primary tool used to guide the calibration process. To provide a quantitative measure of the agreement between modeled and measured data while taking the inherent variability of fecal coliform concentrations into account, each observed value was compared with modeled concentrations in a 2-day window surrounding the observed data point. First, the minimum and maximum modeled values in each modeled window was determined. Figure 4.31 through Figure 4.36 show the relationship between these extreme values and observed data. In addition, standard error in each observation window was calculated as follows:

$$Standard\ Error = \frac{\sqrt{\dfrac{\sum_{i=1}^{n}(observed - modeled_i)^2}{(n-1)}}}{\sqrt{n}}$$

where

$observed$ = an observed value of fecal coliform
$modeled_i$ = a modeled value in the 2 - day window surrounding the observation
n = the number of modeled observations in the 2 - day window

This 2-day window is considered to be a reasonable time frame to take into account the temporal variability in direct loadings from wildlife and livestock, the spatial and temporal variability inherent in the use of point measurements of precipitation, and in the use of daily precipitation data. This is a non-traditional use of standard error, applied here to offer a quantitative measure of model accuracy. In this context, standard error measures the variability of the sample mean of the modeled values about an instantaneous observed value. The use of limited instantaneous observed values to evaluate continuous data introduces error and, therefore, increases standard error. The mean of all standard errors for each station analyzed was calculated. Additionally, the maximum concentration values observed in the simulated data were compared with maximum values obtained from uncensored data and found to be at reasonable levels (Table 4.17).

Table 4.17 Results of analyses on calibration runs.

WQ Monitoring Station	Mean Standard Error (cfu/100 ml)	Maximum Simulated Value (cfu/100 ml)	Modeled% Exceedance of Instantaneous Standard	Observed % Exceedance of Instantaneous Standards
1BMDL061.07	163	56,402	37	61
1BJEN002.46	20	20,784	7	5
1BMFT006.20	171	56,402	34	41
1BLEW002.91	239	245,200	41	78
1BMDL036.08	33	11,097	12	14
1BPCD001.03, 1BPCD000.20*	144	59,077	46	76
1BMDL001.83	93	173,080	22	34

* Values from both stations used for same subwatershed.

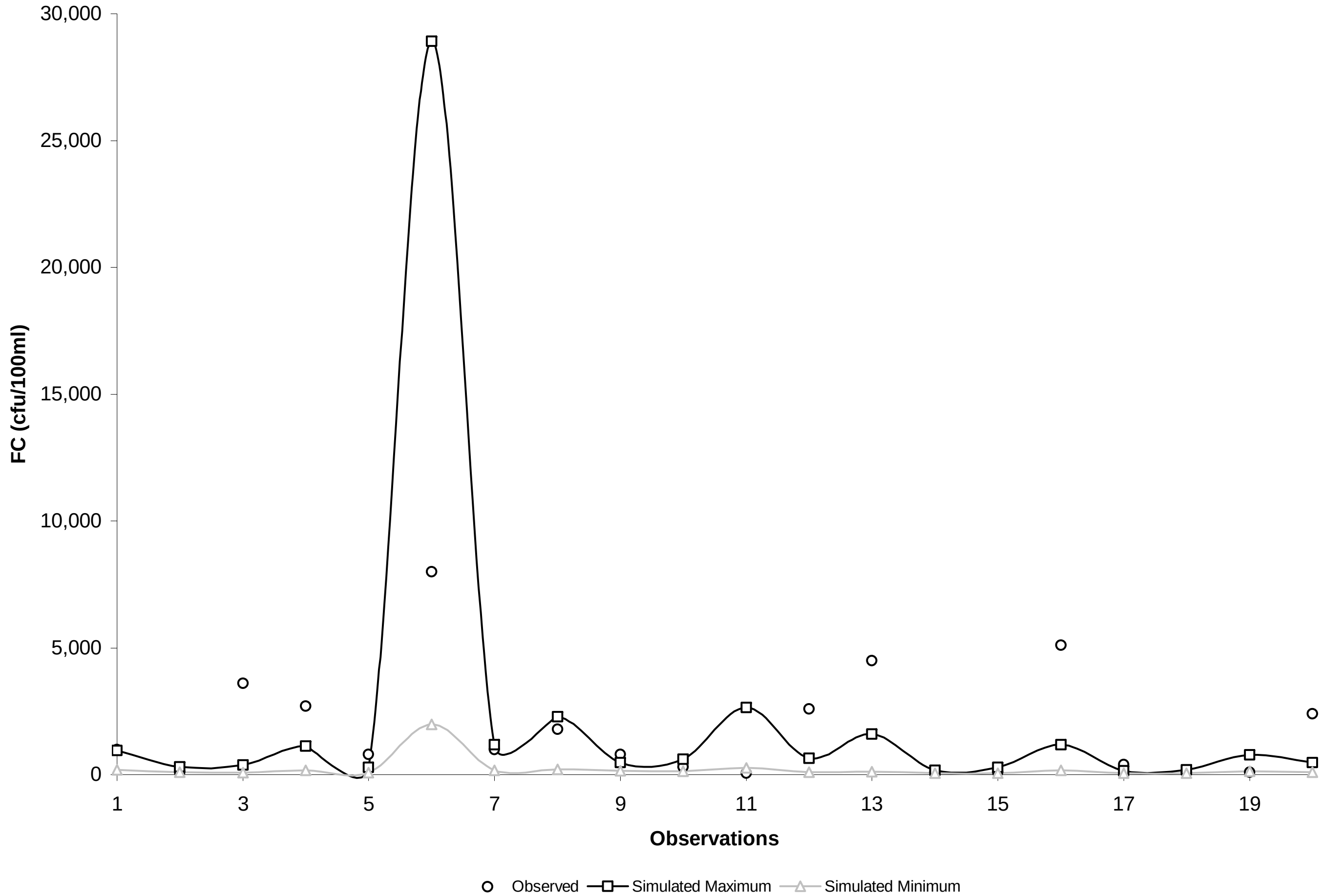

Figure 4.31 **Comparison of minimum and maximum modeled values in a 2-day window, centered on a single observed value. Calibration period for subwatershed 1 in the Upper Middle River impairment.**

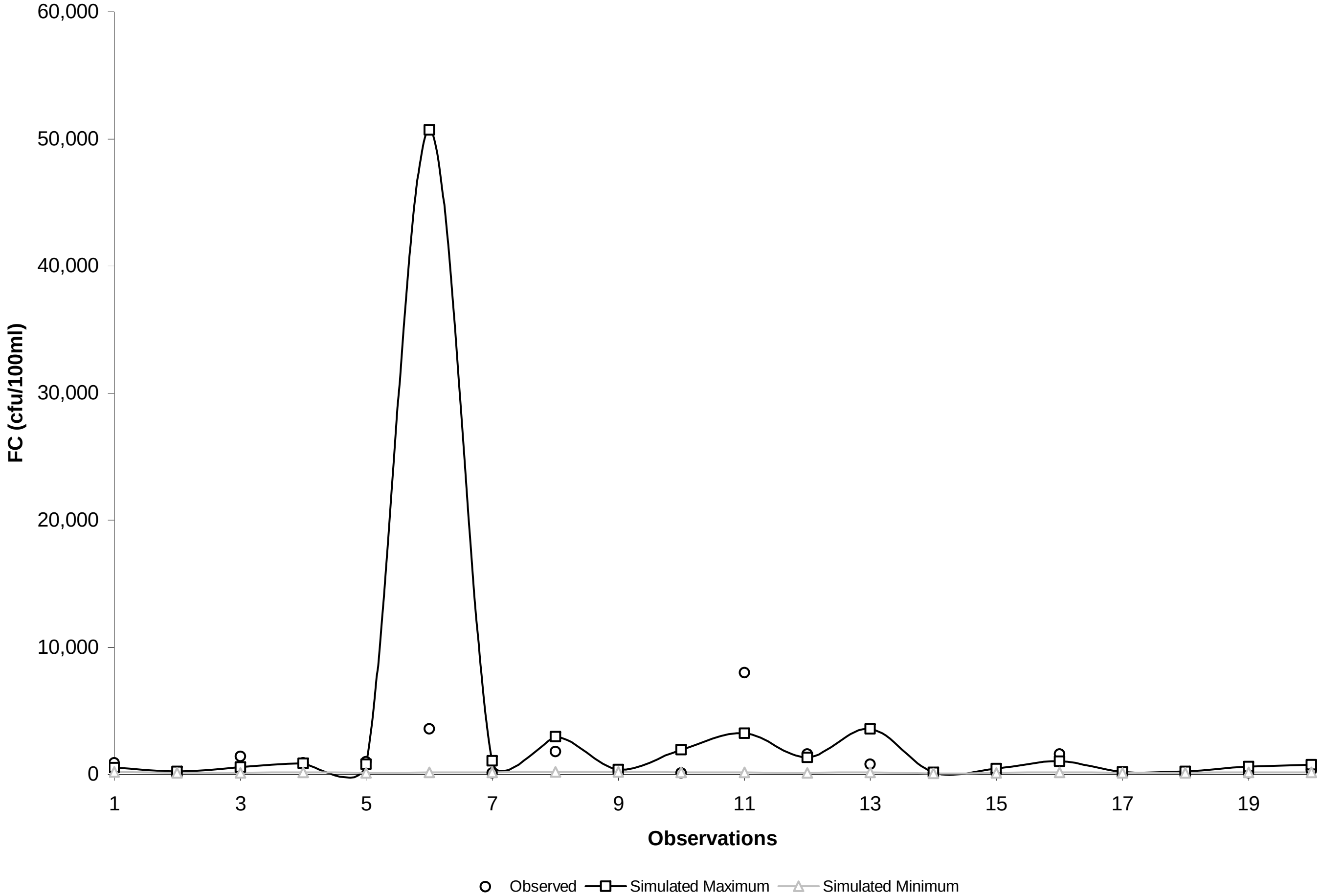

Figure 4.32 Comparison of minimum and maximum modeled values in a 2-day window, centered on a single observed value. Calibration period for subwatershed 14 in Moffett Creek impairment.

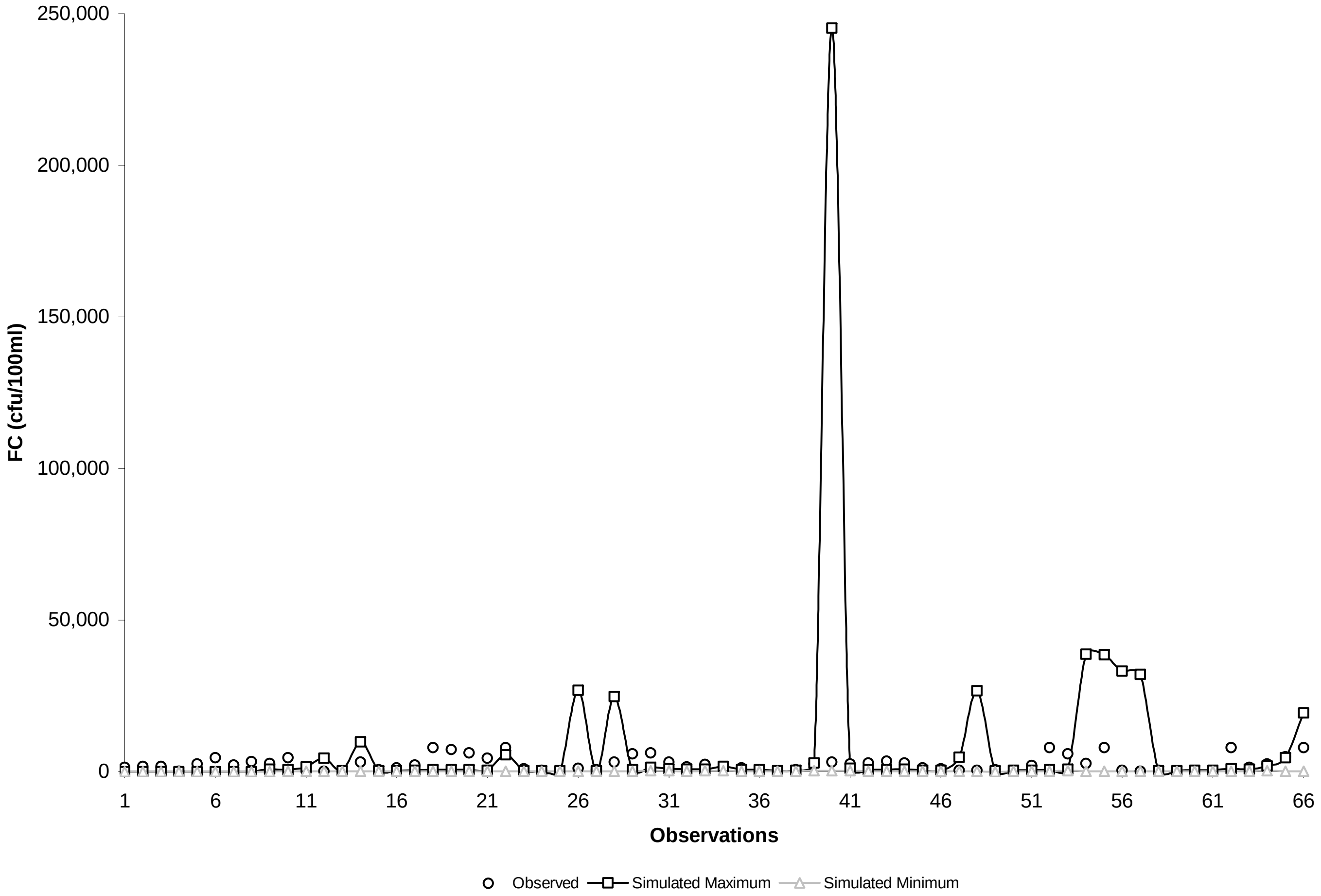

Figure 4.33 Comparison of minimum and maximum modeled values in a 2-day window, centered on a single observed value. Calibration period for subwatershed 23 in Lewis Creek impairment.

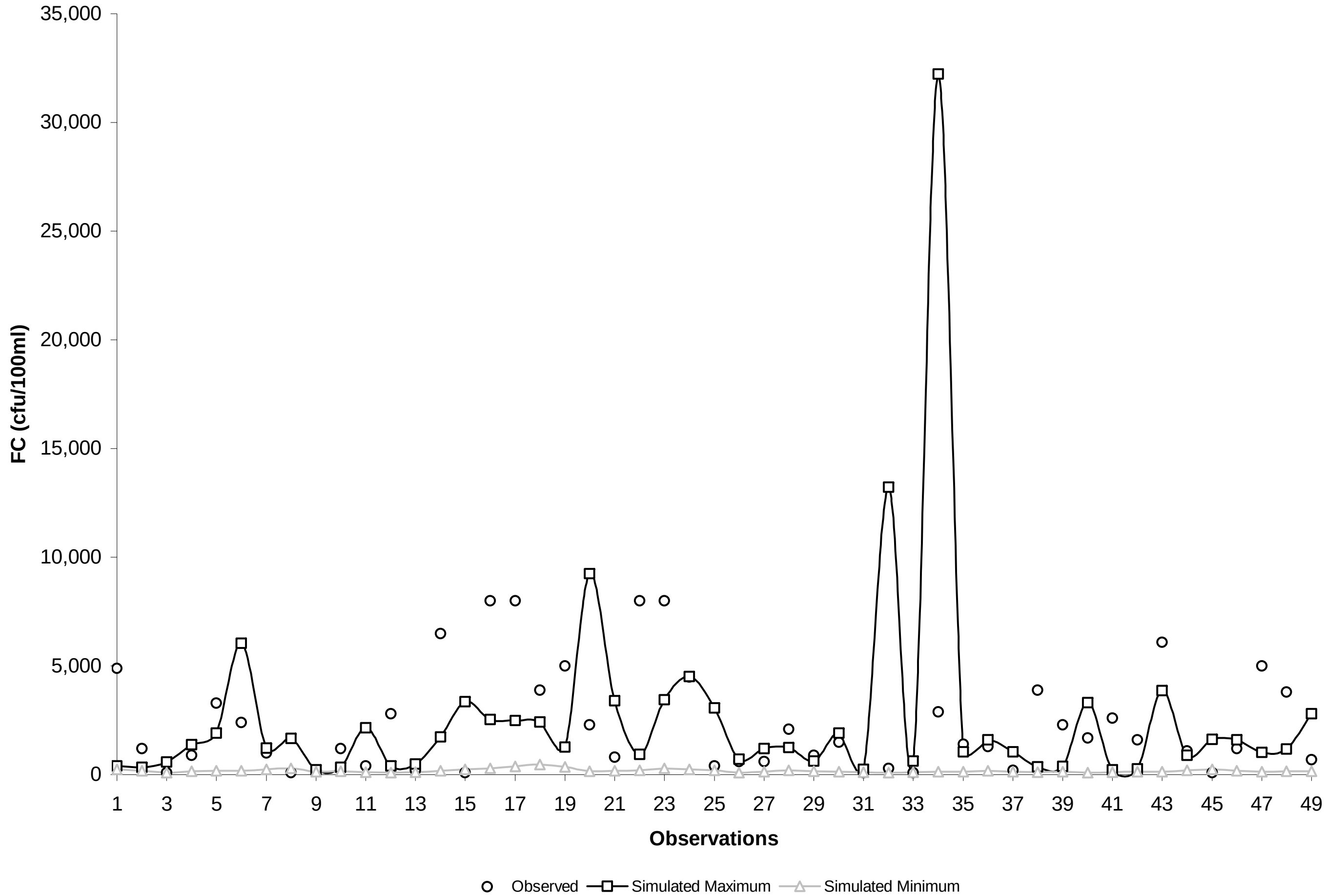

Figure 4.34 Comparison of minimum and maximum modeled values in a 2-day window, centered on a single observed value. Calibration period for subwatershed 33 in the Polecat Draft impairment.

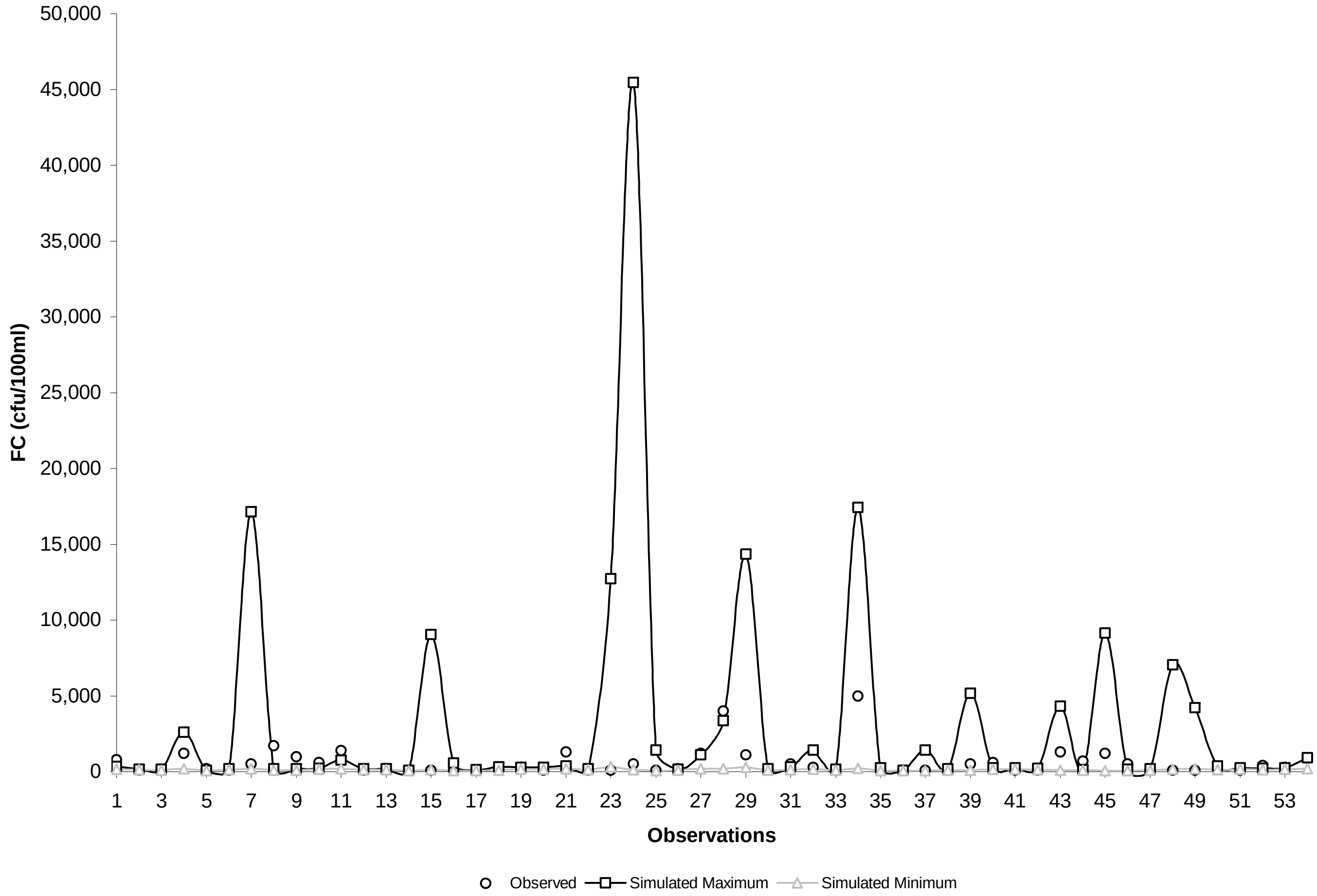

Figure 4.35 Comparison of minimum and maximum modeled values in a 2-day window, centered on a single observed value. Calibration period for subwatershed 36 in the Lower Middle River impairment.

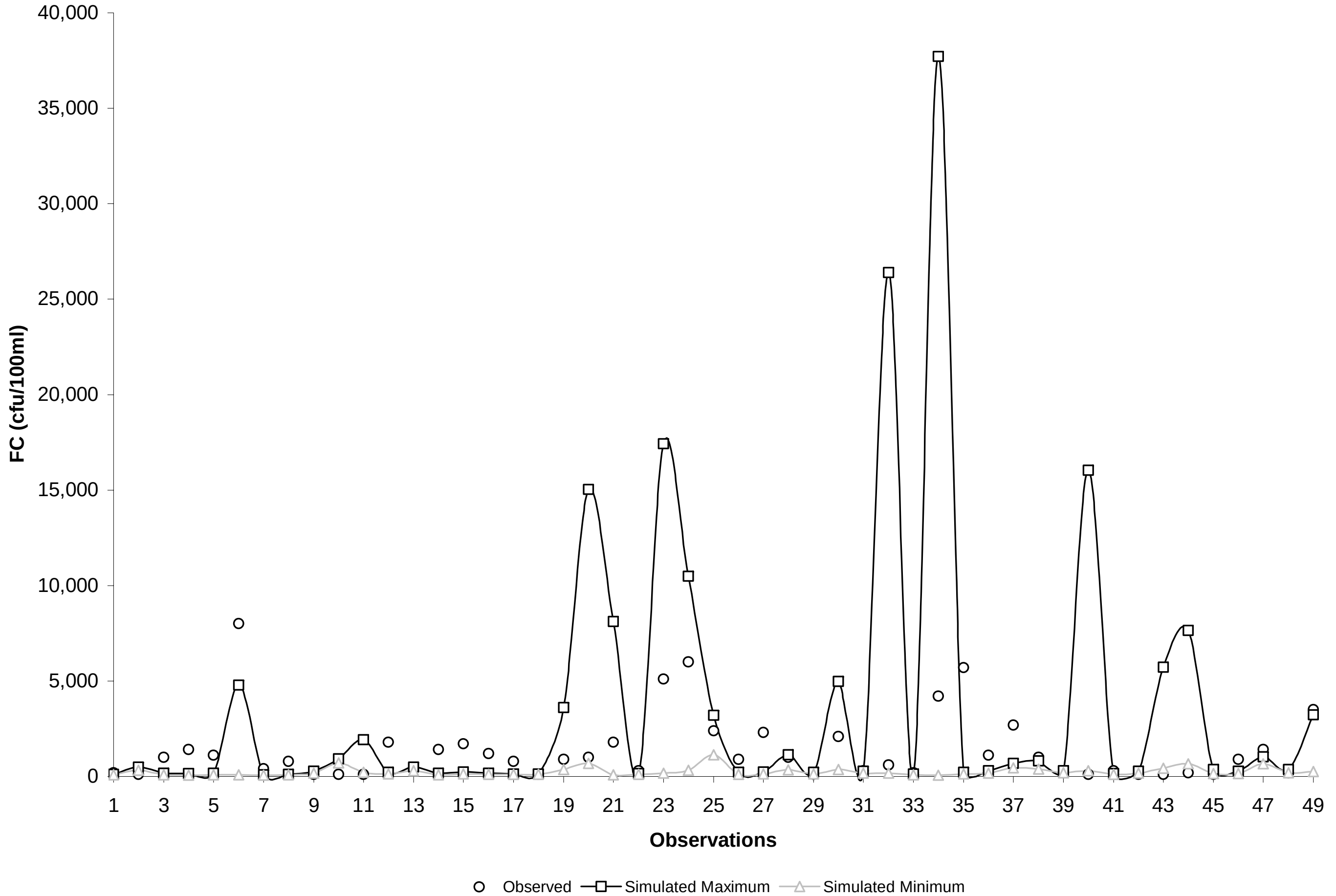

Figure 4.36 Comparison of minimum and maximum modeled values in a 2-day window, centered on a single observed value. Calibration period for subwatershed 43 in the Upper South River impairment.

The water quality validation was conducted using data for the time period from 10/1/97 to 9/30/02. The relationship between observed values and modeled values is shown in Figures 4.37 through 4.52. The results of standard error and maximum value analyses are reported in Table 4.18. Standard errors calculated from validation runs were comparable to standard errors calculated from calibration runs. Maximum simulated values were comparable to observed values in the area (Section 2).

Table 4.18 Results of analyses on validation runs.

WQ Monitoring Station	Mean Standard Error (cfu/100 ml)	Maximum Simulated Value (cfu/100 ml)	Modeled % Exceedance of Instantaneous Standard	Observed % Exceedance of Instantaneous Standard
1BMDL061.07	41	27,846	37	61
1BMDL060.48	105	23,686	32	57
1BMDL051.36	27	24,019	08	8
1BMFT006.20	133	61,816	34	41
1BLEW002.91	125	500,000	40	78
1BPCD001.03, 1BPCD000.20	103	61,680	47	76
1BMDL001.83	148	161,160	22	34

* Values from both stations used for same subwatershed.

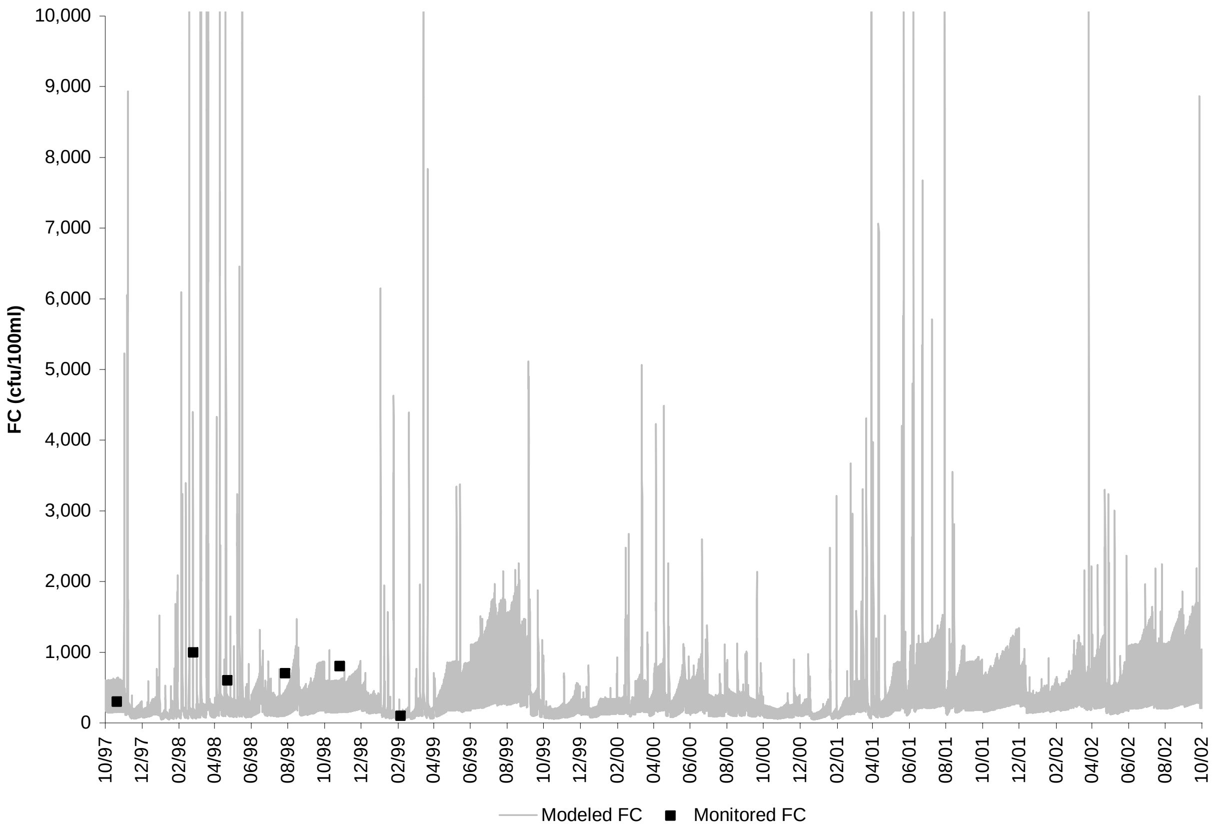

Figure 4.37 Quality validation for subwatershed 1 in the Upper Middle River impairment.

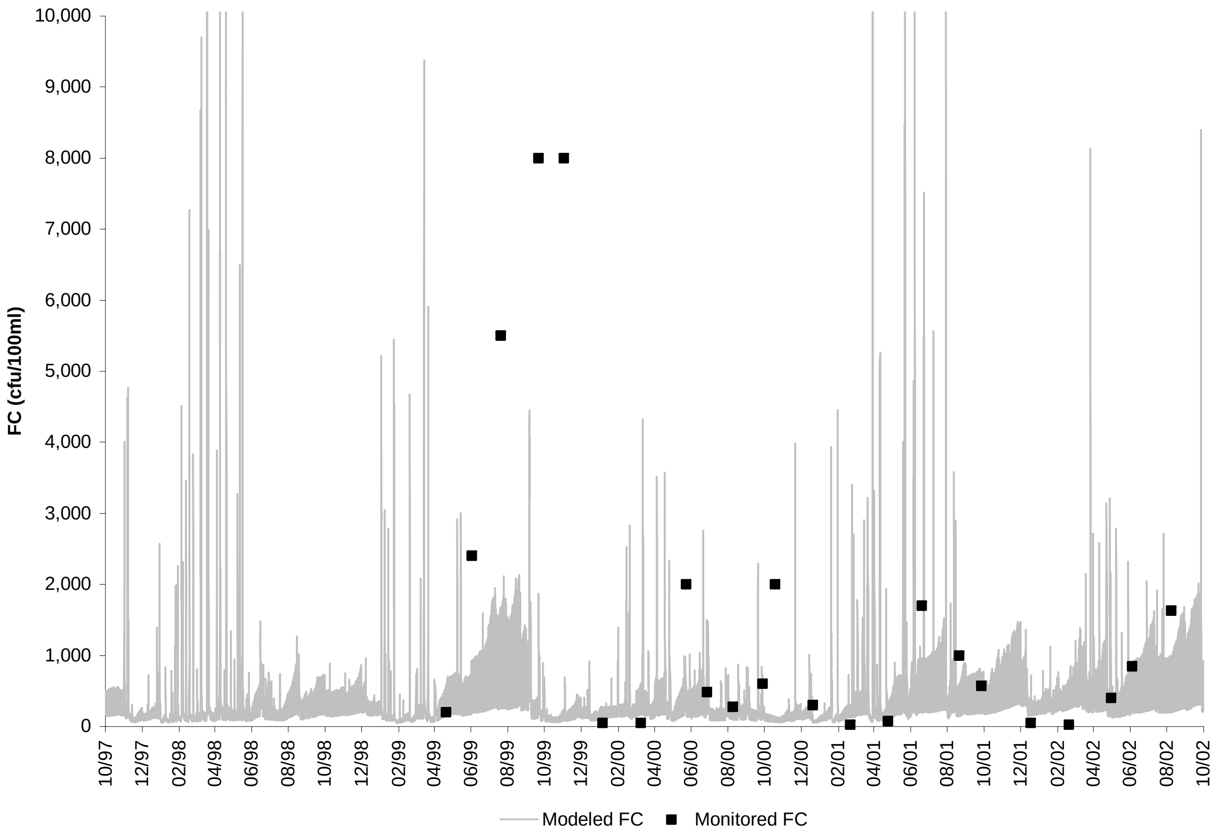

Figure 4.38 Quality validation for subwatershed 2 in the Upper Middle River impairment.

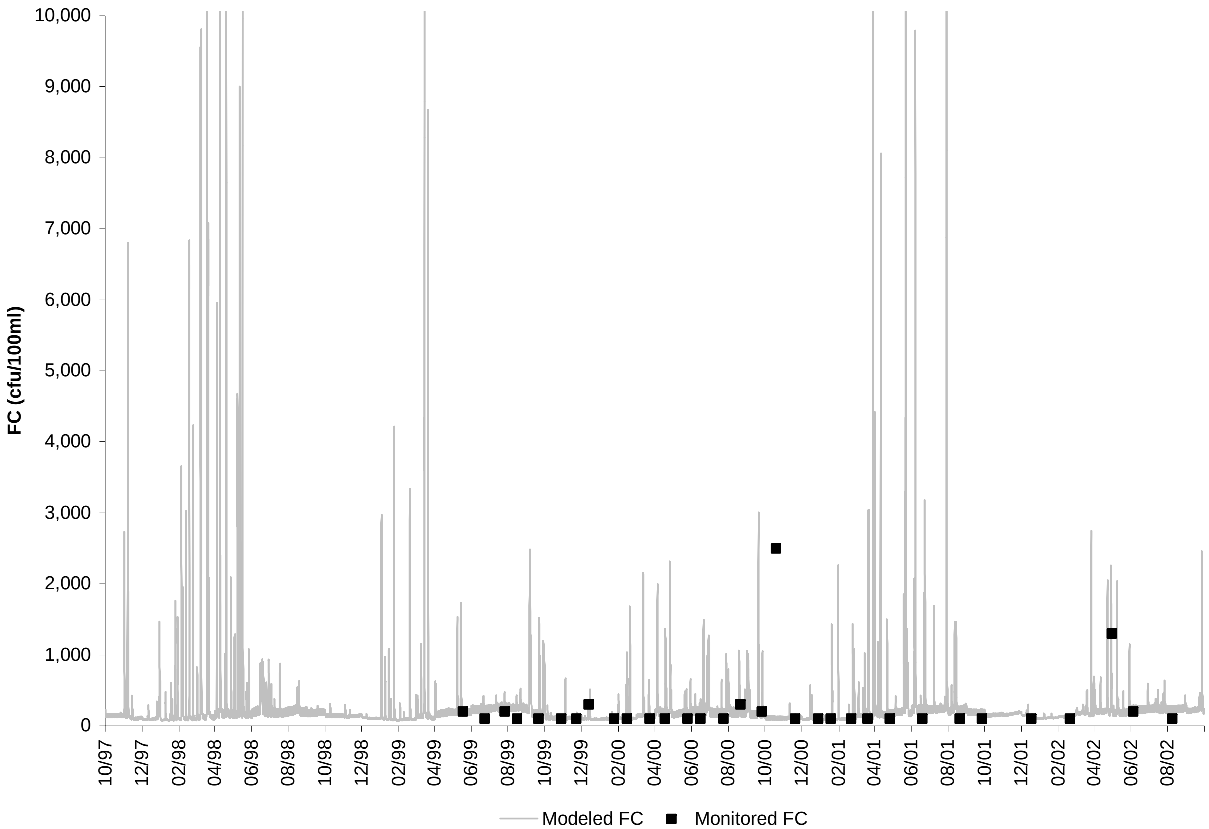

Figure 4.39 Quality validation for subwatershed 7 in the Upper Middle River impairment.

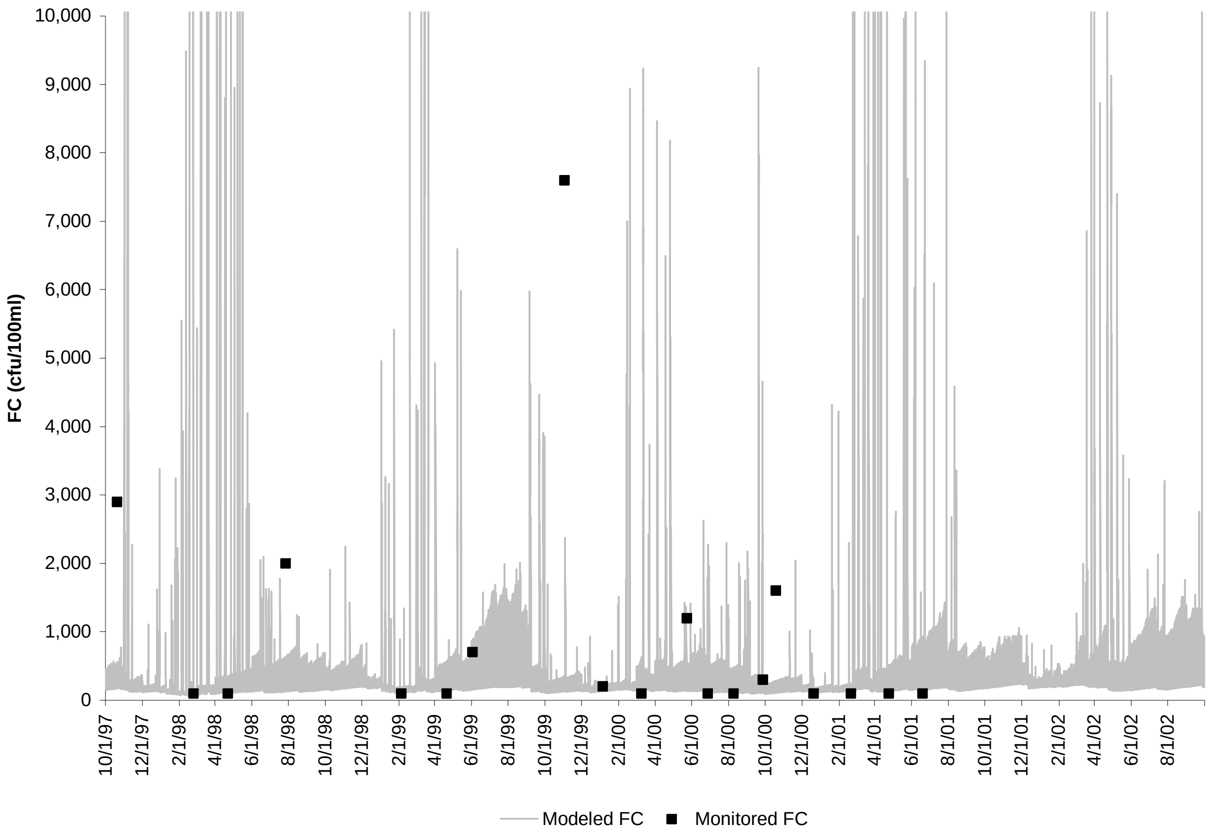

Figure 4.40 Quality validation for subwatershed 14 in the Moffett Creek impairment.

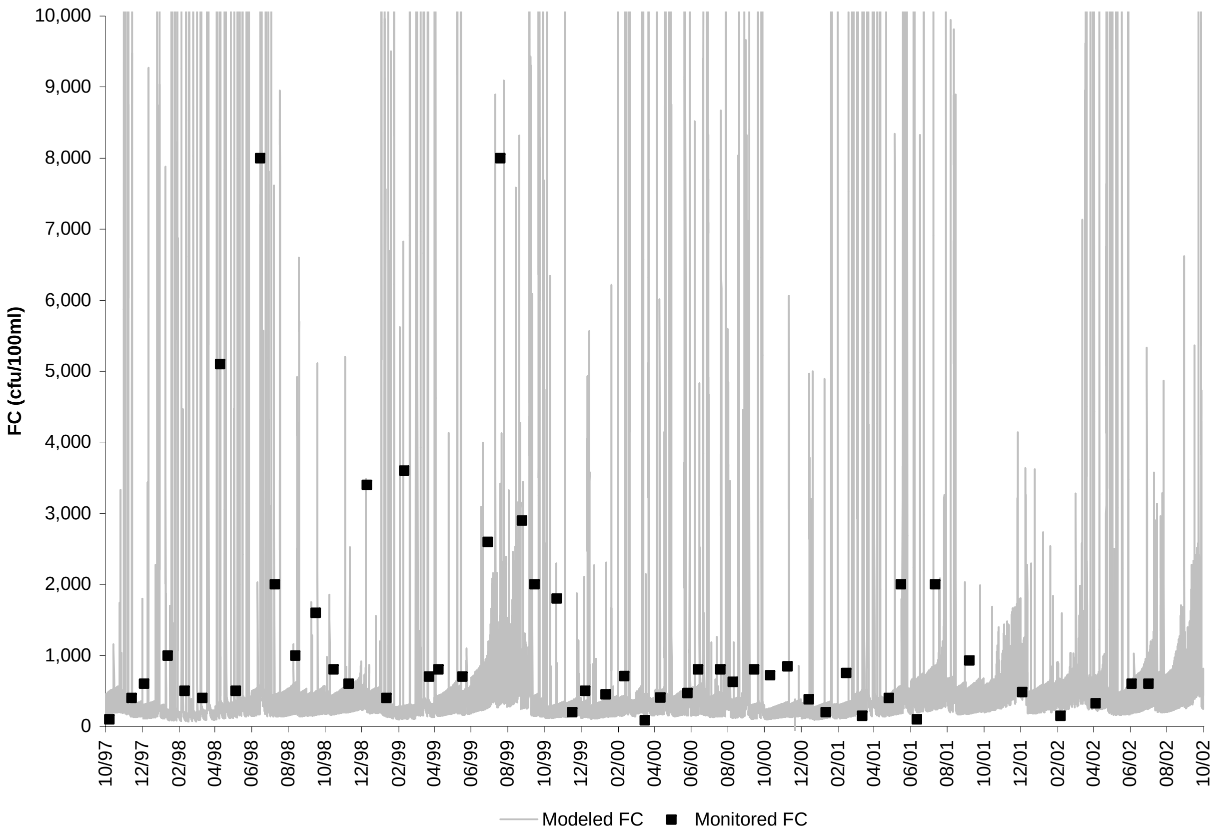

Figure 4.41 Quality validation for subwatershed 23 in the Lewis Creek impairment.

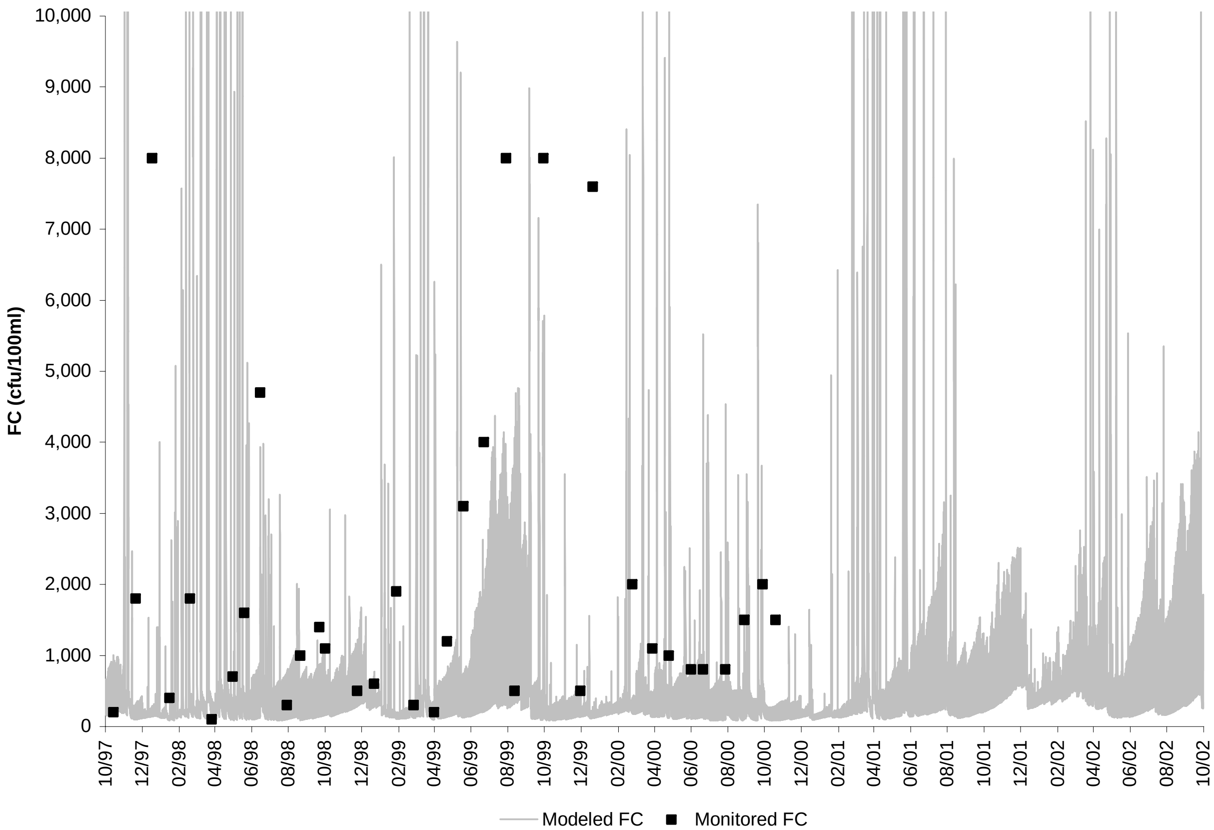

Figure 4.42 Quality validation for subwatershed 33 in the Polecat Draft impairment.

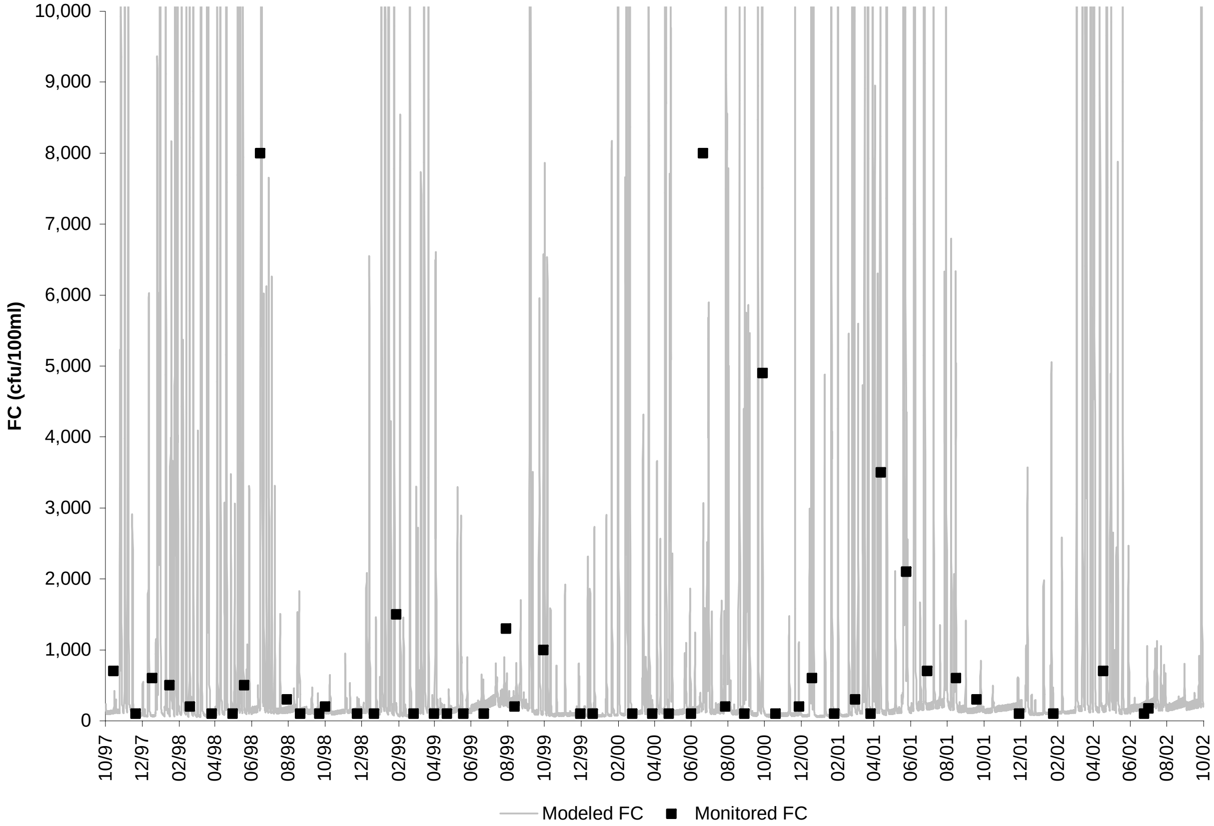

Figure 4.43 Quality validation for subwatershed 36 in the Lower Middle River impairment.

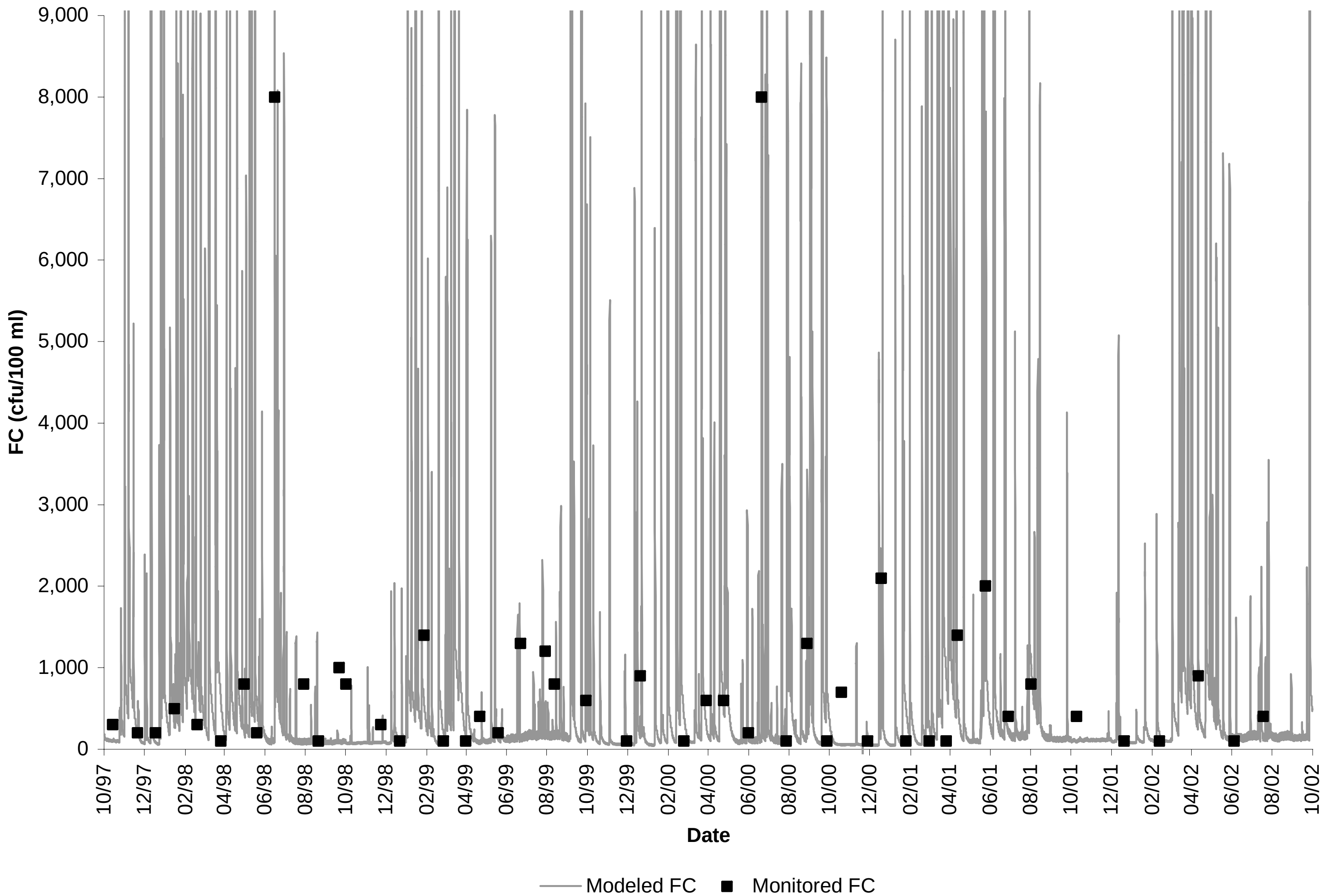

Figure 4.44 Quality validation for subwatershed 43 in the Upper South River impairment.

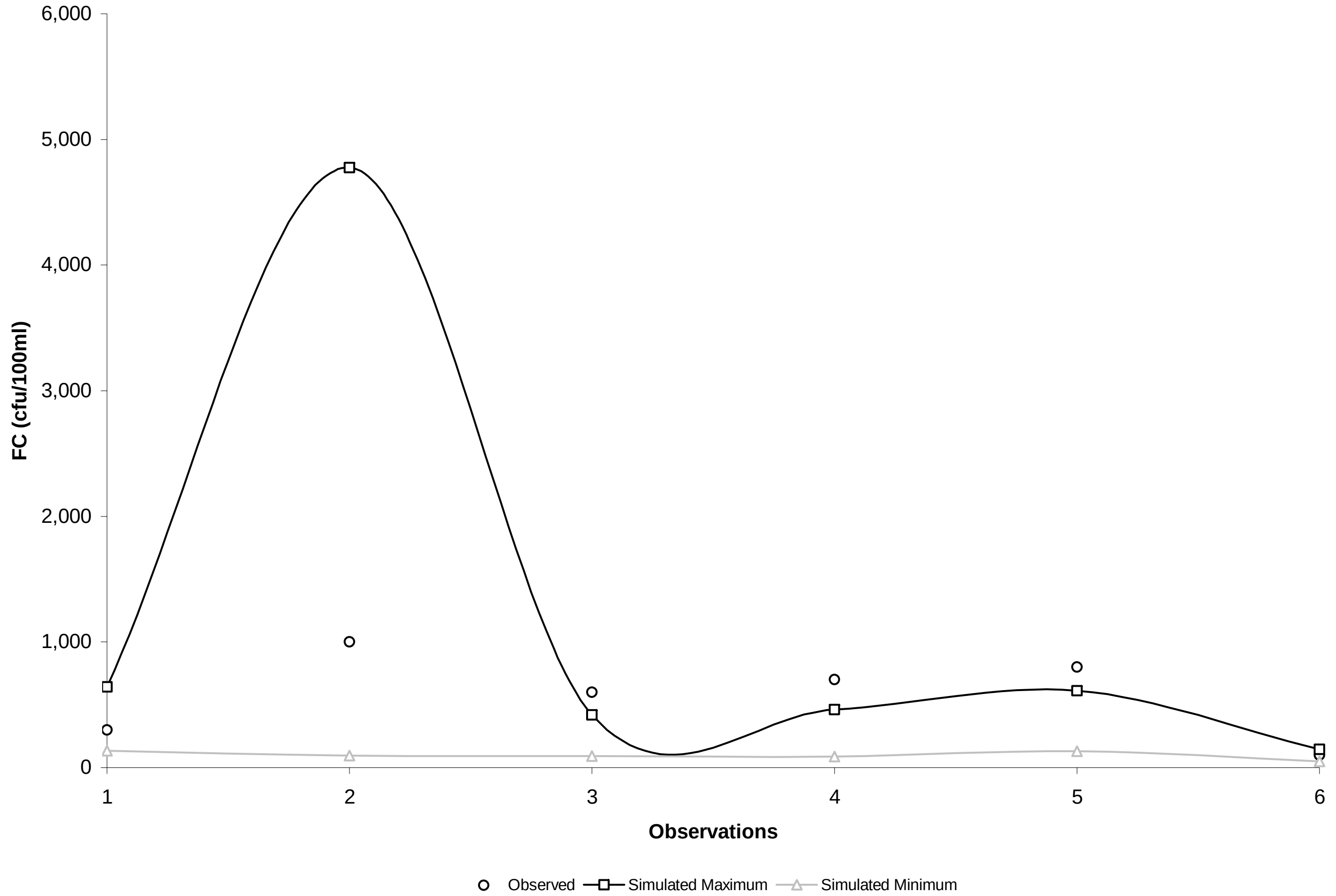

Figure 4.45 Comparison of minimum and maximum modeled values in a 2-day window, centered on a single observed value. Validation period for subwatershed 1 in the Upper Middle River impairment.

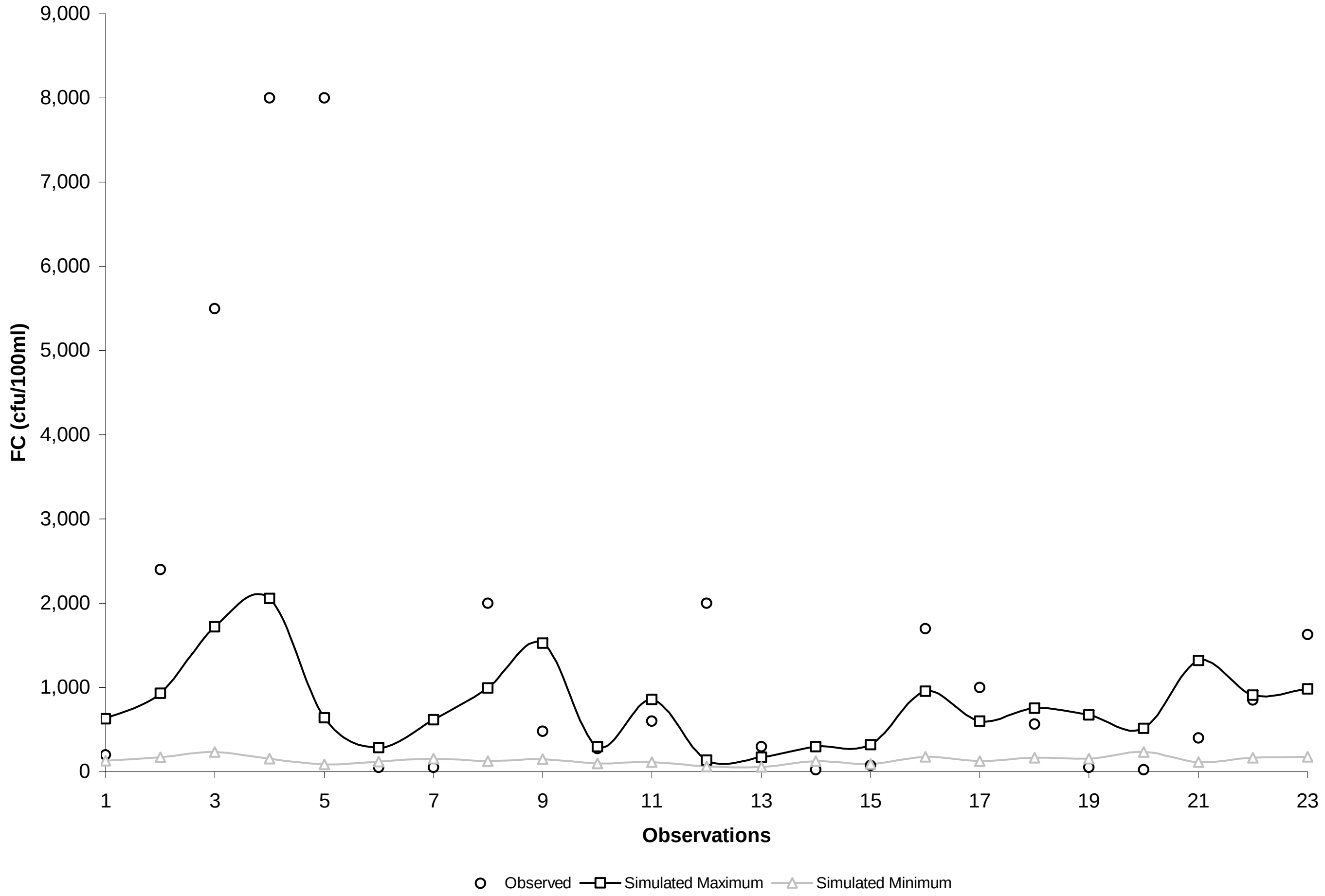

Figure 4.46 Comparison of minimum and maximum modeled values in a 2-day window, centered on a single observed value. Validation period for subwatershed 2 in the Upper Middle River impairment.

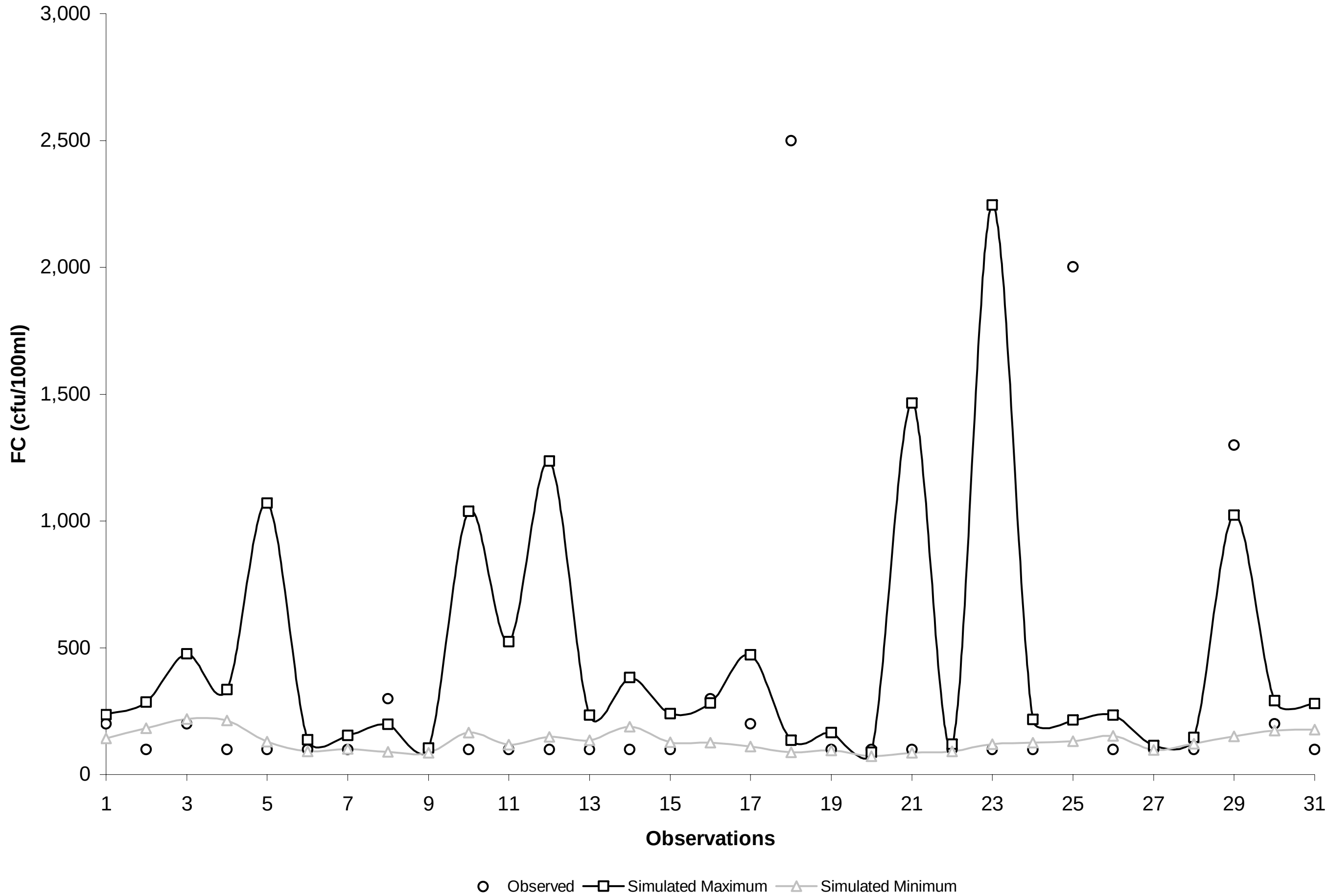

Figure 4.47 Comparison of minimum and maximum modeled values in a 2-day window, centered on a single observed value. Validation period for subwatershed 7 in the Upper Middle River impairment.

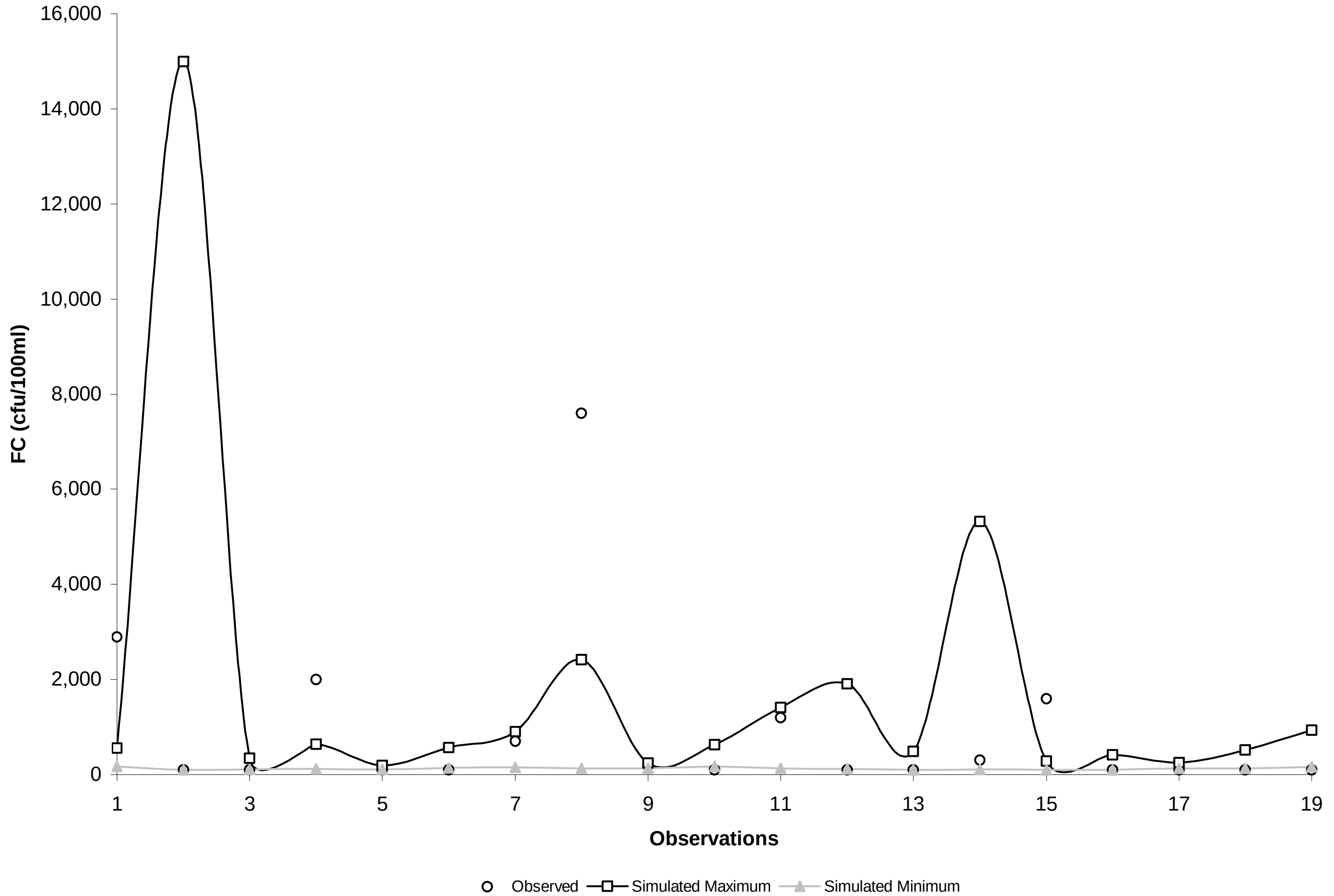

Figure 4.48 Comparison of minimum and maximum modeled values in a 2-day window, centered on a single observed value. Validation period for subwatershed 14 in the Moffett Creek impairment.

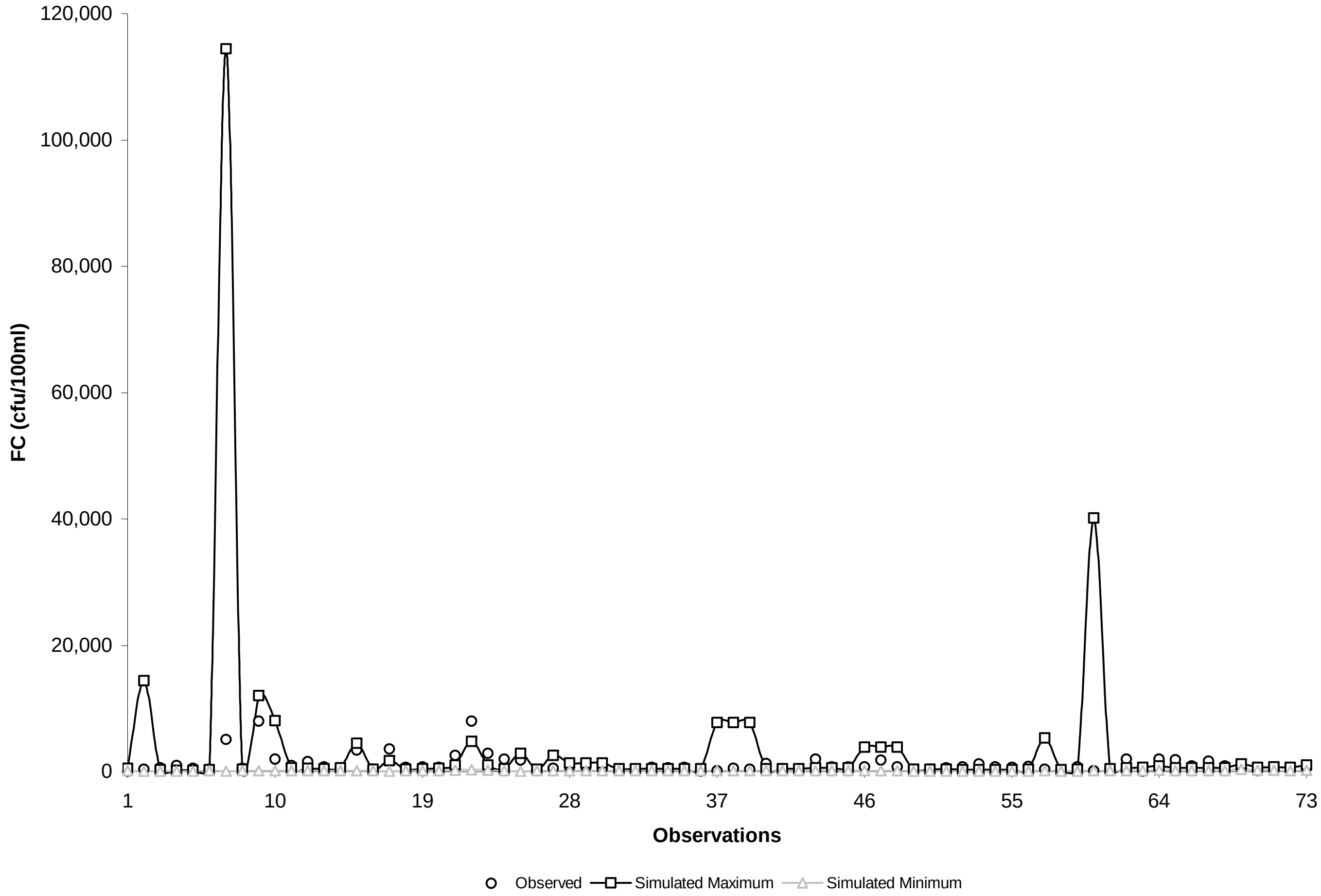

Figure 4.49 Comparison of minimum and maximum modeled values in a 2-day window, centered on a single observed value. Validation period for subwatershed 23 in the Lewis Creek impairment.

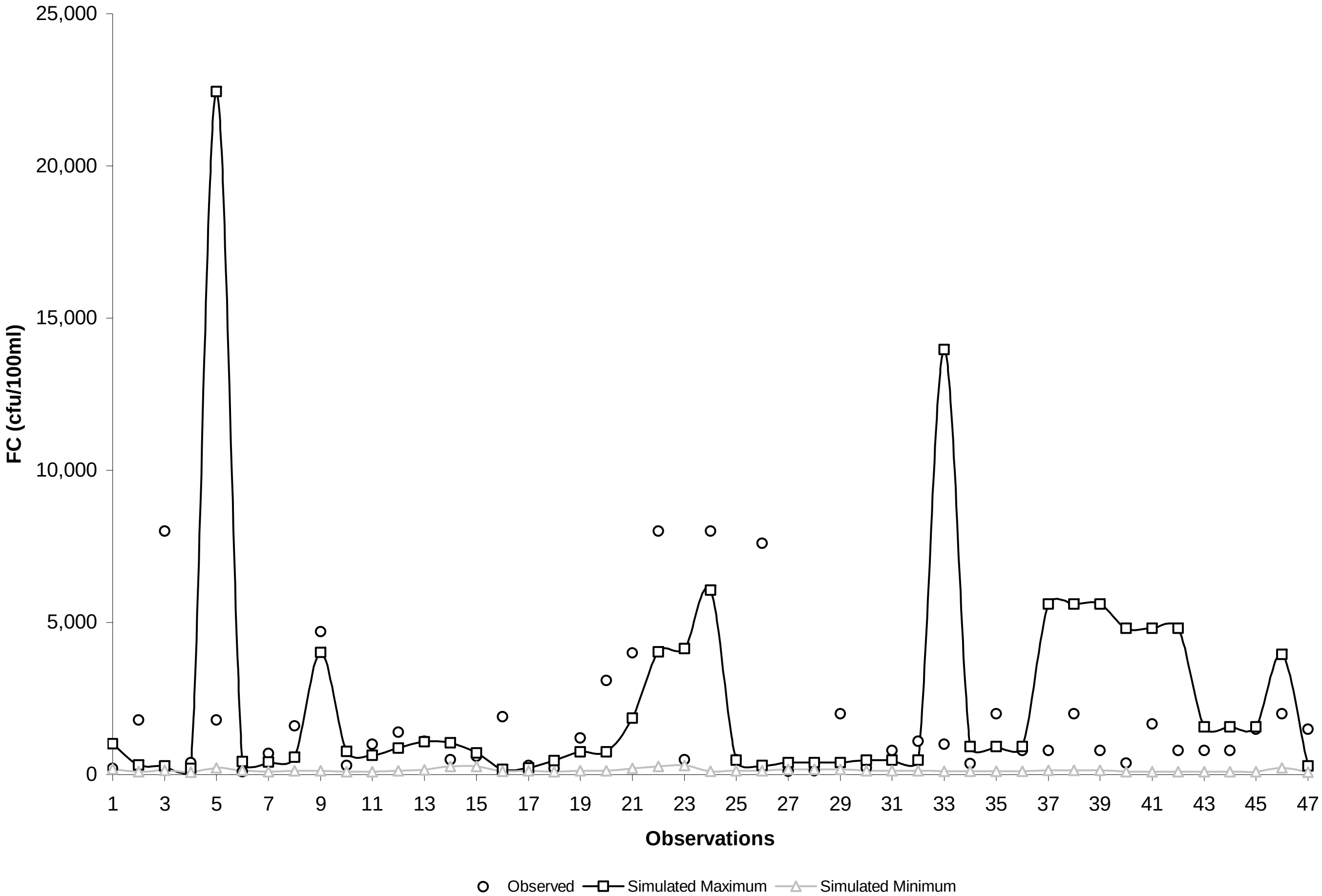

Figure 4.50 Comparison of minimum and maximum modeled values in a 2-day window, centered on a single observed value. Validation period for subwatershed 33 in the Polecat Draft impairment.

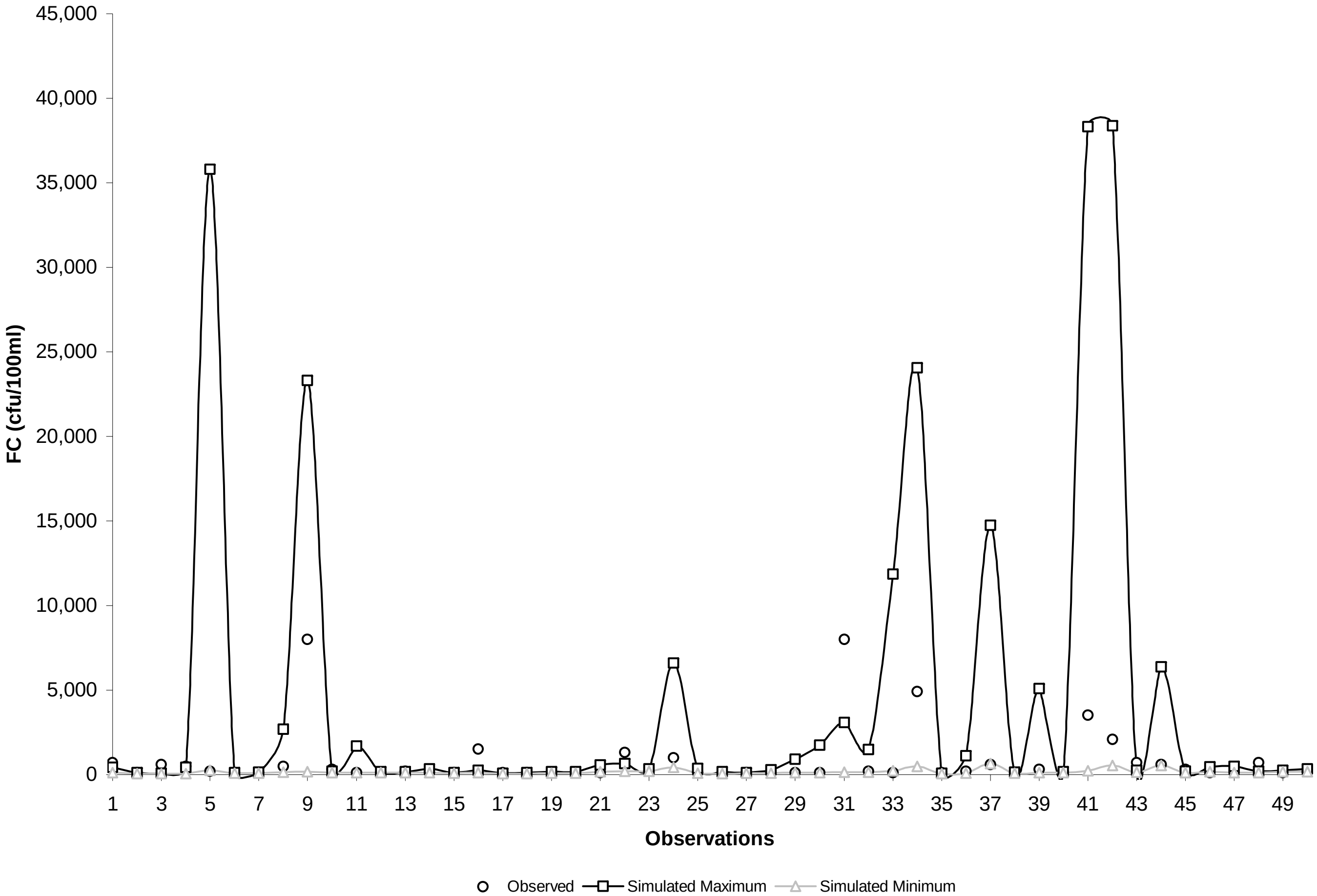

Figure 4.51 Comparison of minimum and maximum modeled values in a 2-day window, centered on a single observed value. Validation period for subwatershed 36 in the Lower Middle River impairment.

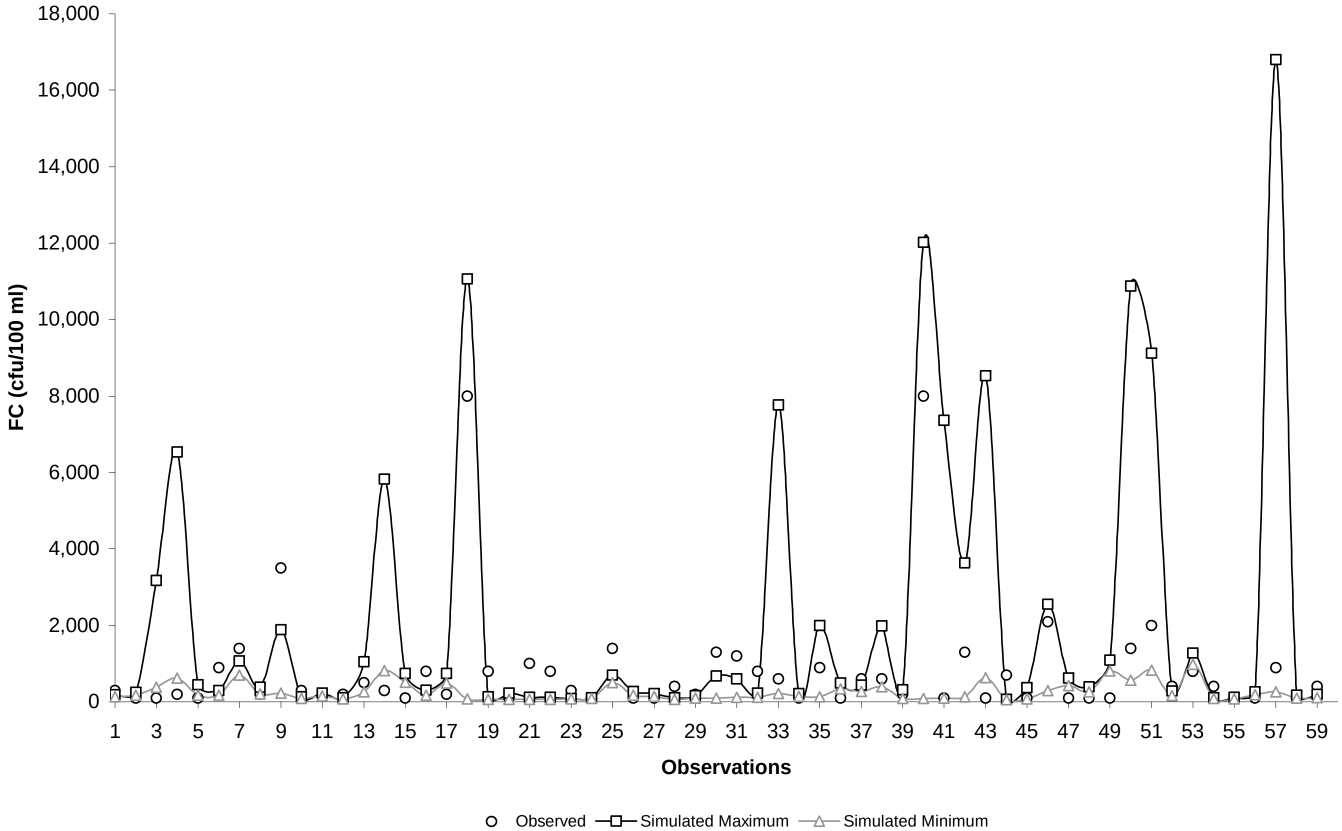

Figure 4.52 Comparison of minimum and maximum modeled values in a 2-day window, centered on a single observed value. Validation period for subwatershed 43 in the Upper South River impairment.

4.8 Existing Loadings

All appropriate inputs were updated to 2003 conditions, as described in Section 4. All model runs were conducted using precipitation data for the representative period used for hydrologic calibration (10/1/92 through 9/30/97). Figure 4.53 through Figure 4.58 show the monthly geometric mean of *E. coli* concentrations in relation to the 126 cfu/100 ml standard. Figure 4.59 through Figure 4.64 show the instantaneous values of *E. coli* concentrations in relation to the 235 cfu/100 ml standard. Appendix B contains tables with monthly loadings to the different landuse areas in each subwatershed.

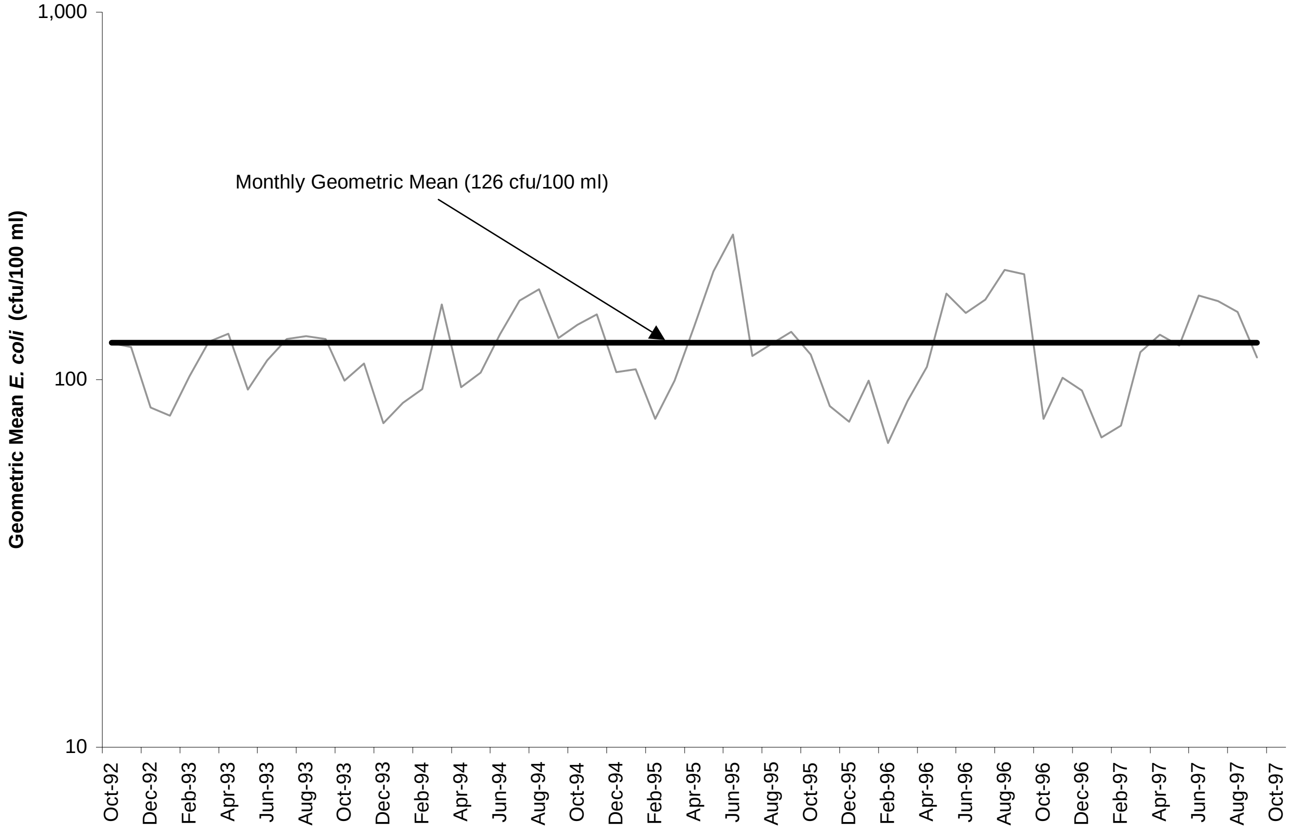

Figure 4.53 Existing conditions of *E. coli* concentrations in subwatershed 10 in the Upper Middle River impairment.

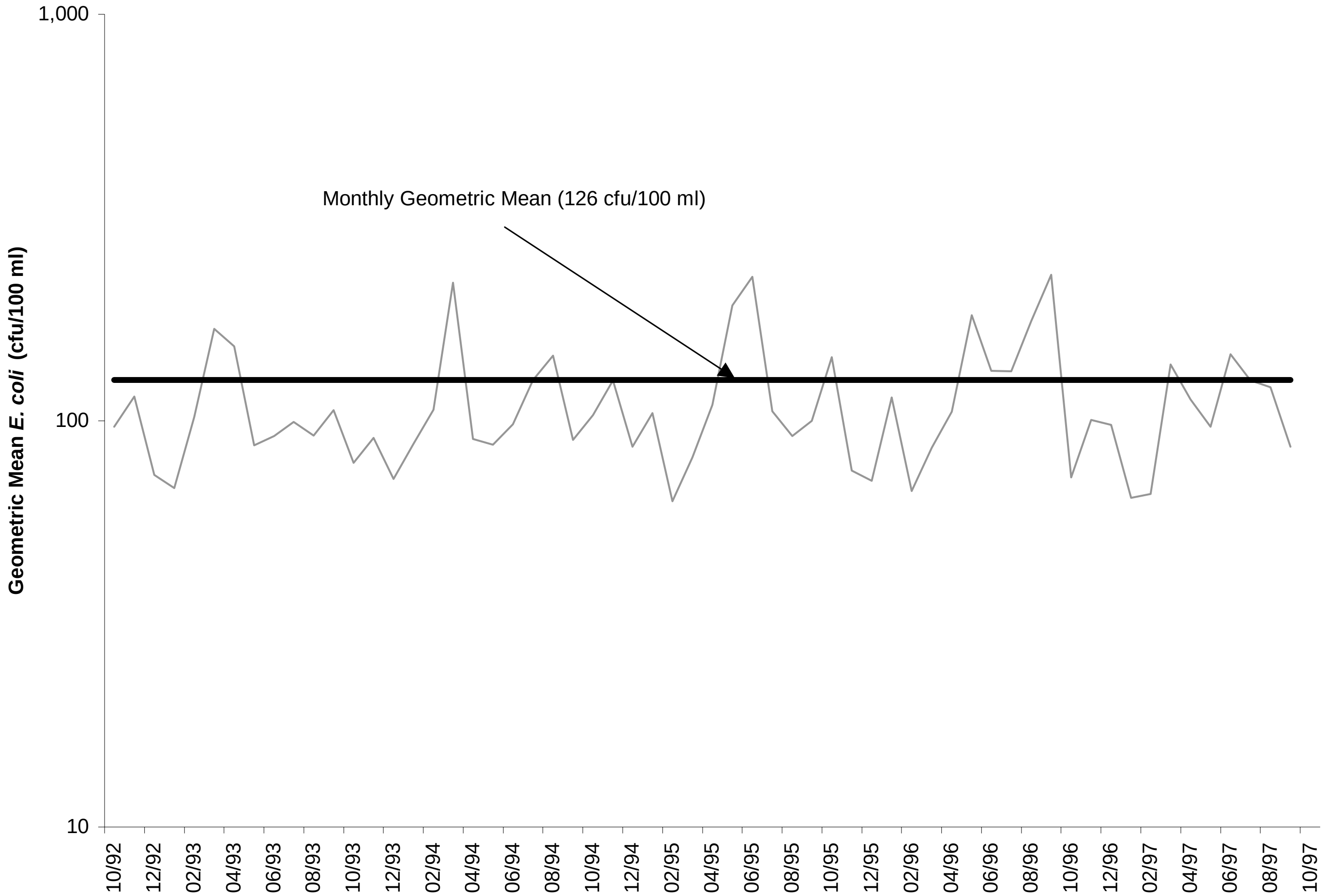

Figure 4.54 Existing conditions of *E. coli* concentrations in subwatershed 17 in the Moffett Creek impairment.

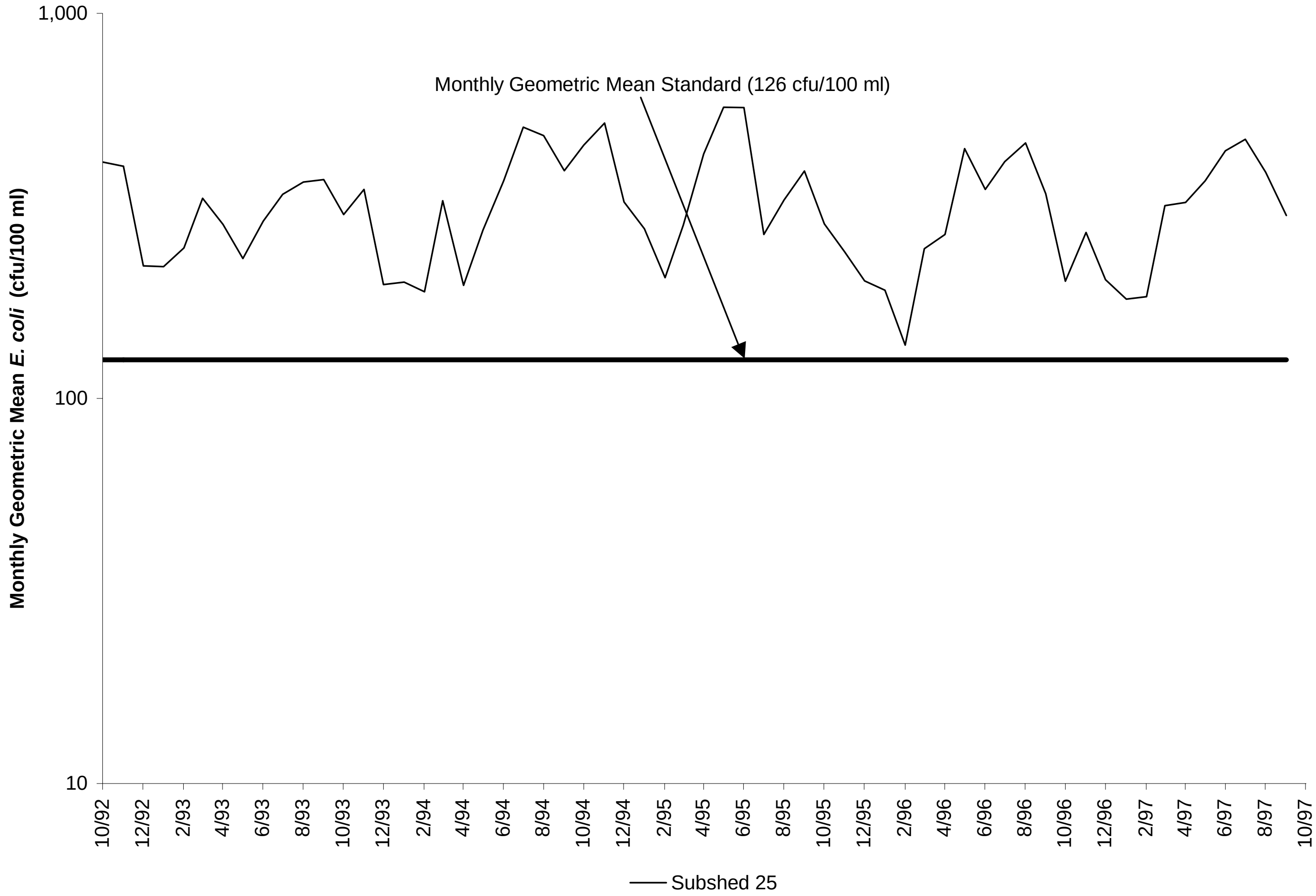

Figure 4.55 Existing conditions of *E. coli* concentrations in subwatershed 25 in the Lewis Creek impairment.

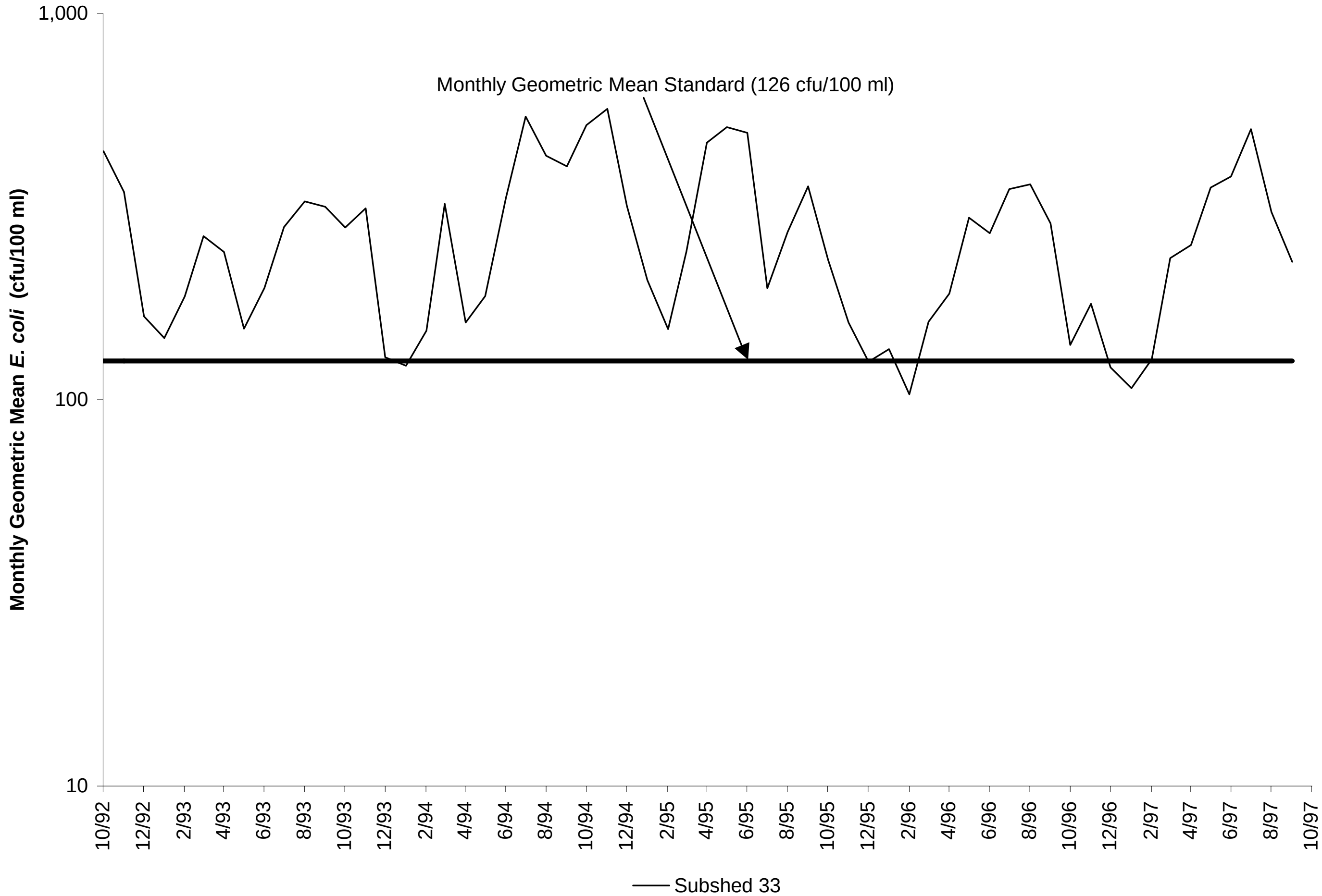

Figure 4.56 Existing conditions of *E. coli* concentrations in subwatershed 33 in the Polecat Draft impairment.

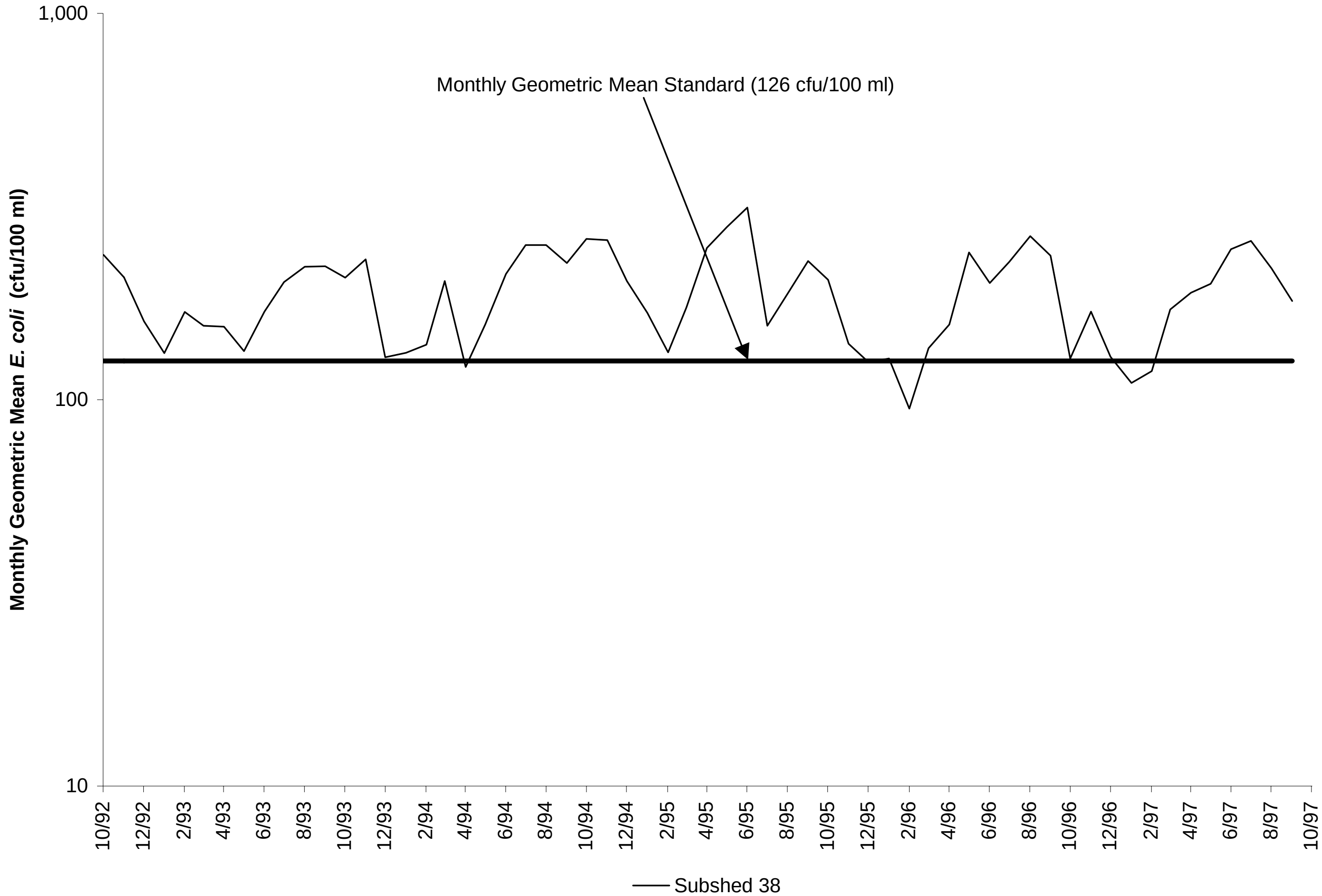

Figure 4.57 Existing conditions of *E. coli* concentrations in subwatershed 38 in the Lower Middle River impairment.

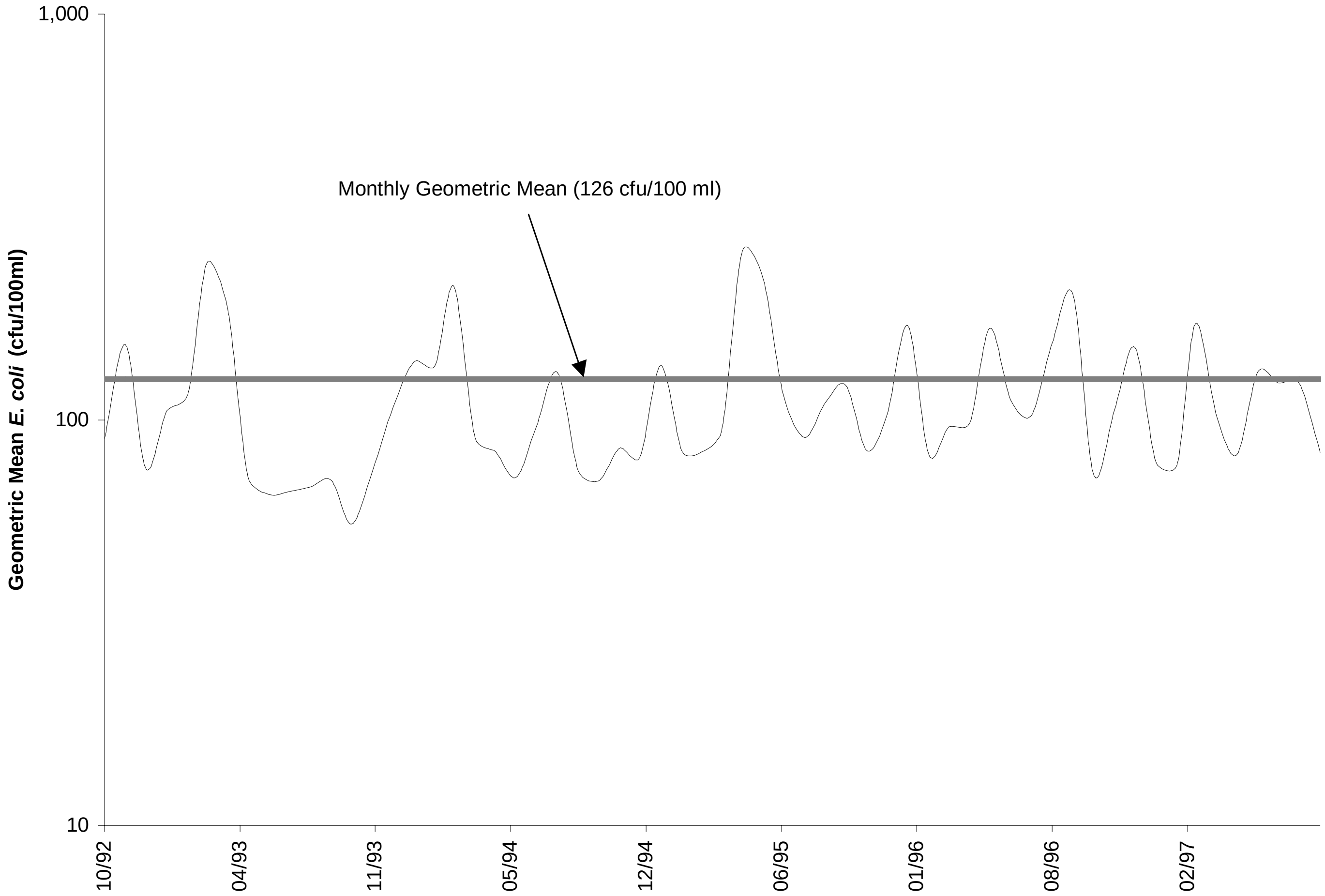

Figure 4.58 Existing conditions of *E. coli* concentrations in subwatershed 44 in the Upper South River impairment.

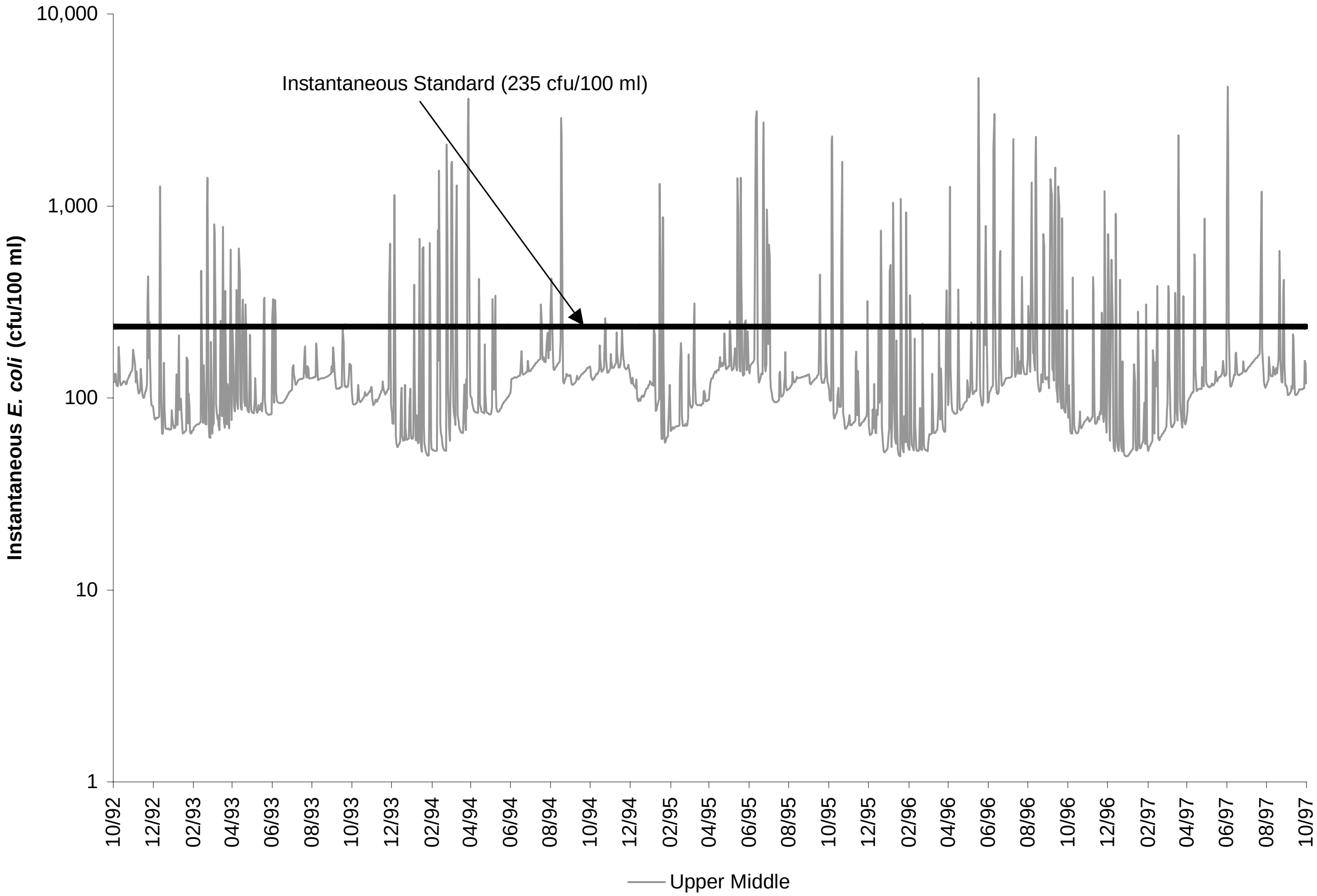

Figure 4.59 Existing conditions of *E. coli* concentrations in subwatershed 10 in the Upper Middle River impairment.

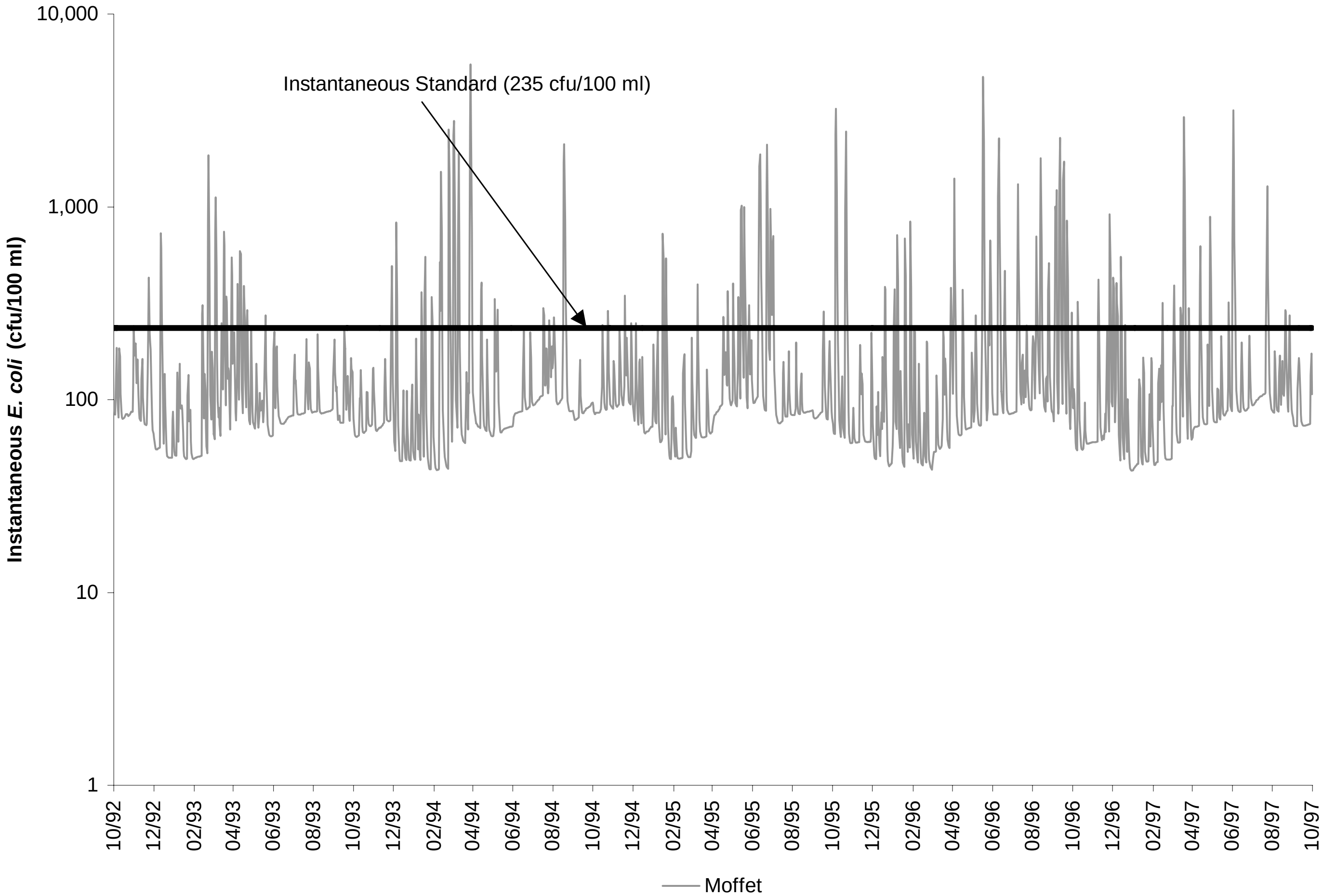

Figure 4.60 Existing conditions of *E. coli* concentrations in subwatershed 17 in the Moffett Creek impairment.

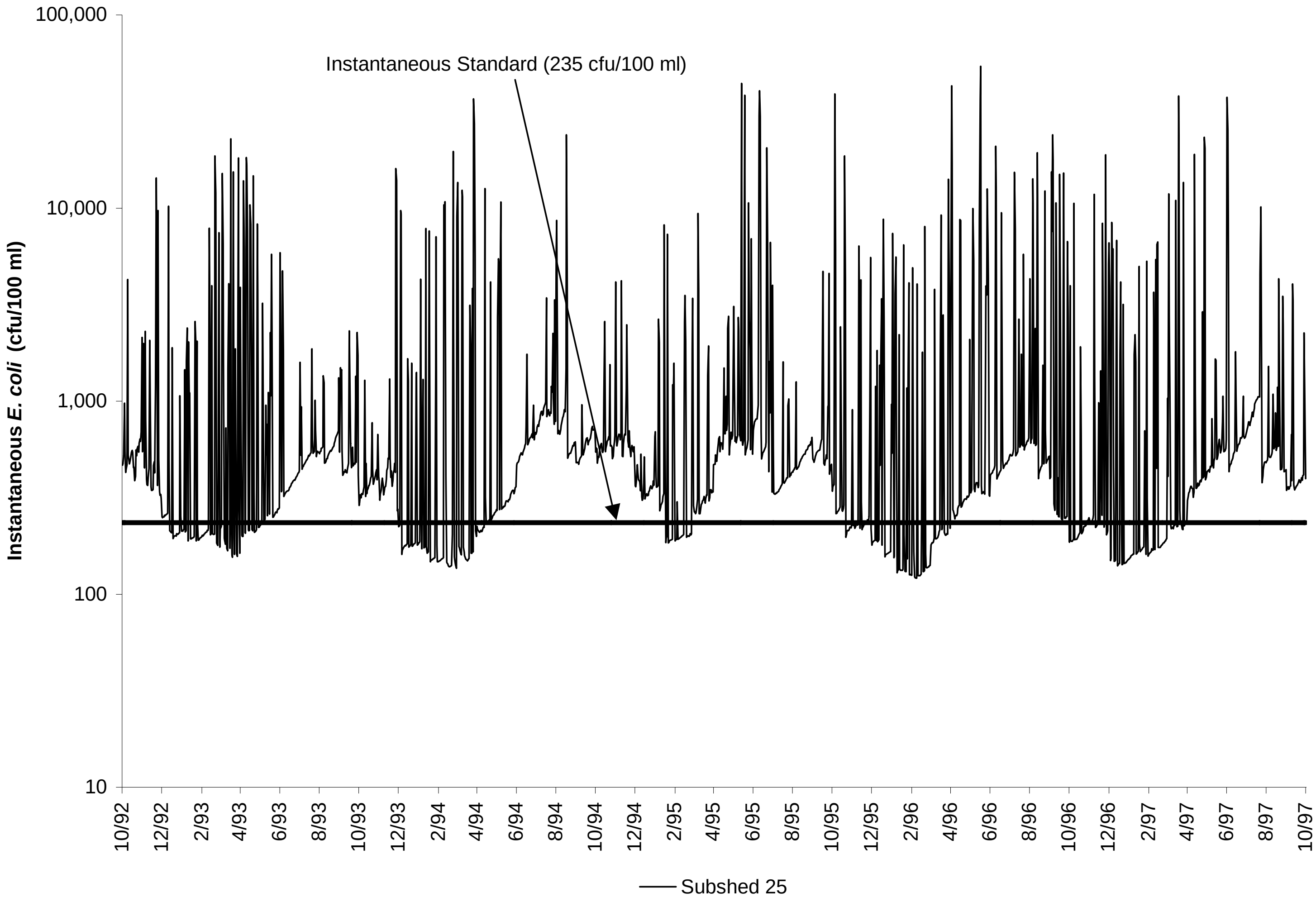

Figure 4.61 Existing conditions of *E. coli* concentrations in subwatershed 25 in the Lewis Creek impairment.

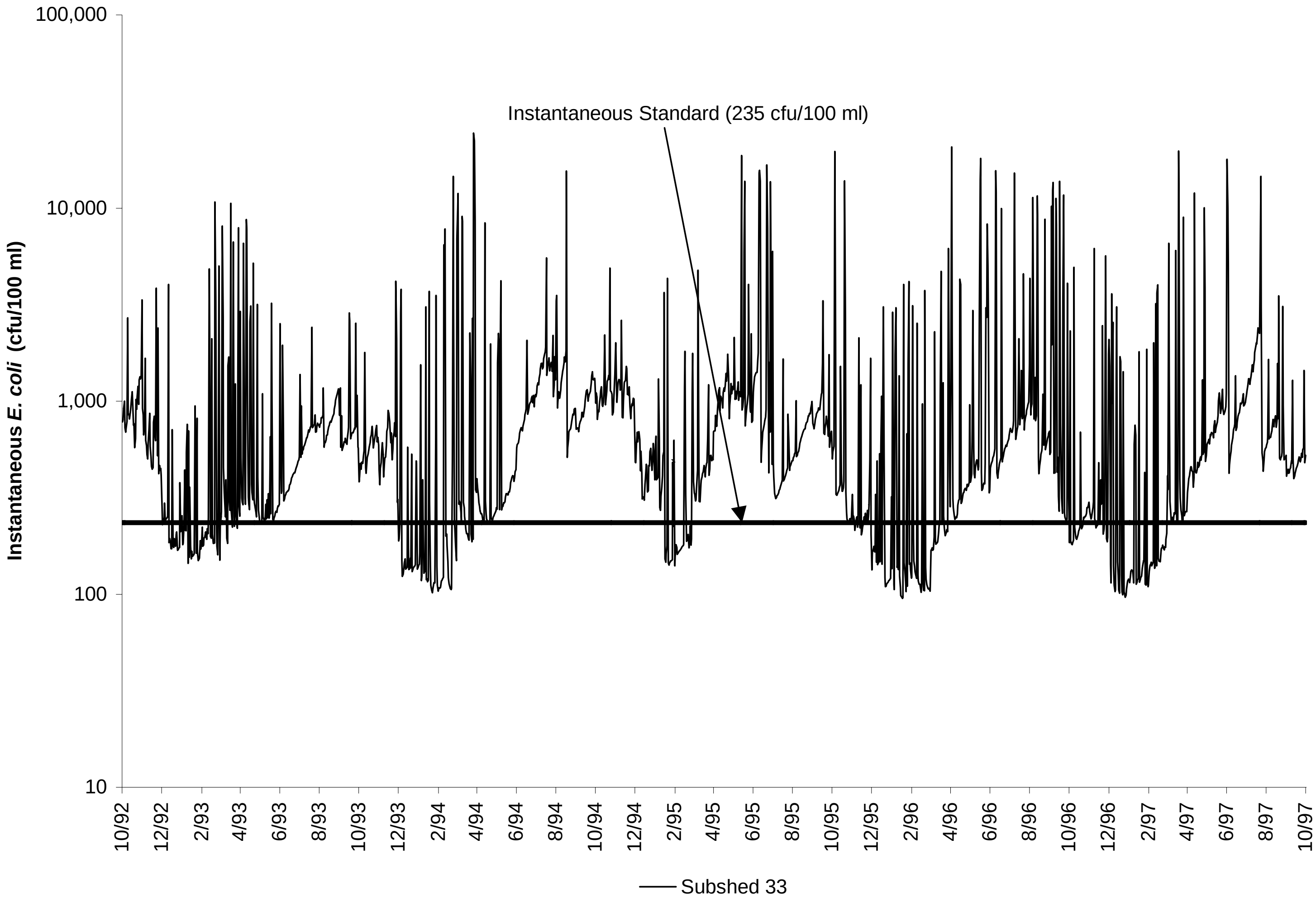

Figure 4.62 Existing conditions of *E. coli* concentrations in subwatershed 33 in the Polecat Draft impairment.

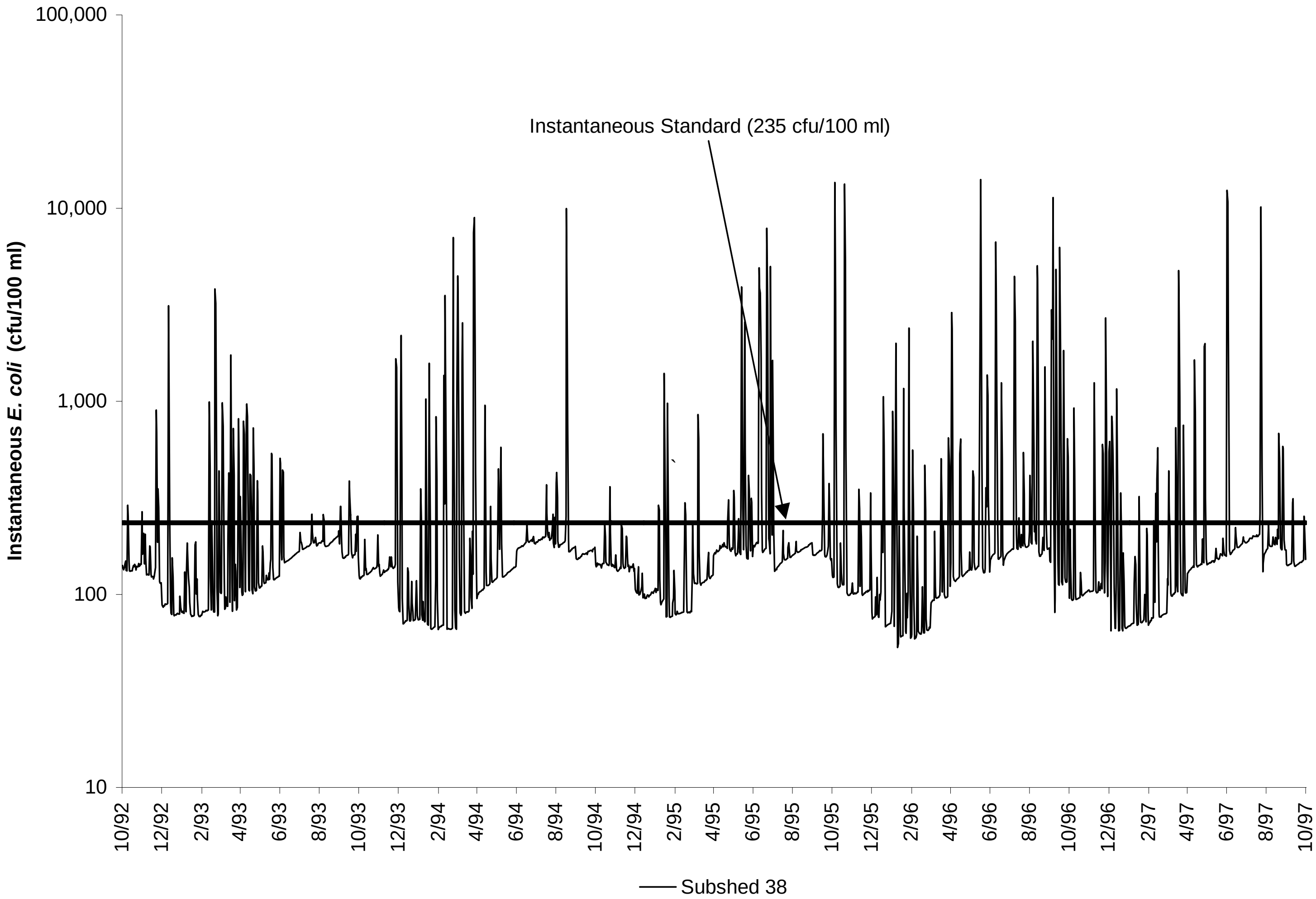

Figure 4.63 Existing conditions of *E. coli* concentrations in subwatershed 38 in the Lower Middle River impairment.

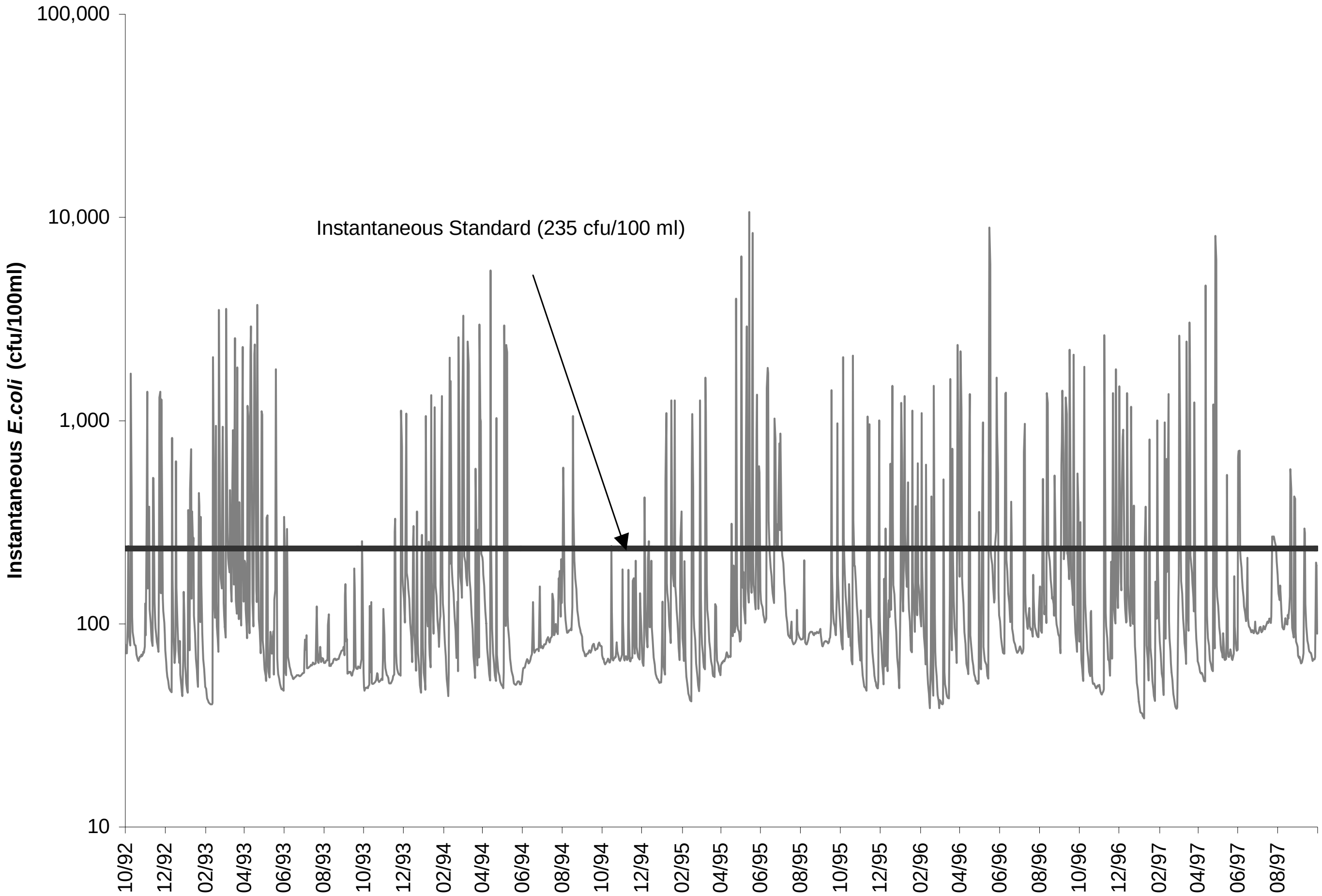

Figure 4.64 Existing conditions of *E. coli* concentrations in subwatershed 44 in the Upper South River impairment.

5. ALLOCATION

Total Maximum Daily Loads (TMDLs) consist of waste load allocations (WLAs, point sources) and load allocations (LAs, nonpoint sources) including natural background levels. Additionally, the TMDL must include a margin of safety (MOS) that either implicitly or explicitly accounts for the uncertainties in the process (e.g. accuracy of wildlife populations). The definition is typically denoted by the expression:

$$TMDL = WLAs + LAs + MOS$$

The TMDL becomes the amount of a pollutant that can be assimilated by the receiving water body and still achieve water quality standards. For fecal bacteria, TMDL is expressed in terms of colony forming units (or resulting concentration). A sensitivity analysis was performed to determine the impact of uncertainties in input parameters.

5.1 Incorporation of a Margin of Safety

In order to account for uncertainty in modeled output, a margin of safety (MOS) was incorporated into the TMDL development process. Individual errors in model inputs, such as data used for developing model parameters or data used for calibration, may affect the load allocations in a positive or a negative way. A margin of safety can be incorporated implicitly in the model through the use of conservative estimates of model parameters, or explicitly as an additional load reduction requirement. The intention of a MOS in the development of a fecal coliform TMDL is to ensure that the modeled loads do not under-estimate the actual loadings that exist in the watershed. An implicit MOS was used in the development of this TMDL. By adopting an implicit MOS in estimating the loads in the watershed, it is insured that the recommended reductions will, in fact, succeed in meeting the water quality standard. Examples of implicit MOS used in the development of this TMDL were:

- allocating permitted point sources at the maximum allowable fecal coliform concentration,
- selecting a modeling period that represented the critical hydrologic conditions in the watershed, and

- modeling biosolids applications at the maximum allowable rate and fecal coliform concentration in all permitted fields.

5.2 Scenario Development

Allocation scenarios were modeled using HSPF. Existing conditions were adjusted until the water quality standard was attained. The TMDLs developed for the Middle and Upper South River watersheds were based on the Virginia State Standard for *E. coli*. As detailed in Section 1.2, the *E. coli* standard states that the calendar month geometric-mean concentration shall not exceed 126 cfu/100 ml, and that a maximum single sample concentration of *E. coli* not exceed 235 cfu/100 ml. According to the guidelines put forth by VADEQ (VADEQ, 2003) for modeling *E. coli* with HSPF, the model was set up to estimate loads of fecal coliform, then the model output was converted to concentrations of *E. coli* through the use of the following equation (developed from a dataset containing n-493 paired data points):

$$\log_2(C_{ec}) = -0.0172 + 0.91905 \cdot \log_2(C_{fc})$$

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

Pollutant concentrations were modeled over the entire duration of a representative modeling period, and pollutant loads were adjusted until the standard was met (Figures 5.1 through 5.12). The development of the allocation scenario was an iterative process that required numerous runs with each followed by an assessment of source reduction against the water quality target.

5.2.1 Wasteload Allocations

There are eighty-seven point sources currently permitted to discharge in the Middle and Upper South River watersheds (Figure 3.1 and Table 3.1). Of these sources, only thirty-three are permitted for fecal control in the impairment areas. For allocation runs, sources without fecal control permits were modeled as discharging the average recorded value of water, with no *E. coli*. The allocation for these sources is zero cfu/100 ml. The allocation for the sources permitted for fecal control is equivalent to their current permit levels (*i.e.*, design flow and 126 cfu/100 ml).

5.2.2 Load Allocations

Load allocations to nonpoint sources are divided into land-based loadings from landuses and directly applied loads in the stream (*e.g.*, livestock, sewer overflows, and wildlife). Source reductions include those that are affected by both high and low flow conditions. Within this framework, however, initial criteria that influenced developing load allocations included how sources were linked for representing existing conditions, and results from bacterial source tracking in the area. Land-based NPS loads had the most significant impact during high-flow conditions, while direct deposition NPS had the most significant impact on low flow concentrations. Bacterial source tracking during 2002-2003 sampling periods confirmed the presence of human, pets, livestock and wildlife contamination.

For modeling of allocation scenarios, the fecal load from Christians Creek was to be represented by the allocated loads developed for the Christians Creek Fecal Coliform TMDL. However, the Christians Creek TMDL was developed based on the former fecal bacteria standard, which only required compliance with a 30-day geometric mean standard of 200 cfu-fecal coliform/100ml. The current standard requires compliance with both a geometric mean standard and an instantaneous standard. The allocated loads from Christians Creek, as modeled for the Christians Creek TMDL, would not allow compliance with the instantaneous standard in the Lower Middle River impairment. Under the guidance of VADEQ and EPA, loads from Christians Creek were modeled to represent 126 cfu-*E.coli*/100ml. This ensured compliance with both the geometric mean and instantaneous standards at the outlet of Christians Creek, and allowed for development of an allocation scenario, for the Lower Middle River impairment, that would comply with the current standard.

Allocation scenarios were run in six parts, corresponding to the six impairments –Upper Middle River, Moffett Creek, Lewis Creek, Polecat Draft, Lower Middle River and Upper South River. Tables 5.1 through 5.6 represent a small portion of the scenarios developed to determine the TMDL for each impairment. Scenario 1 in each table describes a baseline scenario that corresponds to the existing conditions in the watershed. Model results indicate that human, livestock and in-stream depositions by wildlife are significant in all areas of the watershed. This is in agreement with the results of BST analysis presented in Appendix C.

Reduction scenarios exploring the role of anthropogenic sources in standards violations were explored first to determine the feasibility of meeting standards without wildlife reductions. Scenario 2 in each table contains 100% reductions in sewer overflows, uncontrolled residential discharges (*i.e.*, straight pipes), and direct livestock deposition. Land-based loads were not addressed in this scenario, nor were direct loads from wildlife. In all cases this scenario improved conditions in the stream, but failed to eliminate exceedances.

Scenario 3 in all of the tables represents the reductions described in scenario 2 with additional reductions of 50% to land loads from urban and agricultural lands. In all cases, exceedances of the standard persist.

Scenario 4 in each table contains reductions of 100% in all anthropogenic land-based loads, 100% reduction in sewer overflows and uncontrolled residential discharges, 100% reduction in direct livestock deposition and a 0% reduction in wildlife direct and land-based loading to the stream. In all but a single case the model predicted that water quality standards will not be met without reductions in wildlife loads. The single exception was Polecat Draft.

Continuing, in each case, from scenario 4, land-based and direct loads were adjusted until a scenario was developed that met both standards. The strategy for scenario development was to reduce loads from anthropogenic sources first, and to address wildlife loads only when additional reductions in anthropogenic sources were unavailable or ineffective in achieving the goal of zero exceedances. Scenario 5 in each table indicates a viable scenario for achieving zero exceedances of the standard.

Table 5.1 Allocation scenarios for bacterial concentration with current loading estimates in the Upper Middle River impairment.

Scenario Number	Percent Reduction in Loading from Existing Condition						Percent Violations	
	Direct Wildlife	NPS Forest/ Water	Direct Livestock	NPS Pasture / Livestock Access / Crops	NPS Res./ Urban	Straight Pipe/ Sewer Overflow	GM > 126 cfu/ 100ml	Single Sample Exceeds 235 cfu/ 100ml
1	0	0	0	0	0	0	100	38
2	0	0	100	0	0	100	12	9
3	0	0	100	50	50	100	0	7
4	0	0	100	100	100	100	0	2
5	0	99	100	99.9	99.9	100	0	0

Table 5.2 Allocation scenarios for bacterial concentration with current loading estimates in the Moffett Creek impairment.

Scenario Number	Percent Reduction in Loading from Existing Condition						Percent Violations	
	Direct Wildlife	NPS Forest/ Water	Direct Livestock	NPS Pasture / Livestock Access / Crops	NPS Res./ Urban	Straight Pipe/ Sewer Overflow	GM > 126 cfu/ 100ml	Single Sample Exceeds 235 cfu/ 100ml
1	0	0	0	0	0	0	100	60
2	0	0	100	0	0	100	58	17
3	0	100	100	50	50	100	53	17
4	0	0	100	100	100	100	32	17
5	36	93	100	99.9	99.9	100	0	0

Table 5.3 Allocation scenarios for bacterial concentration with current loading estimates in the Lewis Creek impairment.

Scenario Number	Percent Reduction in Loading from Existing Condition						Percent Violations	
	Direct Wildlife	NPS Forest/ Water	Direct Livestock	NPS Pasture / Livestock Access / Crops	NPS Res./ Urban	Straight Pipe/ Sewer Overflow	GM > 126 cfu/ 100ml	Single Sample Exceeds 235 cfu/ 100ml
1	0	0	0	0	0	0	100	55
2	0	0	100	0	0	100	50	55
3	0	0	100	50	50	100	37	53
4	0	0	100	100	100	100	18	49
5	75	99	100	99.9	99.9	100	0	0

Table 5.4 Allocation scenarios for bacterial concentration with current loading estimates in the Polecat Draft impairment.

Scenario Number	Percent Reduction in Loading from Existing Condition						Percent Violations	
	Direct Wildlife	NPS Forest/ Water	Direct Livestock	NPS Pasture / Livestock Access / Crops	NPS Res./ Urban	Straight Pipe/ Sewer Overflow	GM > 126 cfu/ 100ml	Single Sample Exceeds 235 cfu/ 100ml
1	0	0	0	0	0	0	92	46
2	0	0	100	0	0	100	8	7
3	0	0	100	50	50	100	2	5
4	0	0	100	100	100	100	0	0.10
5	6	0	100	99.99	83	100	0	0

Table 5.5 Allocation scenarios for bacterial concentration with current loading estimates in the Lower Middle River impairment.

Scenario Number	Percent Reduction in Loading from Existing Condition						Percent Violations	
	Direct Wildlife	NPS Forest/ Water	Direct Livestock	NPS Pasture / Livestock Access / Crops	NPS Res./ Urban	Straight Pipe/ Sewer Overflow	GM > 126 cfu/ 100ml	Single Sample Exceeds 235 cfu/ 100ml
1	0	0	0	0	0	0	100	36
2	0	0	100	0	0	100	47	13
3	0	0	100	50	50	100	27	9
4	0	0	100	100	100	100	2	2
5	0	71	100	99.9	99.9	100	0	0

Table 5.6 Allocation scenarios for bacterial concentration with current loading estimates in the Upper South River impairment.

Scenario Number	Percent Reduction in Loading from Existing Condition						Percent Violations	
	Direct Wildlife	NPS Forest/ Water	Direct Livestock	NPS Pasture / Livestock Access / Crops	NPS Res./ Urban	Straight Pipe/ Sewer Overflow	GM > 126 cfu/ 100ml	Single Sample Exceeds 235 cfu/ 100ml
1	0	0	0	0	0	0	40	14
2	0	0	100	0	0	100	19	12
3	0	0	100	50	50	100	14	11
4	0	0	100	100	100	100	11	10
5	0	97.5	55	99.9	99.9	100	0	0

Figures 5.1 through 5.12 show graphically the allocated conditions for the geometric-mean concentrations and instantaneous concentrations in each impairment. The existing curves are black while the allocated values are overlaid in grey. Tables 5.7 through 5.12

indicate the land-based and direct load reductions resulting from the final location. Table 5.13 shows the final TMDL loads for all of the impairments.

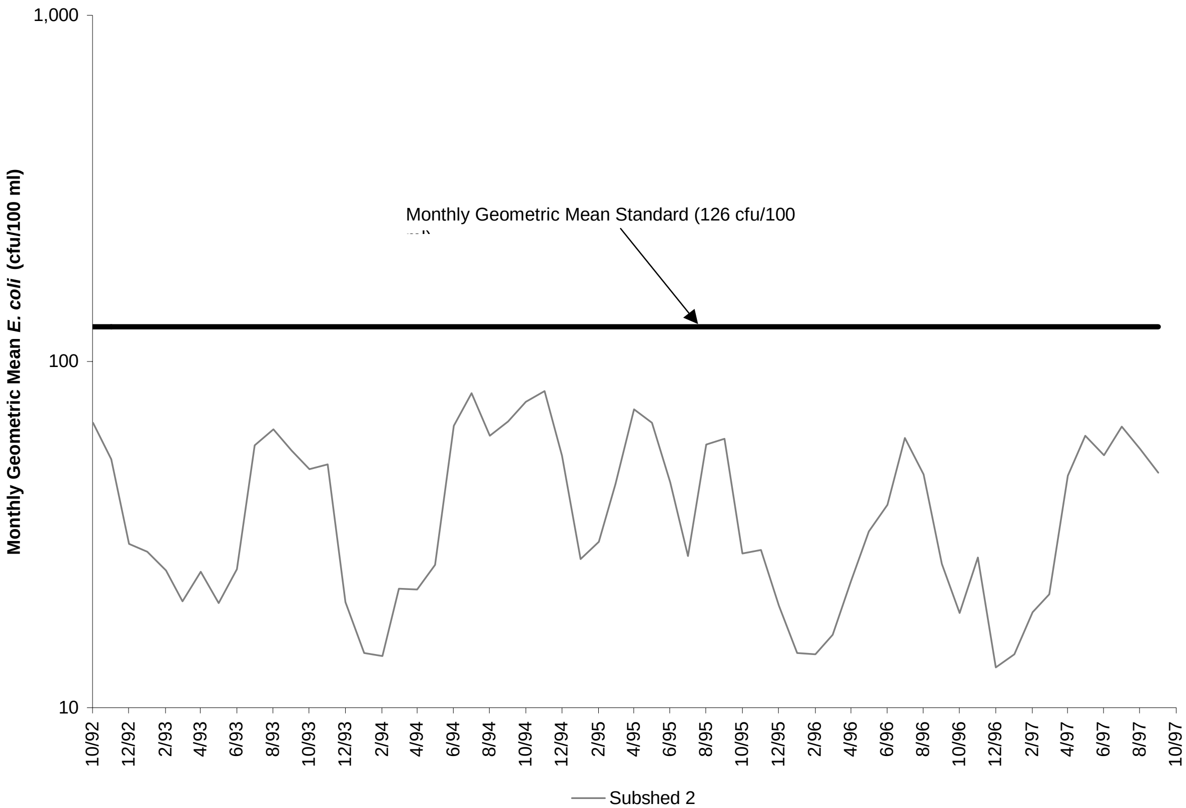

Figure 5.1 Monthly geometric mean *E. coli* concentrations for the Upper Middle River impairment, under allocated conditions.

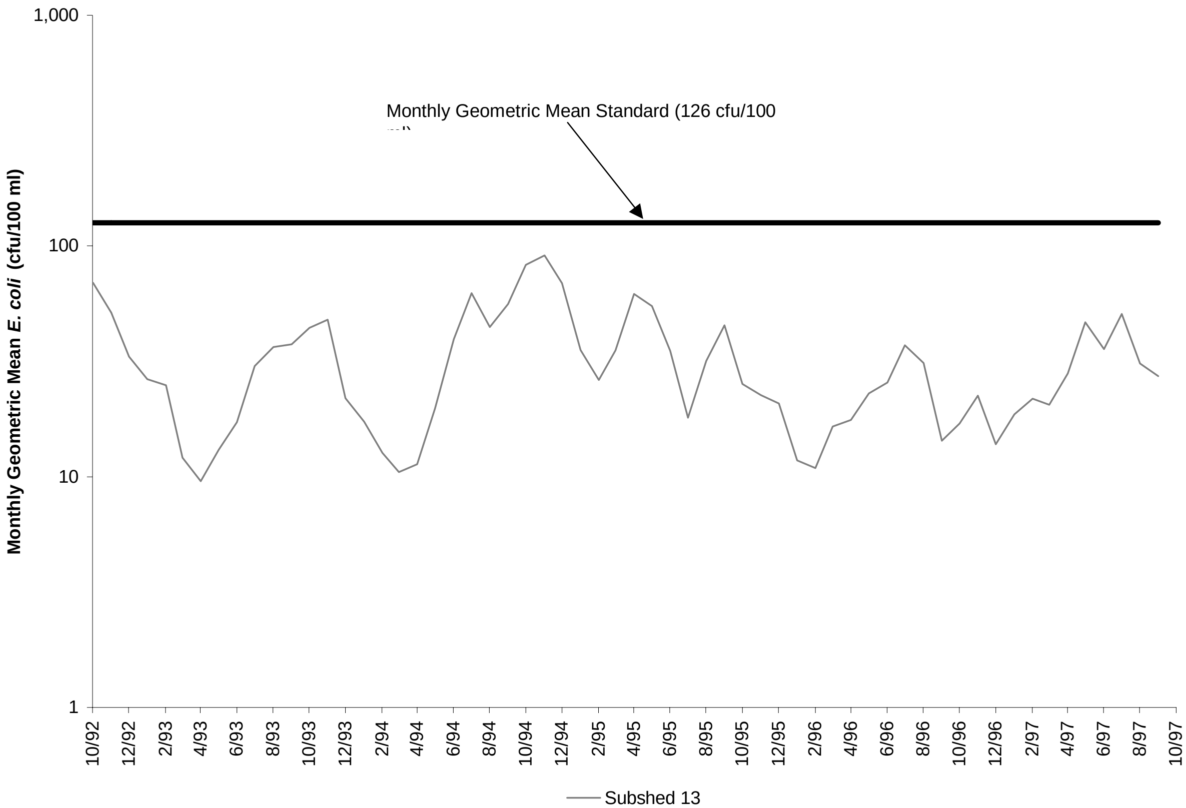

Figure 5.2 **Monthly geometric mean *E. coli* concentrations for the Moffett Creek impairment, under allocated conditions.**

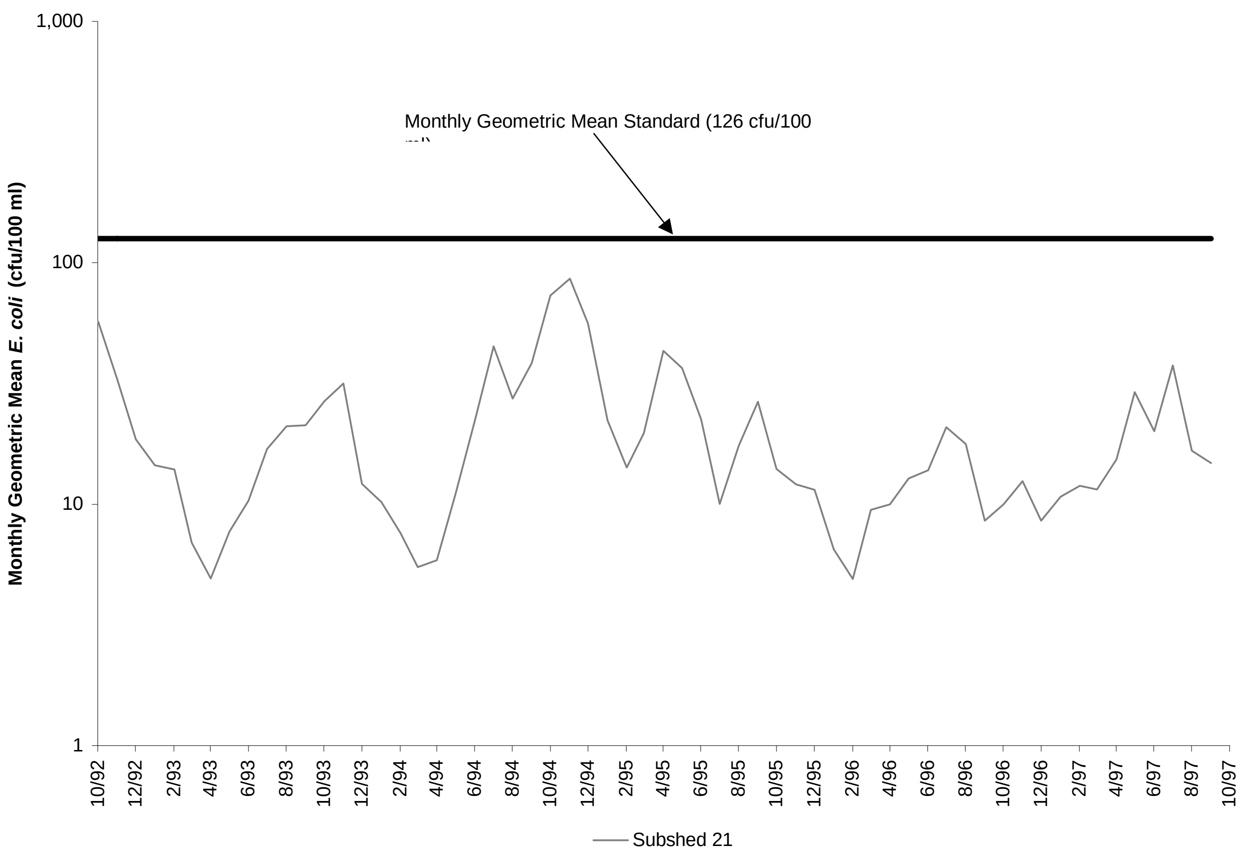

Figure 5.3 Monthly geometric mean *E. coli* concentrations for the Lewis Creek impairment, under allocated conditions.

Figure 5.4 **Monthly geometric mean *E. coli* concentrations for the Polecat Draft impairment, under allocated conditions.**

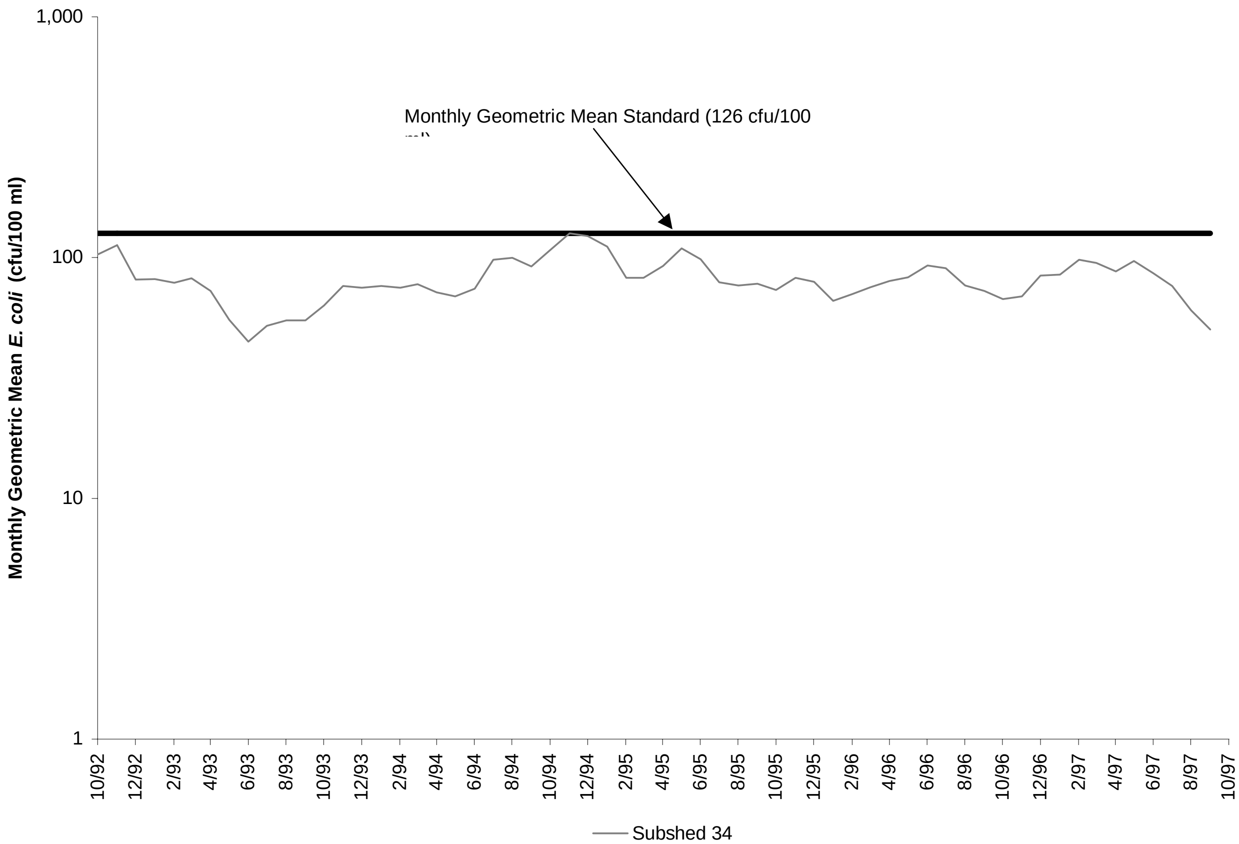

Figure 5.5 Monthly geometric mean *E. coli* concentrations for the Lower Middle River impairment, under allocated conditions.

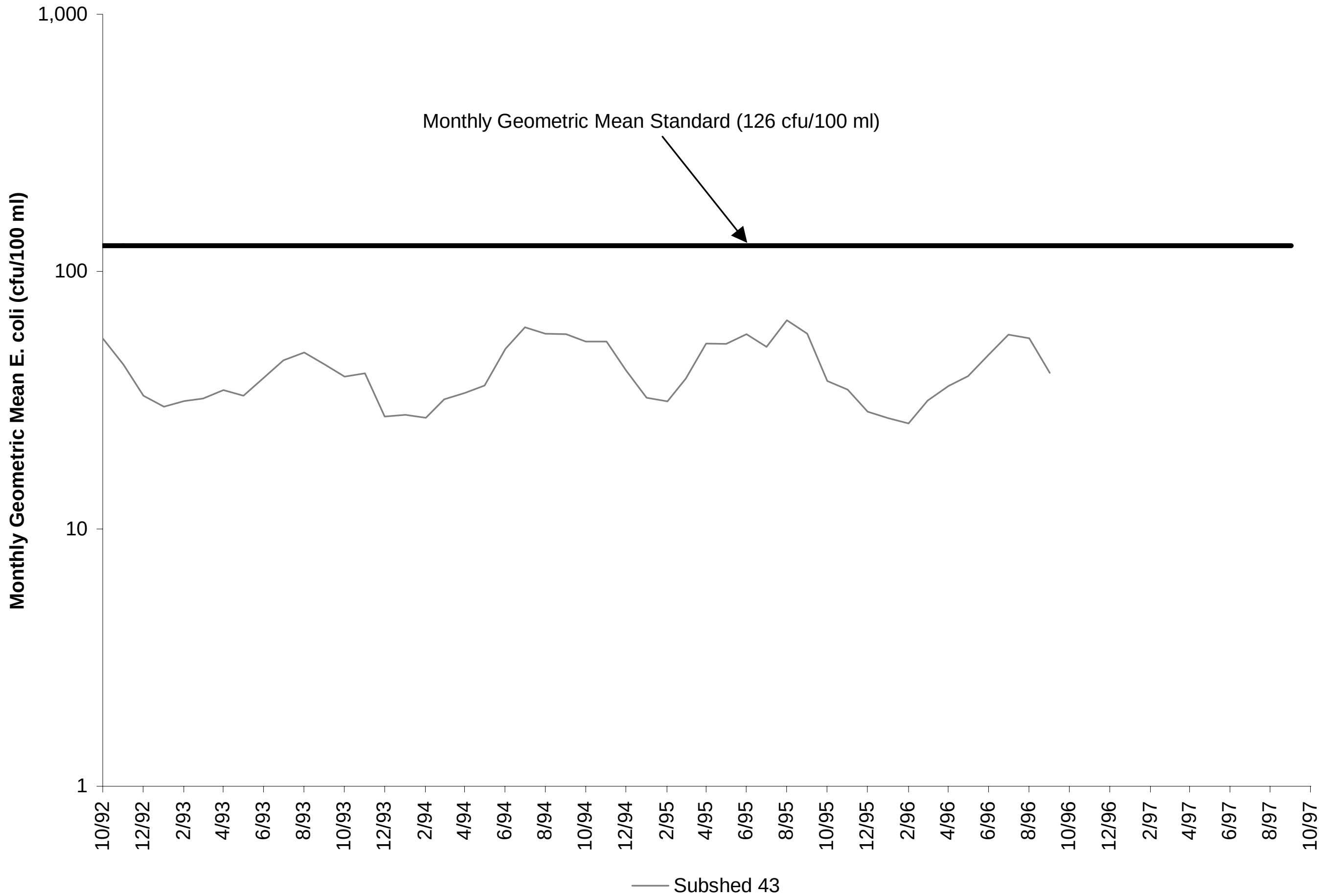

Figure 5.6 Monthly geometric mean *E. coli* concentrations for the Upper South River impairment, under allocated conditions.

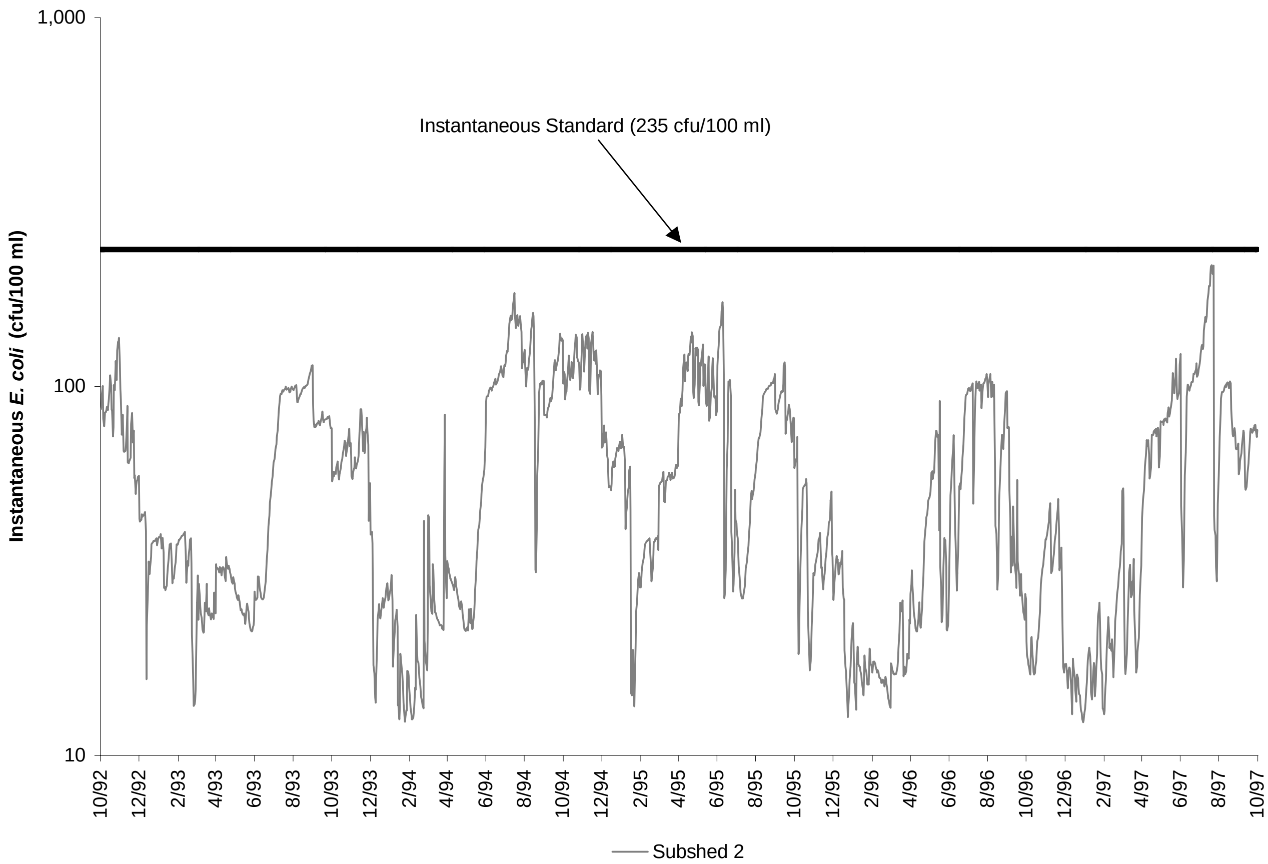

Figure 5.7 Instantaneous *E. coli* concentrations for the Upper Middle River impairment, under allocated conditions.

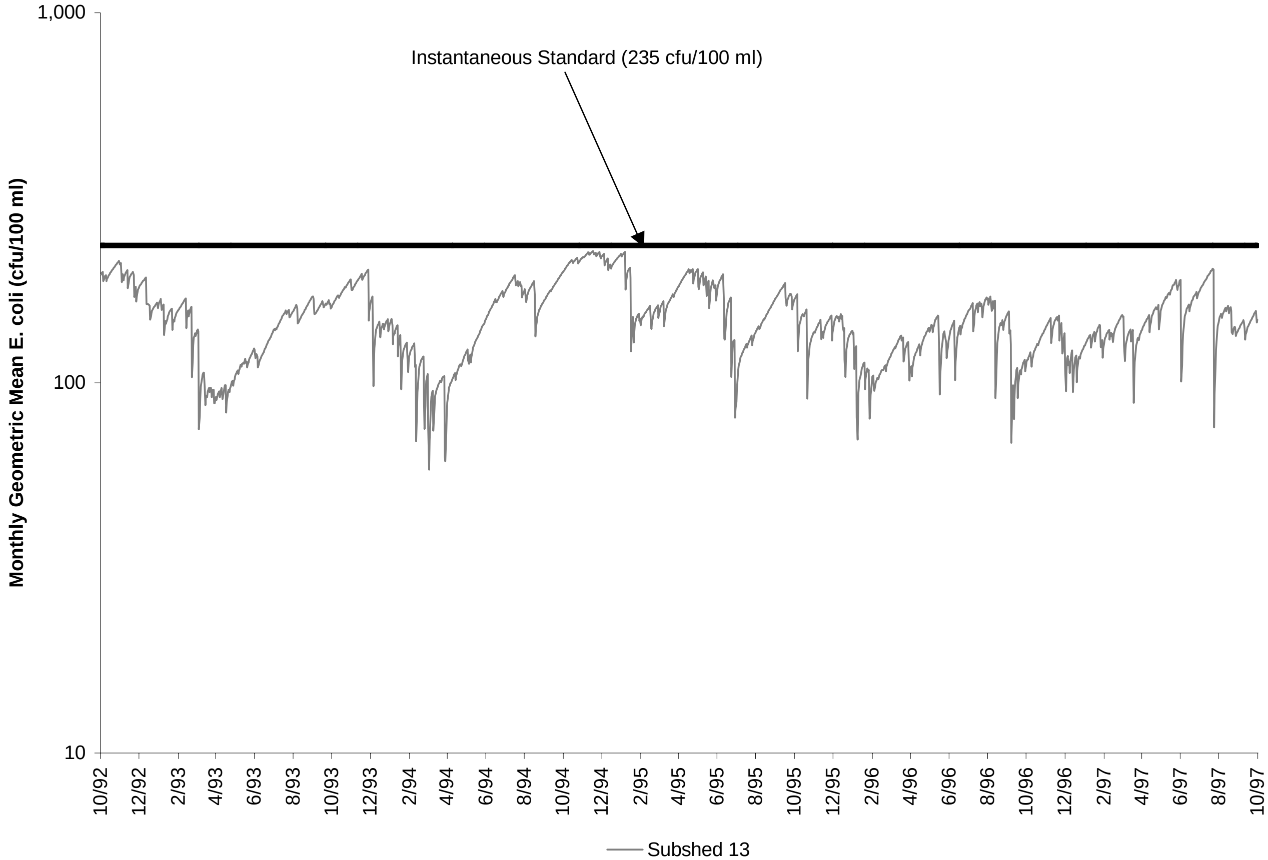

Figure 5.8 Instantaneous *E. coli* concentrations for the Moffett Creek impairment, under allocated conditions.

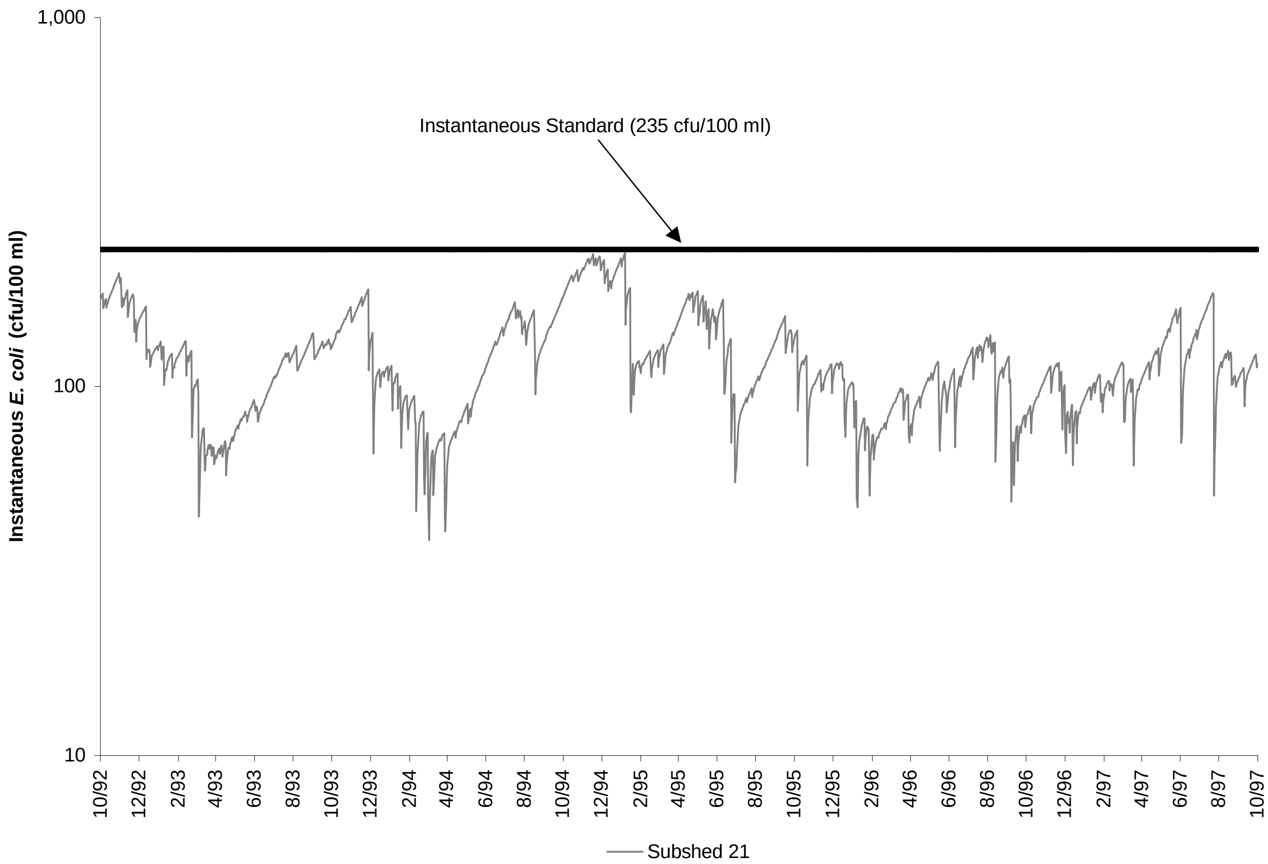

Figure 5.9 Instantaneous *E. coli* concentrations for the Lewis Creek impairment, under allocated conditions.

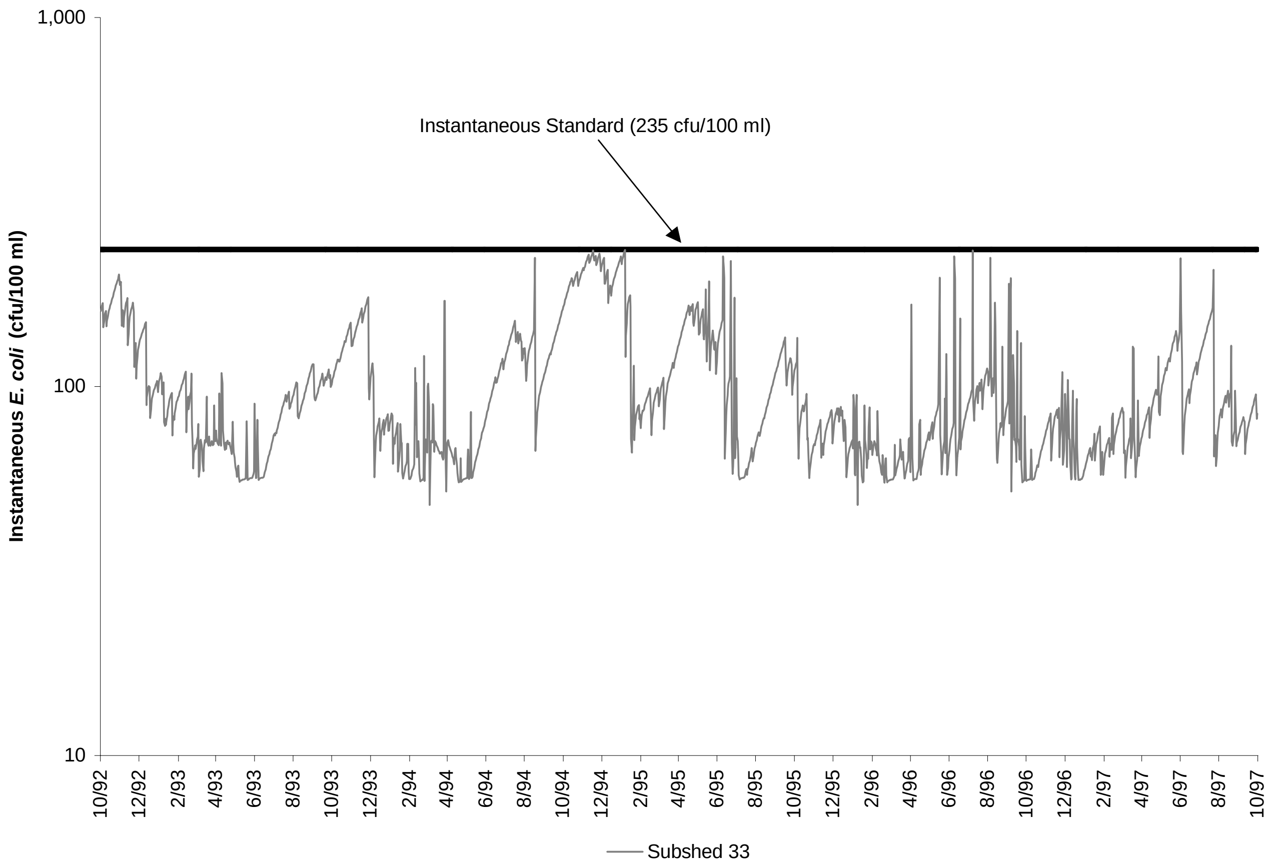

Figure 5.10 Instantaneous *E. coli* concentrations for the Polecat Draft impairment, under allocated conditions.

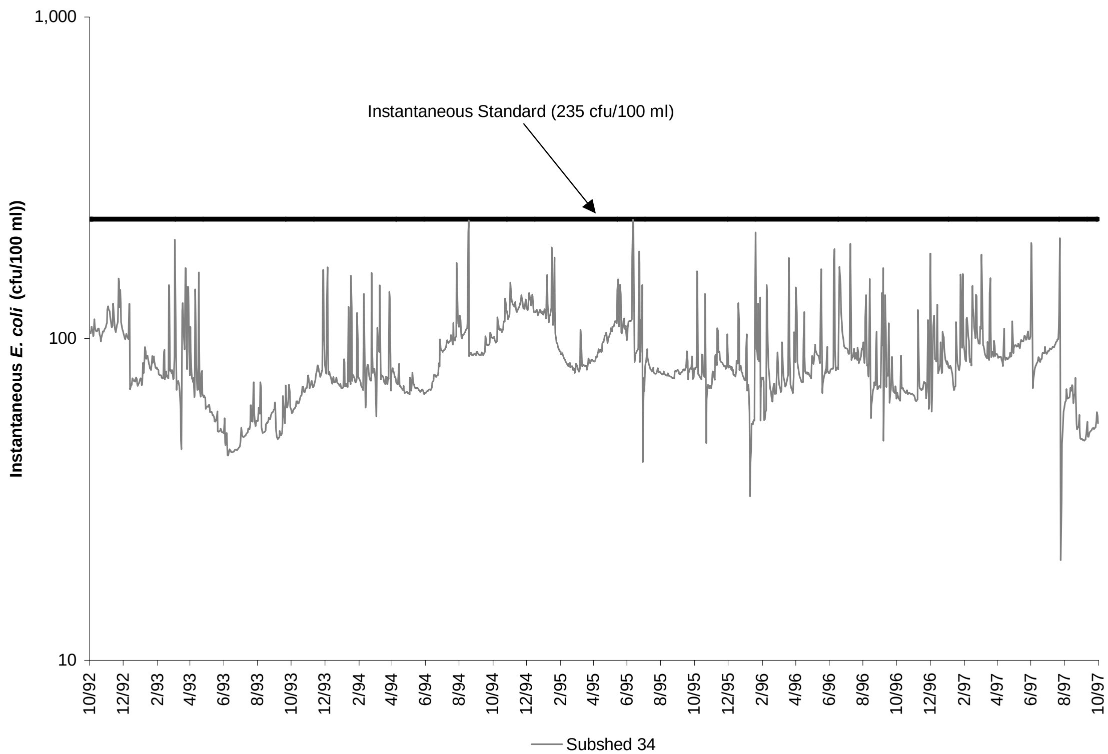

Figure 5.11 Instantaneous *E. coli* concentrations for the Lower Middle River impairment, under allocated conditions.

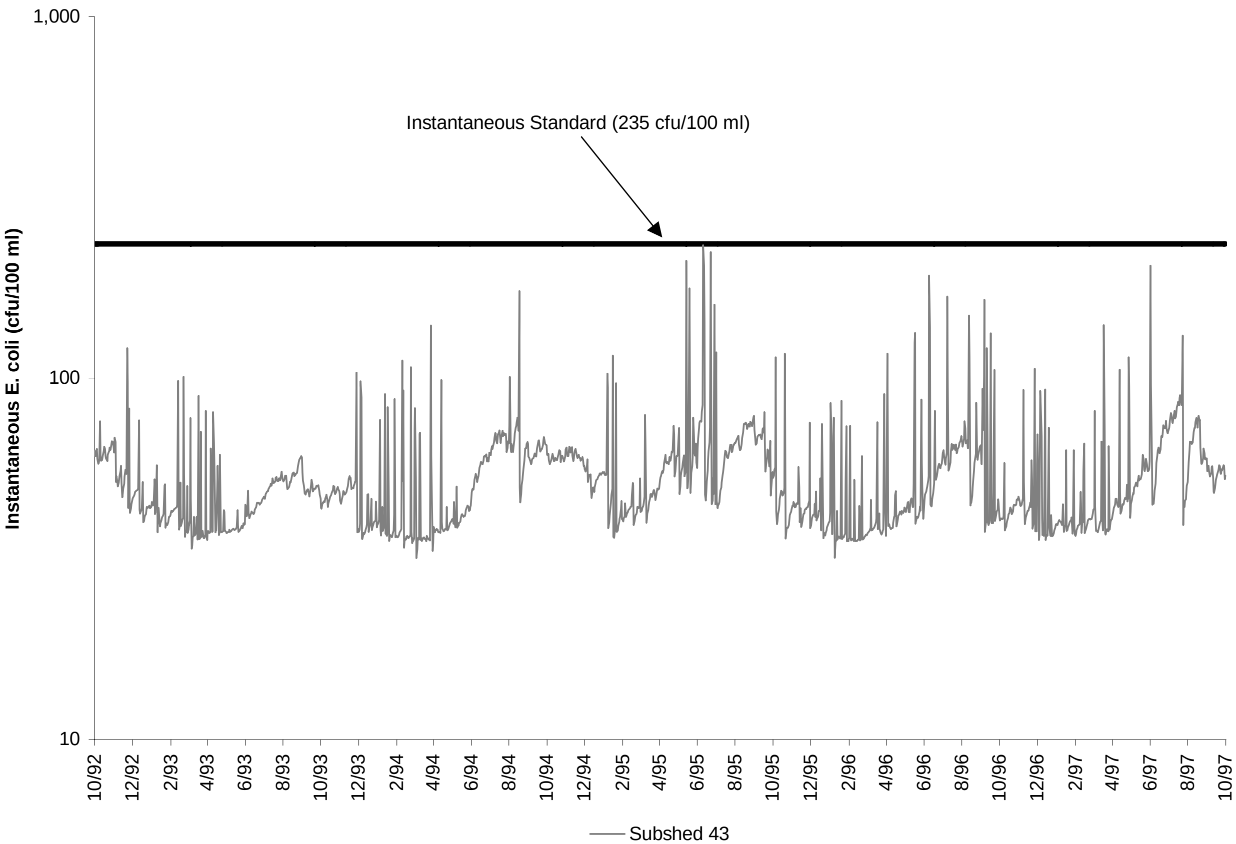

Figure 5.12 Instantaneous *E. coli* concentrations for the Upper South River impairment, under allocated conditions.

Table 5.7 Land-based and Direct nonpoint source load reductions in the Upper Middle River impairment for final allocation.

Source	Total Annual Loading for Existing Run (cfu/yr)	Total Annual Loading for Allocation Run (cfu/yr)	Percent Reduction
Land Based			
Residential	1.42E+14	1.42E+11	99.9
Commercial	6.02E+11	6.02E+08	99.9
Farmstead	1.88E+13	1.88E+10	99.9
Cropland	1.23E+16	1.23E+13	99.9
Livestock Access	7.70E+14	7.70E+11	99.9
Improved Pasture	1.01E+16	1.01E+13	99.9
Unimproved Pasture	2.24E+14	2.24E+11	99.9
Livestock Operations	6.89E+12	6.89E+09	99.9
Forest	1.12E+15	1.12E+13	99
Water	0.00E+00	0.00E+00	0
Direct			
Livestock	1.89E+14	0.00E+00	100
Wildlife	6.13E+13	6.13E+13	0
Straight Pipes and Sewer Overflows	1.33E+12	0.00E+00	100

Table 5.8 Land-based and Direct nonpoint source load reductions in the Moffett Creek impairment for final allocation.

Source	Total Annual Loading for Existing Run (cfu/yr)	Total Annual Loading for Allocation Run (cfu/yr)	Percent Reduction
Land Based			
Residential	2.86E+13	2.86E+10	99.9
Commercial	2.68E+10	2.68E+07	99.9
Farmstead	1.18E+13	1.18E+10	99.9
Cropland	7.44E+15	7.44E+12	99.9
Livestock Access	2.58E+14	2.58E+11	99.9
Improved Pasture	3.61E+15	3.61E+12	99.9
Unimproved Pasture	4.01E+14	4.01E+11	99.9
Livestock Operations	4.31E+11	4.31E+08	99.9
Forest	3.88E+14	2.72E+13	93
Water	0.00E+00	0.00E+00	0
Direct			
Livestock	6.66E+13	0.00E+00	100
Wildlife	1.84E+13	1.18E+13	36
Straight Pipes and Sewer Overflows	3.07E+11	0.00E+00	100

Table 5.9 Land-based and Direct nonpoint source load reductions in the Lewis Creek impairment for final allocation.

Source	Total Annual Loading for Existing Run (cfu/yr)	Total Annual Loading for Allocation Run (cfu/yr)	Percent Reduction
Land Based			
Residential	6.26E+14	6.26E+11	99.9
Commercial	5.91E+12	5.91E+09	99.9
Farmstead	3.38E+12	3.38E+09	99.9
Cropland	5.54E+15	5.54E+12	99.9
Livestock Access	2.23E+14	2.23E+11	99.9
Improved Pasture	2.29E+15	2.29E+12	99.9
Unimproved Pasture	1.66E+13	1.66E+10	99.9
Livestock Operations	5.35E+09	5.35E+06	99.9
Forest	1.70E+14	1.70E+12	99
Water	0.00E+00	0.00E+00	0
Direct			
Livestock	4.14E+03	0.00E+00	100
Wildlife	1.97E+13	4.93E+12	75
Straight Pipes and Sewer Overflows	4.39E+11	0.00E+00	100

Table 5.10 Land-based and Direct nonpoint source load reductions in the Polecat Draft impairment for final allocation.

Source	Total Annual Loading for Existing Run (cfu/yr)	Total Annual Loading for Allocation Run (cfu/yr)	Percent Reduction
Land Based			
Residential	1.55E+13	2.79E+12	82
Commercial	0.00E+00	0.00E+00	82
Farmstead	2.63E+12	4.74E+11	82
Cropland	2.23E+15	2.23E+11	99.99
Livestock Access	8.84E+13	8.84E+09	99.99
Improved Pasture	1.41E+15	1.41E+11	99.99
Unimproved Pasture	4.80E+11	4.80E+07	99.99
Livestock Operations	7.91E+10	7.91E+06	99.99
Forest	3.47E+13	3.47E+13	0
Water	0.00E+00	0.00E+00	0
Direct			
Livestock	2.18E+13	0.00E+00	100
Wildlife	5.82E+12	5.47E+12	6
Straight Pipes and Sewer Overflows	6.15E+10	0.00E+00	100

Table 5.11 Land-based and Direct nonpoint source load reductions in the Lower Middle River impairment for final allocation.

Source	Total Annual Loading for Existing Run (cfu/yr)	Total Annual Loading for Allocation Run (cfu/yr)	Percent Reduction
Land Based			
Residential	7.35E+13	7.35E+11	99
Commercial	1.45E+12	1.45E+10	99
Farmstead	1.06E+13	1.06E+11	99
Cropland	2.18E+16	2.18E+13	99.9
Livestock Access	6.45E+14	6.45E+11	99.9
Improved Pasture	9.52E+15	9.52E+12	99.9
Unimproved Pasture	1.26E+14	1.26E+11	99.9
Livestock Operations	8.57E+10	8.57E+07	99.9
Forest	2.34E+14	6.79E+13	71
Water	0.00E+00	0.00E+00	0
Direct			
Livestock	2.03E+14	0.00E+00	100
Wildlife	7.26E+15	7.26E+15	0
Straight Pipes and Sewer Overflows	1.93E+11	0.00E+00	100

Table 5.12 Land-based and Direct nonpoint source load reductions in the Upper South River impairment for final allocation.

Source	Total Annual Loading for Existing Run (cfu/yr)	Total Annual Loading for Allocation Run (cfu/yr)	Percent Reduction
Land Based			
Residential	1.59E+14	1.59E+11	99.9
Commercial	1.12E+13	1.12E+10	99.9
Farmstead	1.23E+13	1.23E+10	99.9
Cropland	1.85E+15	1.85E+12	99.9
Livestock Access	2.80E+14	2.80E+11	99.9
Improved Pasture	3.04E+15	3.04E+12	99.9
Unimproved Pasture	7.09E+13	7.09E+10	99.9
Livestock Operations	3.30E+11	3.30E+08	99.9
Forest	7.80E+14	1.95E+13	97.5
Water	0.00E+00	0.00E+00	0
Direct			
Livestock	1.77E+15	7.97E+14	55
Wildlife	3.37E+13	3.37E+13	0
Straight Pipes and Sewer Overflows	2.57E+12	0.00E+00	100

Table 5.13 Average annual loads (cfu/year) modeled after TMDL allocation in the Upper Middle River, Moffett Creek, Lewis Creek, Polecat Draft, and Lower Middle River watersheds.

Impairment		WLA (cfu/year)	LA (cfu/year)	MOS	TMDL (cfu/year)
Upper Middle River		8.53E+09	3.36E+13		3.36E+13
	VA0060917	*5.05E+09*			
Moffett Creek		0.0	5.39E+12		5.39E+12
		0.0			
Lewis Creek		3.48E+09	6.96E+12		6.97E+12
	VAG401072	*1.74E+09*			
	VAG401882	*1.74E+09*			
Polecat Draft		0.0	2.61E+12		2.61E+12
		0.0			
Lower Middle River		1.22E+13	8.80E+13	*Implicit*	1.00E+14
	VA0022322	*2.61E+11*			
	VA0062481	*6.09E+10*			
	VA0064793	*1.18E+13*			
	VA0084212	*5.22E+09*			
	VAG401064	*1.74E+09*			
	VAG401312	*1.74E+09*			
	VAG401359	*1.74E+09*			
	VAG401498	*1.74E+09*			
	VAG401664	*1.74E+09*			
	VAG401915	*1.74E+09*			
South River		1.06E+11	2.02E+13		2.03E+13
	VA0023400	*1.04E+11*			
	VAG401981	*1.74E+09*			

To determine if the allocation scenarios presented (Tables 5.1 through 5.6, scenario 5) will be applicable in the future, the same scenarios were evaluated with an increase in permitted loads. The permitted loads were increased by a factor of 5 to simulate a population growth. This future scenario resulted in no violations of the geometric or instantaneous *E. coli* standard. The TMDL table that reflects this future scenario is in Appendix G.

PART III: GENERAL WATER QUALITY (BENTHIC) TMDLS

6. WATER QUALITY ASSESSMENT

The Middle River benthic impairments first appeared on Virginia's 1996 303(d) TMDL Priority List and have remained on the 1998 and 2002 303(d) lists. The monitoring for the assessments was performed by VADEQ, and gauged the health of aquatic life through measurement of the eight biometrics discussed in Section 1.4. The benthic impairments in the Middle River watershed include Upper Middle River, Lewis Creek, Christians Creek, and Moffett Creek (Figure 6.1).

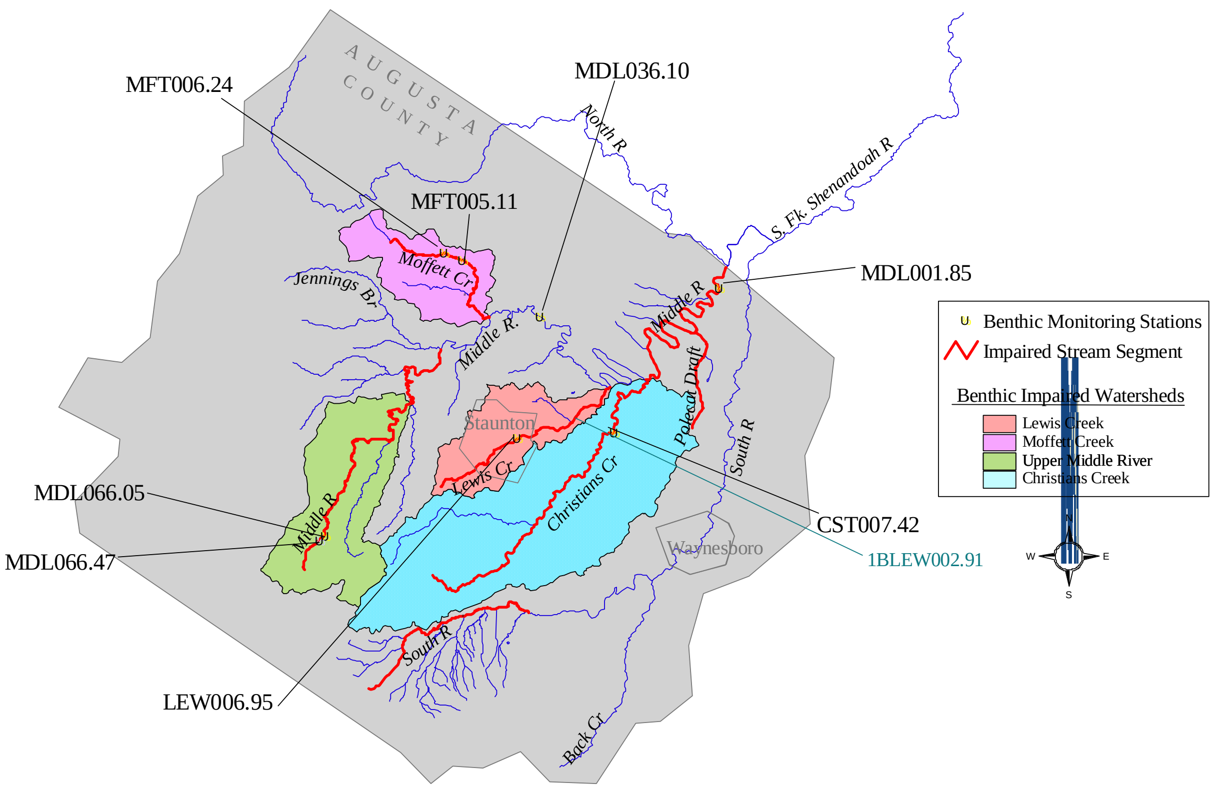

Figure 6.1 Augusta County benthic impairments and benthic monitoring stations.

6.1 Results from the Rapid Bioassessment Protocol II (RBPII) Procedure

Biological monitoring was conducted by VADEQ at seven locations in the benthic impaired stream segments of the Middle River watershed. Benthic macroinvertebrate sampling was performed on 10 dates between 10/20/94 and 11/1/02 at station 1BCST007.42 (Tables 6.1 through 6.10). Biological sampling was conducted on 6/1/95 and 5/28/02 at stations 1BMDL066.05 and 1BMDL066.47 (Tables 6.11 and 6.14). Benthic macroinvertebrate sampling was performed on two dates, 10/16/00 and 9/24/01 at station 1BMFT005.11 (Tables 6.15 through 6.16), and on six dates between 10/20/94 and 10/6/98 at station 1BMFT006.24 (Tables 6.17 through 6.22). Sampling was performed on two dates, 5/28/02 and 11/1/02, at station 1BLEW000.61 (Tables 6.23 and 6.24), and on 11 dates between 10/20/94 and 11/1/02 at station 1BLEW006.95 (Tables 6.25 through 6.35).

Table 6.1 Biological monitoring conducted by VADEQ on 10/20/94.

Examined Sample: CST007.42—Christians Creek 10/20/1994
Reference Sample: JKS067.00—Jackson River 10/24/1994

Metrics[1]	Value		Ratio	Scores	
	Reference	Target		Reference	Target
TR	24	19	0.792	6	3
MFBI	3.23	4.59	0.703	6	3
SCR/FC	4.20	0.68	0.161	6	0
EPT/C	13.40	14.20	1.060	6	6
% DT	23	18	N/A	6	6
EPTI	11	10	0.909	6	6
CLI	N/A	0.500	N/A	6	3
SHR/T	0.173	0.0351	0.203	6	0
Total Score				48	27
% Comp to Reference					56
Biological Condition					SL

[1]TR: taxa richness, MFBI: Modified Family Biotic Index, SCR/FC: Scraper/Filter Collector ratio, EPT/C: EPT/Chironomidae, %DT: percent Dominant Taxon, EPTI: EPT Index, CLI: Community Loss Index
[2]NI: not impaired, SL: slightly impaired, MI: moderately impaired, SI: severely impaired, N/A=not applicable

Table 6.2 Biological monitoring conducted by VADEQ on 5/1/95.

Examined Sample: CST007.42—Christians Creek 5/1/1995
Reference Sample: STY006.73—Stony Creek 5/9/1995

Metrics[1]	Value		Ratio	Scores	
	Reference	Target		Reference	Target
TR	26	20	0.769	6	3
MFBI	3.77	4.64	0.812	6	3
SCR/FC	2.33	1.16	0.496	6	3
EPT/C	6.38	3.39	0.531	6	3
% DT	11	17	N/A	6	6
EPTI	13	9	0.692	6	0
CLI	N/A	0.385	N/A	6	6
SHR/T	0.142	0.0244	0.172	6	0
Total Score				48	24
% Comp to Reference					50
Biological Condition					MI

[1]TR: taxa richness, MFBI: Modified Family Biotic Index, SCR/FC: Scraper/Filter Collector ratio, EPT/C: EPT/Chironomidae, %DT: percent Dominant Taxon, EPTI: EPT Index, CLI: Community Loss Index
[2]NI: not impaired, SL: slightly impaired, MI: moderately impaired, SI: severely impaired, N/A=not applicable

Table 6.3 Biological monitoring conducted by VADEQ on 10/11/95.

Examined Sample: CST007.42—Christians Creek 10/11/1995
Reference Sample: BLP000.79—Bullpasture River 10/26/1995

Metrics[1]	Value		Ratio	Scores	
	Reference	Target		Reference	Target
TR	20	16	0.800	6	3
MFBI	3.12	4.31	0.725	6	3
SCR/FC	2.23	1.18	0.529	6	6
EPT/C	60.00	17.00	0.283	6	3
% DT	26	22	N/A	6	6
EPTI	10	8	0.800	6	3
CLI	N/A	0.400	N/A	6	6
SHR/T	0.093	0.0364	0.393	6	3
Total Score				48	33
% Comp to Reference					69
Biological Condition					SL

[1]TR: taxa richness, MFBI: Modified Family Biotic Index, SCR/FC: Scraper/Filter Collector ratio, EPT/C: EPT/Chironomidae, %DT: percent Dominant Taxon, EPTI: EPT Index, CLI: Community Loss Index
[2]NI: not impaired, SL: slightly impaired, MI: moderately impaired, SI: severely impaired, N/A=not applicable

Table 6.4 Biological monitoring conducted by VADEQ on 10/6/98.

Examined Sample: CST007.42—Christians Creek 10/6/1998
Reference Sample: BLP000.79—Bullpasture River10/7/1998

Metrics[1]	Value		Ratio	Scores	
	Reference	Target		Reference	Target
TR	15	13	0.867	6	6
MFBI	4.25	4.43	0.959	6	6
SCR/FC	3.15	2.46	0.781	6	6
EPT/C	24.00	5.14	0.214	6	0
% DT	42	35	N/A	3	3
EPTI	9	6	0.667	6	0
CLI	N/A	0.400	N/A	6	6
SHR/T	0.010	0.0000	0.000	6	0
Total Score				45	27
% Comp to Reference					60
Biological Condition					SL

[1]TR: taxa richness, MFBI: Modified Family Biotic Index, SCR/FC: Scraper/Filter Collector ratio, EPT/C: EPT/Chironomidae, %DT: percent Dominant Taxon, EPTI: EPT Index, CLI: Community Loss Index
[2]NI: not impaired, SL: slightly impaired, MI: moderately impaired, SI: severely impaired, N/A=not applicable

Table 6.5 Biological monitoring conducted by VADEQ on 5/24/99.

Examined Sample: CST007.42—Christians Creek 5/24/1999
Reference Sample: BLP000.79—Bullpasture River 5/13/1999

Metrics[1]	Value		Ratio	Scores	
	Reference	Target		Reference	Target
TR	18	17	0.944	6	6
MFBI	4.34	4.48	0.970	6	6
SCR/FC	2.12	21.00	9.917	6	6
EPT/C	1.97	1.65	0.837	6	6
% DT	30	25	N/A	3	6
EPTI	10	7	0.700	6	3
CLI	N/A	0.444	N/A	6	6
SHR/T	0.071	0.0126	0.178	6	0
Total Score				45	39
% Comp to Reference					87
Biological Condition					NI

[1]TR: taxa richness, MFBI: Modified Family Biotic Index, SCR/FC: Scraper/Filter Collector ratio, EPT/C: EPT/Chironomidae, %DT: percent Dominant Taxon, EPTI: EPT Index, CLI: Community Loss Index
[2]NI: not impaired, SL: slightly impaired, MI: moderately impaired, SI: severely impaired, N/A=not applicable

Table 6.6 Biological monitoring conducted by VADEQ on 10/26/99.

Examined Sample: CST007.42—Christians Creek 10/26/1999
Reference Sample: BLP000.79—Bullpasture River 10/12/2000

Metrics[1]	Value		Ratio	Scores	
	Reference	Target		Reference	Target
TR	17	17	1.000	6	6
MFBI	4.10	4.13	0.994	6	6
SCR/FC	2.83	1.28	0.454	6	3
EPT/C	21.75	86.00	3.954	6	6
% DT	37	25.68%	N/A	3	6
EPTI	9	7	0.778	6	3
CLI	N/A	0.471	N/A	6	6
SHR/T	0.034	0.0000	0.000	6	0
Total Score				45	36
% Comp to Reference					80
Biological Condition					SL

[1]TR: taxa richness, MFBI: Modified Family Biotic Index, SCR/FC: Scraper/Filter Collector ratio, EPT/C: EPT/Chironomidae, %DT: percent Dominant Taxon, EPTI: EPT Index, CLI: Community Loss Index
[2]NI: not impaired, SL: slightly impaired, MI: moderately impaired, SI: severely impaired, N/A=not applicable

Table 6.7 Biological monitoring conducted by VADEQ on 4/11/00.

Examined Sample: CST007.42—Christians Creek 4/11/2000
Reference Sample: BLP000.79—Bullpasture River 5/3/2000

Metrics[1]	Value		Ratio	Scores	
	Reference	Target		Reference	Target
TR	15	19	1.267	6	6
MFBI	4.41	5.05	0.873	6	6
SCR/FC	7.33	3.56	0.486	6	3
EPT/C	3.43	1.01	0.294	6	3
% DT	19	34	N/A	6	3
EPTI	6	10	1.667	6	6
CLI	N/A	0.400	N/A	6	6
SHR/T	0.029	0.0031	0.105	6	0
Total Score				48	33
% Comp to Reference					69
Biological Condition					SL

[1]TR: taxa richness, MFBI: Modified Family Biotic Index, SCR/FC: Scraper/Filter Collector ratio, EPT/C: EPT/Chironomidae, %DT: percent Dominant Taxon, EPTI: EPT Index, CLI: Community Loss Index
[2]NI: not impaired, SL: slightly impaired, MI: moderately impaired, SI: severely impaired, N/A=not applicable

Table 6.8 Biological monitoring conducted by VADEQ on 10/16/01.

Examined Sample: CST007.42—Christians Creek 10/16/2001
Reference Sample: BLP000.79—Bullpasture River 10/31/2001

Metrics[1]	Value		Ratio	Scores	
	Reference	Target		Reference	Target
TR	12	14	1.167	6	6
MFBI	3.78	4.69	0.804	6	3
SCR/FC	3.94	1.55	0.393	6	3
EPT/C	106.00	6.89	0.065	6	0
% DT	46	24	N/A	3	6
EPTI	9	5	0.556	6	0
CLI	N/A	0.333	N/A	6	6
SHR/T	0.008	0.0000	0.000	6	0
Total Score				45	24
% Comp to Reference					53
Biological Condition					SL

[1]TR: taxa richness, MFBI: Modified Family Biotic Index, SCR/FC: Scraper/Filter Collector ratio, EPT/C: EPT/Chironomidae, %DT: percent Dominant Taxon, EPTI: EPT Index, CLI: Community Loss Index
[2]NI: not impaired, SL: slightly impaired, MI: moderately impaired, SI: severely impaired, N/A=not applicable

Table 6.9 Biological monitoring conducted by VADEQ on 5/28/02.

Examined Sample: CST007.42—Christians Creek 5/28/2002
Reference Sample: BLP000.79—Bullpasture River 5/6/2002

Metrics[1]	Value		Ratio	Scores	
	Reference	Target		Reference	Target
TR	16	18	1.125	6	6
MFBI	3.68	4.85	0.760	6	3
SCR/FC	1.82	4.70	2.575	6	6
EPT/C	36.00	1.48	0.041	6	0
% DT	24	27	N/A	6	6
EPTI	11	7	0.636	6	0
CLI	N/A	0.438	N/A	6	6
SHR/T	0.098	0.0042	0.043	6	0
Total Score				48	27
% Comp to Reference					56
Biological Condition					SL

[1]TR: taxa richness, MFBI: Modified Family Biotic Index, SCR/FC: Scraper/Filter Collector ratio, EPT/C: EPT/Chironomidae, %DT: percent Dominant Taxon, EPTI: EPT Index, CLI: Community Loss Index
[2]NI: not impaired, SL: slightly impaired, MI: moderately impaired, SI: severely impaired, N/A=not applicable

Table 6.10 Biological monitoring conducted by VADEQ on 11/1/02.

Examined Sample: CST007.42—Christians Creek 11/1/2002
Reference Sample: BLP000.79—Bullpasture River 11/8/2002

Metrics[1]	Value		Ratio	Scores	
	Reference	Target		Reference	Target
TR	18	15	0.833	6	6
MFBI	3.71	4.22	0.879	6	6
SCR/FC	7.80	2.06	0.265	6	3
EPT/C	106.00	9.83	0.093	6	0
% DT	39	22	N/A	3	6
EPTI	9	6	0.667	6	0
CLI	N/A	0.500	N/A	6	3
SHR/T	0.017	0.0090	0.536	6	6
Total Score				45	30
% Comp to Reference					67
Biological Condition					SL

[1]TR: taxa richness, MFBI: Modified Family Biotic Index, SCR/FC: Scraper/Filter Collector ratio, EPT/C: EPT/Chironomidae, %DT: percent Dominant Taxon, EPTI: EPT Index, CLI: Community Loss Index
[2]NI: not impaired, SL: slightly impaired, MI: moderately impaired, SI: severely impaired, N/A=not applicable

Table 6.11 Biological monitoring conducted by VADEQ on 6/1/95

Examined Sample: MDL066.47—Middle River 6/1/95
Reference Sample: BIG001.80—Big Run

Metrics[1]	Value		Ratio	Scores	
	Reference	Target			Reference
TR	27	15	0.556	6	3
MFBI	4.41	5.55	0.795	6	3
SCR/FC	2.64	0.77	0.292	6	3
EPT/C	4.063	1.467	0.361	6	3
% DT	14.7	22.7	N/A	6	6
EPTI	11	7	0.636	6	0
CLI	N/A	0.875	N/A	6	3
SHR/T	0.073	0.055	0.753	6	0
Total Score				48	21
% Comp to Reference					44
Biological Condition					MI

[1]TR: taxa richness, MFBI: Modified Family Biotic Index, SCR/FC: Scraper/Filter Collector ratio, EPT/C: EPT/Chironomidae, %DT: percent Dominant Taxon, EPTI: EPT Index, CLI: Community Loss Index
[2]NI: not impaired, SL: slightly impaired, MI: moderately impaired, SI: severely impaired, N/A=not applicable

Table 6.12 Biological monitoring conducted by VADEQ on 6/1/95.

Examined Sample: MDL066.05—Middle River 6/1/95
Reference Sample: BIG001.80—Big Run

	Value			Scores	
Metrics[1]	**Reference**	**Target**	**Ratio**	**Reference**	**Target**
TR	27	11	0.407	6	3
MFBI	4.41	6.21	0.710	6	3
SCR/FC	2.64	0.22	0.083	6	0
EPT/C	4.063	1	0.246	6	0
% DT	14.7	24.4	N/A	6	6
EPTI	11	2	0.182	6	0
CLI	N/A	1.5	N/A	6	3
SHR/T	0.073	0.057	0.781	6	0
Total Score				48	15
% Comp to Reference					31
Biological Condition					MI

[1]TR: taxa richness, MFBI: Modified Family Biotic Index, SCR/FC: Scraper/Filter Collector ratio, EPT/C: EPT/Chironomidae, %DT: percent Dominant Taxon, EPTI: EPT Index, CLI: Community Loss Index
[2]NI: not impaired, SL: slightly impaired, MI: moderately impaired, SI: severely impaired, N/A=not applicable

Table 6.13 Biological monitoring conducted by VADEQ on 5/28/02.

Examined Sample: MDL066.05—Middle River 5/28/2002
Reference Sample: STC004.27—Straight Creek 4/24/2002

Metrics[1]	Value		**Ratio**	Scores	
	Reference	**Target**		**Reference**	**Target**
TR	19	14	0.737	6	3
MFBI	3.81	6.49	0.587	6	3
SCR/FC	1.68	0.55	0.325	6	3
EPT/C	7.64	0.14	0.018	6	0
% DT	20	50	N/A	6	0
EPTI	11	2	0.182	6	0
CLI	N/A	0.632	N/A	6	3
SHR/T	0.273	0.0071	0.026	6	0
Total Score				48	12
% Comp to Reference					25
Biological Condition					MI

[1]TR: taxa richness, MFBI: Modified Family Biotic Index, SCR/FC: Scraper/Filter Collector ratio, EPT/C: EPT/Chironomidae, %DT: percent Dominant Taxon, EPTI: EPT Index, CLI: Community Loss Index
[2]NI: not impaired, SL: slightly impaired, MI: moderately impaired, SI: severely impaired, N/A=not applicable

Table 6.14 Biological monitoring conducted by VADEQ on 5/28/02.

Examined Sample: MDL066.47—Middle River 5/28/2002
Reference Sample: STC004.27—Straight Creek 4/24/2002

Metrics[1]	Value		Ratio	Scores	
	Reference	Target		Reference	Target
TR	19	13	0.684	6	3
MFBI	3.81	6.82	0.559	6	3
SCR/FC	1.68	0.15	0.088	6	0
EPT/C	7.64	0.16	0.021	6	0
% DT	20	32	N/A	6	3
EPTI	11	3	0.273	6	0
CLI	N/A	0.579	N/A	6	3
SHR/T	0.273	0.0082	0.030	6	0
Total Score				48	12
% Comp to Reference					25
Biological Condition					MI

[1]TR: taxa richness, MFBI: Modified Family Biotic Index, SCR/FC: Scraper/Filter Collector ratio, EPT/C: EPT/Chironomidae, %DT: percent Dominant Taxon, EPTI: EPT Index, CLI: Community Loss Index
[2]NI: not impaired, SL: slightly impaired, MI: moderately impaired, SI: severely impaired, N/A=not applicable

Table 6.15 Biological monitoring conducted by VADEQ on 10/16/00.

Examined Sample: MFT005.11—Moffett Creek 10/16/2000
Reference Sample: STC004.27—Straight Creek 10/13/2000

Metrics[1]	Value		Ratio	Scores	
	Reference	Target		Reference	Target
TR	19	13	0.684	6	3
MFBI	3.61	5.33	0.678	6	3
SCR/FC	7.11	1.55	0.218	6	0
EPT/C	20.00	0.85	0.042	6	0
% DT	25	39	N/A	6	3
EPTI	12	6	0.500	6	0
CLI	N/A	0.632	N/A	6	3
SHR/T	0.054	0.0060	0.111	6	0
Total Score				48	12
% Comp to Reference					25
Biological Condition					MI

[1]TR: taxa richness, MFBI: Modified Family Biotic Index, SCR/FC: Scraper/Filter Collector ratio, EPT/C: EPT/Chironomidae, %DT: percent Dominant Taxon, EPTI: EPT Index, CLI: Community Loss Index
[2]NI: not impaired, SL: slightly impaired, MI: moderately impaired, SI: severely impaired, N/A=not applicable

Table 6.16 Biological monitoring conducted by VADEQ on 9/24/01.

Examined Sample: MFT005.11—Moffett Creek 9/24/2001
Reference Sample: STC004.27—Straight Creek 10/15/2001

Metrics[1]	Value		Ratio	Scores	
	Reference	Target		Reference	Target
TR	15	17	1.133	6	6
MFBI	3.77	5.21	0.724	6	3
SCR/FC	4.83	1.02	0.211	6	0
EPT/C	35.00	0.62	0.018	6	0
% DT	24	40	N/A	6	3
EPTI	9	6	0.667	6	0
CLI	N/A	0.533	N/A	6	3
SHR/T	0.043	0.0123	0.290	6	3
Total Score				48	18
% Comp to Reference					38
Biological Condition					MI

[1]TR: taxa richness, MFBI: Modified Family Biotic Index, SCR/FC: Scraper/Filter Collector ratio, EPT/C: EPT/Chironomidae, %DT: percent Dominant Taxon, EPTI: EPT Index, CLI: Community Loss Index
[2]NI: not impaired, SL: slightly impaired, MI: moderately impaired, SI: severely impaired, N/A=not applicable

Table 6.17 Biological monitoring conducted by VADEQ on 10/20/94.

Examined Sample: MFT006.24—Moffett Creek 10/20/1994
Reference Sample: STC004.27—Straight Creek 10/11/1994

Metrics[1]	Value		Ratio	Scores	
	Reference	Target		Reference	Target
TR	23	18	0.783	6	3
MFBI	3.49	4.79	0.729	6	3
SCR/FC	1.74	0.22	0.123	6	0
EPT/C	16.29	5.10	0.313	6	3
% DT	24	29	N/A	6	6
EPTI	11	6	0.545	6	0
CLI	N/A	0.478	N/A	6	6
SHR/T	0.042	0.0313	0.742	6	6
Total Score				48	27
% Comp to Reference					56
Biological Condition					MI

[1]TR: taxa richness, MFBI: Modified Family Biotic Index, SCR/FC: Scraper/Filter Collector ratio, EPT/C: EPT/Chironomidae, %DT: percent Dominant Taxon, EPTI: EPT Index, CLI: Community Loss Index
[2]NI: not impaired, SL: slightly impaired, MI: moderately impaired, SI: severely impaired, N/A=not applicable

Table 6.18 Biological monitoring conducted by VADEQ on 5/10/95.

Examined Sample: MFT006.24—Moffett Creek 5/10/1995
Reference Sample: STC004.27—Straight Creek 5/11/1995

Metrics[1]	Value		Ratio	Scores	
	Reference	Target		Reference	Target
TR	25	17	0.680	6	3
MFBI	3.05	4.51	0.675	6	3
SCR/FC	6.83	1.19	0.174	6	0
EPT/C	18.60	2.15	0.116	6	0
% DT	17	20	N/A	6	6
EPTI	12	7	0.583	6	0
CLI	N/A	0.640	N/A	6	3
SHR/T	0.224	0.0396	0.177	6	0
Total Score				48	15
% Comp to Reference					31
Biological Condition					MI

[1]TR: taxa richness, MFBI: Modified Family Biotic Index, SCR/FC: Scraper/Filter Collector ratio, EPT/C: EPT/Chironomidae, %DT: percent Dominant Taxon, EPTI: EPT Index, CLI: Community Loss Index
[2]NI: not impaired, SL: slightly impaired, MI: moderately impaired, SI: severely impaired, N/A=not applicable

Table 6.19 Biological monitoring conducted by VADEQ on 10/10/95.

Examined Sample: MFT006.24—Moffett Creek 10/10/1995
Reference Sample: STC004.27—Straight Creek 10/26/1995

Metrics[1]	Value		Ratio	Scores	
	Reference	Target		Reference	Target
TR	19	7	0.368	6	0
MFBI	2.89	5.30	0.545	6	3
SCR/FC	1.29	9.75	7.548	6	6
EPT/C	74.00	-1	-0.014	6	0
% DT	21	43	N/A	6	3
EPTI	10	1	0.100	6	0
CLI		0.789		6	3
SHR/T	0.157	0.0192	0.122	6	0
Total Score				48	0
% Comp to Reference					31
Biological Condition					MI

[1]TR: taxa richness, MFBI: Modified Family Biotic Index, SCR/FC: Scraper/Filter Collector ratio, EPT/C: EPT/Chironomidae, %DT: percent Dominant Taxon, EPTI: EPT Index, CLI: Community Loss Index
[2]NI: not impaired, SL: slightly impaired, MI: moderately impaired, SI: severely impaired, N/A=not applicable

Table 6.20 Biological monitoring conducted by VADEQ on 5/8/97.

Examined Sample: MFT006.24—Moffett Creek 5/8/1997
Reference Sample: STC004.27—Straight Creek 5/21/1997

Metrics[1]	Value		Ratio	Scores	
	Reference	Target		Reference	Target
TR	19	18	0.947	6	6
MFBI	3.37	4.31	0.783	6	3
SCR/FC	0.95	1.47	1.556	6	6
EPT/C	19.67	3.56	0.181	6	0
% DT	21	16	N/A	6	6
EPTI	13	8	0.615	6	0
CLI		0.474		6	6
SHR/T	0.093	0.0612	0.659	6	6
Total Score				48	33
% Comp to Reference					69
Biological Condition					MI

[1]TR: taxa richness, MFBI: Modified Family Biotic Index, SCR/FC: Scraper/Filter Collector ratio, EPT/C: EPT/Chironomidae, %DT: percent Dominant Taxon, EPTI: EPT Index, CLI: Community Loss Index
[2]NI: not impaired, SL: slightly impaired, MI: moderately impaired, SI: severely impaired, N/A=not applicable

Table 6.21 Biological monitoring conducted by VADEQ on 10/14/97.

Examined Sample: MFT006.24—Moffett Creek 10/14/1997
Reference Sample: STC004.27—Straight Creek 9/30/1997

Metrics[1]	Value		Ratio	Scores	
	Reference	Target		Reference	Target
TR	17	13	0.765	6	3
MFBI	3.86	4.96	0.778	6	3
SCR/FC	0.56	0.10	0.178	6	0
EPT/C	63.00	8.22	0.131	6	0
% DT	28	38	N/A	6	3
EPTI	9	6	0.667	6	0
CLI	N/A	0.647	N/A	6	3
SHR/T	0.075	0.0189	0.250	6	3
Total Score				48	15
% Comp to Reference					31
Biological Condition					MI

[1]TR: taxa richness, MFBI: Modified Family Biotic Index, SCR/FC: Scraper/Filter Collector ratio, EPT/C: EPT/Chironomidae, %DT: percent Dominant Taxon, EPTI: EPT Index, CLI: Community Loss Index
[2]NI: not impaired, SL: slightly impaired, MI: moderately impaired, SI: severely impaired, N/A=not applicable

Table 6.22 Biological monitoring conducted by VADEQ on 10/6/98.

Examined Sample: MFT006.24—Moffett Creek 10/6/1998
Reference Sample: STC004.27—Straight Creek 10/28/1998

Metrics[1]	**Value**		**Ratio**	**Scores**	
	Reference	**Target**		**Reference**	**Target**
TR	19	12	0.632	6	3
MFBI	3.22	4.99	0.646	6	3
SCR/FC	0.79	5.20	6.576	6	6
EPT/C	35.25	0.82	0.023	6	0
% DT	22	43	N/A	6	3
EPTI	13	4	0.308	6	0
CLI	N/A	0.632	N/A	6	3
SHR/T	0.284	0.2361	0.831	6	6
Total Score				48	24
% Comp to Reference					50
Biological Condition					MI

[1]TR: taxa richness, MFBI: Modified Family Biotic Index, SCR/FC: Scraper/Filter Collector ratio, EPT/C: EPT/Chironomidae, %DT: percent Dominant Taxon, EPTI: EPT Index, CLI: Community Loss Index
[2]NI: not impaired, SL: slightly impaired, MI: moderately impaired, SI: severely impaired, N/A=not applicable

Table 6.23 Biological monitoring conducted by VADEQ on 5/7/02.

Examined Sample: LEW000.61—Lewis Creek 5/7/2002
Reference Sample: STC004.27—Straight Creek 4/24/2002

Metrics[1]	**Value**		**Ratio**	**Scores**	
	Reference	**Target**		**Reference**	**Target**
TR	19	10	0.526	6	3
MFBI	3.81	5.26	0.724	6	3
SCR/FC	1.68	9.20	5.463	6	6
EPT/C	7.64	0.11	0.014	6	0
% DT	20	51	N/A	6	0
EPTI	11	4	0.364	6	0
CLI	N/A	0.737	N/A	6	3
SHR/T	0.273	0.0000	0.000	6	0
Total Score				48	15
% Comp to Reference					31
Biological Condition					MI

[1]TR: taxa richness, MFBI: Modified Family Biotic Index, SCR/FC: Scraper/Filter Collector ratio, EPT/C: EPT/Chironomidae, %DT: percent Dominant Taxon, EPTI: EPT Index, CLI: Community Loss Index
[2]NI: not impaired, SL: slightly impaired, MI: moderately impaired, SI: severely impaired, N/A=not applicable

Table 6.24 Biological monitoring conducted by VADEQ on 11/1/02.

Examined Sample: LEW000.61—Lewis Creek 11/1/2002
Reference Sample: STC004.27—Straight Creek 11/6/2002

Metrics[1]	Value		Ratio	Scores	
	Reference	Target		Reference	Target
TR	16	19	1.188	6	6
MFBI	2.89	5.59	0.518	6	3
SCR/FC	17.50	4.50	0.257	6	3
EPT/C	13.40	1.32	0.099	6	0
% DT	22	22	N/A	6	6
EPTI	9	8	0.889	6	3
CLI	N/A	0.563	N/A	6	3
SHR/T	0.383	0.0079	0.021	6	0
Total Score				48	24
% Comp to Reference					50
Biological Condition					MI

[1]TR: taxa richness, MFBI: Modified Family Biotic Index, SCR/FC: Scraper/Filter Collector ratio, EPT/C: EPT/Chironomidae, %DT: percent Dominant Taxon, EPTI: EPT Index, CLI: Community Loss Index
[2]NI: not impaired, SL: slightly impaired, MI: moderately impaired, SI: severely impaired, N/A=not applicable

Table 6.25 Biological monitoring conducted by VADEQ on 10/20/94.

Examined Sample: LEW006.95—Lewis Creek 10/20/1994
Reference Sample: STC004.27—Straight Creek 10/11/1994

Metrics[1]	Value		Ratio	Scores	
	Reference	Target		Reference	Target
TR	23	6	0.261	6	0
MFBI	3.49	6.12	0.570	6	3
SCR/FC	1.74	0.02	0.013	6	0
EPT/C	16.29	5.50	0.338	6	3
% DT	24	76	N/A	6	0
EPTI	11	1	0.091	6	0
CLI	N/A	0.870	N/A	6	3
SHR/T	0.042	0.0172	0.409	6	3
Total Score				48	12
% Comp to Reference					25
Biological Condition					MI

[1]TR: taxa richness, MFBI: Modified Family Biotic Index, SCR/FC: Scraper/Filter Collector ratio, EPT/C: EPT/Chironomidae, %DT: percent Dominant Taxon, EPTI: EPT Index, CLI: Community Loss Index
[2]NI: not impaired, SL: slightly impaired, MI: moderately impaired, SI: severely impaired, N/A=not applicable

Table 6.26 Biological monitoring conducted by VADEQ on 5/16/95.

Examined Sample: LEW006.95—Lewis Creek 5/16/1995
Reference Sample: STC004.27—Straight Creek 5/11/1995

Metrics[1]	Value		Ratio	Scores	
	Reference	Target		Reference	Target
TR	25	12	0.480	6	3
MFBI	3.05	6.11	0.499	6	0
SCR/FC	6.83	0.05	0.008	6	0
EPT/C	18.60	0.85	0.046	6	0
% DT	17	29	N/A	6	6
EPTI	12	1	0.083	6	0
CLI	N/A	0.720	N/A	6	3
SHR/T	0.224	0.0517	0.231	6	0
Total Score				48	12
% Comp to Reference					25
Biological Condition					MI

[1]TR: taxa richness, MFBI: Modified Family Biotic Index, SCR/FC: Scraper/Filter Collector ratio, EPT/C: EPT/Chironomidae, %DT: percent Dominant Taxon, EPTI: EPT Index, CLI: Community Loss Index
[2]NI: not impaired, SL: slightly impaired, MI: moderately impaired, SI: severely impaired, N/A=not applicable

Table 6.27 Biological monitoring conducted by VADEQ on 10/10/95.

Examined Sample: LEW006.95—Lewis Creek 10/10/1995
Reference Sample: STC004.27—Straight Creek 10/26/1995

Metrics[1]	Value		Ratio	Scores	
	Reference	Target		Reference	Target
TR	19	7	0.368	6	0
MFBI	2.89	6.28	0.460	6	0
SCR/FC	1.29	0.09	0.070	6	0
EPT/C	74.00	14.83	0.200	6	0
% DT	21	64	N/A	6	0
EPTI	10	1	0.100	6	0
CLI	N/A	0.789	N/A	6	3
SHR/T	0.157	0.0290	0.184	6	0
Total Score				48	3
% Comp to Reference					6
Biological Condition					SI

[1]TR: taxa richness, MFBI: Modified Family Biotic Index, SCR/FC: Scraper/Filter Collector ratio, EPT/C: EPT/Chironomidae, %DT: percent Dominant Taxon, EPTI: EPT Index, CLI: Community Loss Index
[2]NI: not impaired, SL: slightly impaired, MI: moderately impaired, SI: severely impaired, N/A=not applicable

Table 6.28 Biological monitoring conducted by VADEQ on 6/3/96.

Examined Sample: LEW006.95—Lewis Creek 6/3/1996
Reference Sample: STC004.27—Straight Creek 5/20/1996

Metrics[1]	Value		Ratio	Scores	
	Reference	Target		Reference	Target
TR	27	10	0.370	6	0
MFBI	3.41	6.69	0.510	6	3
SCR/FC	1.00	0.15	0.150	6	0
EPT/C	6.46	14.00	2.167	6	6
% DT	17	42	N/A	6	3
EPTI	17	3	0.176	6	0
CLI		0.741		6	3
SHR/T	0.245	0.0208	0.085	6	0
Total Score				48	15
% Comp to Reference					31
Biological Condition					MI

[1]TR: taxa richness, MFBI: Modified Family Biotic Index, SCR/FC: Scraper/Filter Collector ratio, EPT/C: EPT/Chironomidae, %DT: percent Dominant Taxon, EPTI: EPT Index, CLI: Community Loss Index
[2]NI: not impaired, SL: slightly impaired, MI: moderately impaired, SI: severely impaired, N/A=not applicable

Table 6.29 Biological monitoring conducted by VADEQ on 5/5/97.

Examined Sample: LEW006.95—Lewis Creek 5/5/1997
Reference Sample: STC004.27—Straight Creek 5/21/1997

Metrics[1]	Value		Ratio	Scores	
	Reference	Target		Reference	Target
TR	19	6	0.316	6	0
MFBI	3.37	6.26	0.538	6	3
SCR/FC	0.95	0.00	0.000	6	0
EPT/C	19.67	0.10	0.005	6	0
% DT	21	65	N/A	6	0
EPTI	13	2	0.154	6	0
CLI	N/A	0.842	N/A	6	3
SHR/T	0.093	0.0000	0.000	6	0
Total Score				48	6
% Comp to Reference					13
Biological Condition					SI

[1]TR: taxa richness, MFBI: Modified Family Biotic Index, SCR/FC: Scraper/Filter Collector ratio, EPT/C: EPT/Chironomidae, %DT: percent Dominant Taxon, EPTI: EPT Index, CLI: Community Loss Index
[2]NI: not impaired, SL: slightly impaired, MI: moderately impaired, SI: severely impaired, N/A=not applicable

Table 6.30 Biological monitoring conducted by VADEQ on 9/18/97.

Examined Sample: LEW006.95—Lewis Creek 9/18/1997
Reference Sample: STC004.27—Straight Creek 9/30/1997

Metrics[1]	Value		Ratio	Scores	
	Reference	Target		Reference	Target
TR	17	8	0.471	6	3
MFBI	3.86	6.64	0.582	6	3
SCR/FC	0.56	0.05	0.085	6	0
EPT/C	63.00	12.00	0.190	6	0
% DT	28	44	N/A	6	3
EPTI	9	2	0.222	6	0
CLI	N/A	0.647	N/A	6	3
SHR/T	0.075	0.0182	0.241	6	0
Total Score				48	12
% Comp to Reference					25
Biological Condition					SI

[1]TR: taxa richness, MFBI: Modified Family Biotic Index, SCR/FC: Scraper/Filter Collector ratio, EPT/C: EPT/Chironomidae, %DT: percent Dominant Taxon, EPTI: EPT Index, CLI: Community Loss Index
[2]NI: not impaired, SL: slightly impaired, MI: moderately impaired, SI: severely impaired, N/A=not applicable

Table 6.31 Biological monitoring conducted by VADEQ on 10/26/99.

Examined Sample: LEW006.95—Lewis Creek 10/26/1999
Reference Sample: STC004.27—Straight Creek 10/13/1999

Metrics[1]	Value		Ratio	Scores	
	Reference	Target		Reference	Target
TR	21	6	0.286	6	0
MFBI	3.64	5.77	0.631	6	3
SCR/FC	6.56	0.12	0.018	6	0
EPT/C	29.00	16.60	0.572	6	3
% DT	25	81	N/A	6	0
EPTI	10	1	0.100	6	0
CLI	N/A	0.762	N/A	6	3
SHR/T	0.162	0.0194	0.120	6	0
Total Score				48	9
% Comp to Reference					19
Biological Condition					SI

[1]TR: taxa richness, MFBI: Modified Family Biotic Index, SCR/FC: Scraper/Filter Collector ratio, EPT/C: EPT/Chironomidae, %DT: percent Dominant Taxon, EPTI: EPT Index, CLI: Community Loss Index
[2]NI: not impaired, SL: slightly impaired, MI: moderately impaired, SI: severely impaired, N/A=not applicable

Table 6.32 Biological monitoring conducted by VADEQ on 4/11/00.

Examined Sample: LEW006.95—Lewis Creek 4/11/2000
Reference Sample: STC004.27—Straight Creek 5/4/2000

Metrics[1]	Value		Ratio	Scores	
	Reference	Target		Reference	Target
TR	20	7	0.350	6	0
MFBI	4.18	6.11	0.685	6	3
SCR/FC	1.71	0.14	0.080	6	0
EPT/C	3.45	0.27	0.078	6	0
% DT	17	70	N/A	6	0
EPTI	12	2	0.167	6	0
CLI	N/A	0.700	N/A	6	3
SHR/T	0.110	0.0082	0.074	6	0
Total Score				48	6
% Comp to Reference					13
Biological Condition					SI

[1]TR: taxa richness, MFBI: Modified Family Biotic Index, SCR/FC: Scraper/Filter Collector ratio, EPT/C: EPT/Chironomidae, %DT: percent Dominant Taxon, EPTI: EPT Index, CLI: Community Loss Index
[2]NI: not impaired, SL: slightly impaired, MI: moderately impaired, SI: severely impaired, N/A=not applicable

Table 6.33 Biological monitoring conducted by VADEQ on 10/16/00.

Examined Sample: LEW006.95—Lewis Creek 10/16/2000
Reference Sample: STC004.27—Straight Creek 10/13/2000

Metrics[1]	Value		Ratio	Scores	
	Reference	Target		Reference	Target
TR	19	10	0.526	6	3
MFBI	3.61	6.00	0.602	6	3
SCR/FC	7.11	0.09	0.012	6	0
EPT/C	20.00	1.80	0.090	6	0
% DT	25	45	N/A	6	3
EPTI	12	2	0.167	6	0
CLI	N/A	0.684	N/A	6	3
SHR/T	0.054	0.0180	0.333	6	3
Total Score				48	15
% Comp to Reference					31
Biological Condition					MI

[1]TR: taxa richness, MFBI: Modified Family Biotic Index, SCR/FC: Scraper/Filter Collector ratio, EPT/C: EPT/Chironomidae, %DT: percent Dominant Taxon, EPTI: EPT Index, CLI: Community Loss Index
[2]NI: not impaired, SL: slightly impaired, MI: moderately impaired, SI: severely impaired, N/A=not applicable

Table 6.34 Biological monitoring conducted by VADEQ on 5/28/02.

Examined Sample: LEW006.95—Lewis Creek 5/28/2002
Reference Sample: STC004.27—Straight 4/24/2002

Metrics[1]	Value		Ratio	Scores	
	Reference	Target		Reference	Target
TR	19	9	0.474	6	3
MFBI	3.81	5.67	0.671	6	3
SCR/FC	1.68	0.30	0.180	6	0
EPT/C	7.64	1.21	0.158	6	0
% DT	20	31	N/A	6	3
EPTI	11	3	0.273	6	0
CLI	N/A	0.579	N/A	6	3
SHR/T	0.273	0.0727	0.267	6	3
Total Score				48	15
% Comp to Reference					31
Biological Condition					MI

[1]TR: taxa richness, MFBI: Modified Family Biotic Index, SCR/FC: Scraper/Filter Collector ratio, EPT/C: EPT/Chironomidae, %DT: percent Dominant Taxon, EPTI: EPT Index, CLI: Community Loss Index
[2]NI: not impaired, SL: slightly impaired, MI: moderately impaired, SI: severely impaired, N/A=not applicable

Table 6.35 Biological monitoring conducted by VADEQ on 11/1/02.

Examined Sample: LEW006.95—Lewis Creek 11/1/2002
Reference Sample: STC004.27—Straight Creek 11/6/2002

Metrics[1]	Value		Ratio	Scores	
	Reference	Target		Reference	Target
TR	16	7	0.438	6	3
MFBI	2.89	5.86	0.494	6	0
SCR/FC	17.50	0.03	0.002	6	0
EPT/C	13.40	7.23	0.540	6	3
% DT	22	74	N/A	6	0
EPTI	9	2	0.222	6	0
CLI	N/A	0.750	N/A	6	3
SHR/T	0.383	0.0565	0.147	6	0
Total Score				48	9
% Comp to Reference					19
Biological Condition					SI

[1]TR: taxa richness, MFBI: Modified Family Biotic Index, SCR/FC: Scraper/Filter Collector ratio, EPT/C: EPT/Chironomidae, %DT: percent Dominant Taxon, EPTI: EPT Index, CLI: Community Loss Index
[2]NI: not impaired, SL: slightly impaired, MI: moderately impaired, SI: severely impaired, N/A=not applicable

Figures 6.2 and 6.3 summarize bioassessment results for the benthic impairments in the Middle River Watershed. The score for Christians Creek was calculated from benthic assessments conducted at VADEQ station 1BCST007.42. The score for the upper Middle River was obtained from benthic assessments conducted by VADEQ at two locations on Middle River very close to the headwaters, stations 1BMDL66.05 and 1BMDL66.47. The score for Moffett Creek was calculated from benthic assessments conducted at VADEQ stations 1BMFT005.11 and

1BMFT006.24. The score for Lewis Creek was obtained from benthic assessments conducted by VADEQ at stations 1BLEW000.61and 1BLEW006.95.

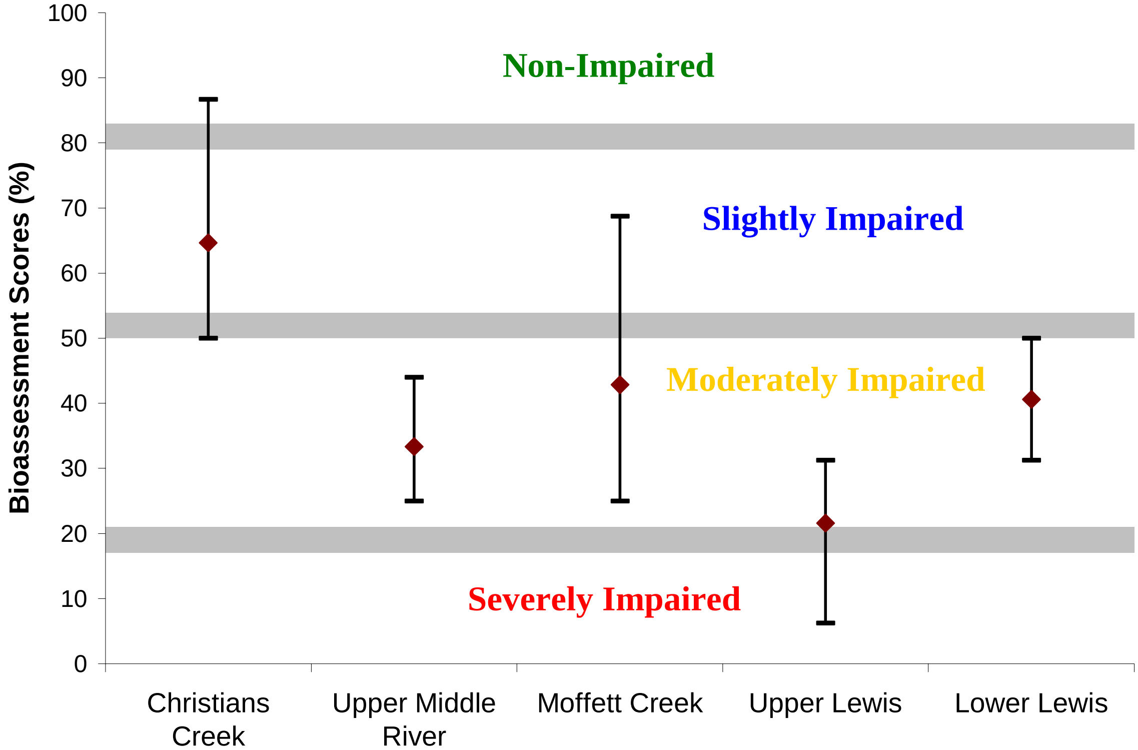

Figure 6.2 Bioassessment scores for benthic impairments in the Middle River Watershed for each impaired segment.

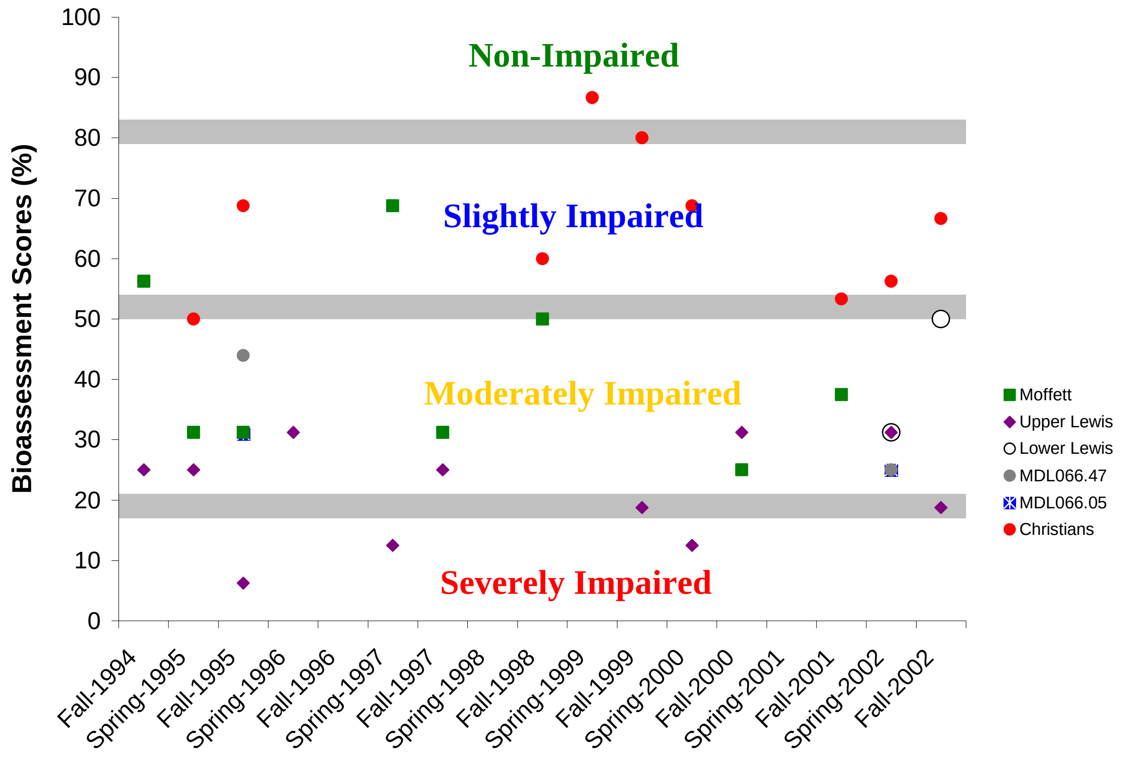

Figure 6.3 Bioassessment scores for benthic impairments in the Middle River Watershed over time.

6.2 Biomonitoring Results using the Stream Condition Index (SCI)

VADEQ is in the process of changing methodologies for assessing the health of aquatic life in Virginia's streams, switching from the Rapid Bioassessment Protocol II (RBPII) to the Stream Condition Index (SCI). Because the Middle River TMDL study took place during the transition period, bioassessment scores have also been calculated using the SCI procedure to compare with results using the RBPII. The SCI procedure, like the RBPII, assesses aquatic life by sampling the benthic community, using the same method for collecting macroinvertebrates and the same eight biometrics as the RBPII for scoring. Unlike the RBPII, the SCI does not require a reference watershed because the score for each metric is calculated from an algorithm based on statistical analysis of the large benthic database for Virginia. Calculation of individual metric scores with the RBPII methodology is based on the ratio of target station score to reference station score and requires the identification of an appropriate reference station, which is often difficult. At this time VADEQ is using an SCI score of 61.5 as the cutoff point for impairment status and stream segments with bioassessment scores below 61.5 are classified as impaired.

SCI scores were calculated using biological monitoring results at five locations on Christians Creek, two locations on Moffett Creek and two locations on the Upper Middle River. SCI scores were not calculated for Lewis Creek because analysis of ambient water quality data and RBPII results indicated that a toxic stressor is probably present in Lewis Creek. Additional inquiries turned up information on legacy pollutants from past industrial activities along the stream as it flows through the City of Staunton. As a result of these findings, further analysis and discussion of the impairment on Lewis Creek is addressed in a separate document (MapTech, 2004).

A summary of data from benthic assessments on Christians Creek is displayed in Table 6.36 and Figure 6.4. Similar data summaries are given for Moffett Creek in Table 6.37 and Figure 6.5, and for the upper Middle River in Table 6.38. A figure was not included for the upper Middle River because only one assessment was carried out at each of the two sites.

Table 6.36 Summary of benthic data from Christians Creek.

Station	Date	Richness	EPT	% Ephem	% PT-H	% Scraper	% Chiron	% 2Dom	% MFBI	SCI
CST001.31	01/03/96	59.1	63.6	38.8	69.6	52.2	97.1	68.7	86.0	66.9
CST002.64	04/10/95	40.9	45.5	47.8	29.1	52.8	86.2	87.1	80.4	58.7
CST002.64	06/10/97	36.4	36.4	61.6	5.3	21.3	90.6	54.5	75.7	47.7
							CST002.64 Mean SCI			53.2
CST007.42	10/20/94	86.4	90.9	48.7	41.9	39.6	95.6	100.0	79.6	72.8
CST007.42	05/01/95	90.9	81.8	55.7	22.8	31.5	85.4	98.5	78.8	68.2
CST007.42	10/11/95	72.7	72.7	43.0	40.9	67.4	96.4	82.6	83.7	69.9
CST007.42	10/06/98	59.1	54.5	18.0	20.6	88.8	93.6	66.2	81.9	60.3
CST007.42	05/24/99	77.3	63.6	46.2	3.5	76.1	80.5	79.9	81.2	63.5
CST007.42	10/26/99	77.3	63.6	25.4	60.7	56.7	99.3	77.0	86.4	68.3
CST007.42	04/11/00	86.4	90.9	38.4	14.6	38.5	66.1	64.9	72.8	59.1
CST007.42	10/16/01	63.6	45.5	54.4	0.0	62.7	91.7	84.2	78.0	60.0
CST007.42	05/28/02	81.8	63.6	45.9	8.3	59.6	72.7	69.7	75.8	59.7
CST007.42	11/01/02	68.2	54.5	42.6	48.1	59.6	94.6	83.2	85.1	67.0
							CST007.42 Mean SCI			64.9
CST010.18	01/03/96	59.1	81.8	17.4	43.6	54.8	89.3	75.7	86.1	63.5
CST013.29	04/10/95	63.6	63.6	77.7	2.7	43.0	88..6	75.6	84.7	62.4
CST013.29	06/10/97	45.5	45.5	76.9	2.7	26.4	82.7	79.1	77.3	54.5
							CST013.29 Mean SCI			58.5

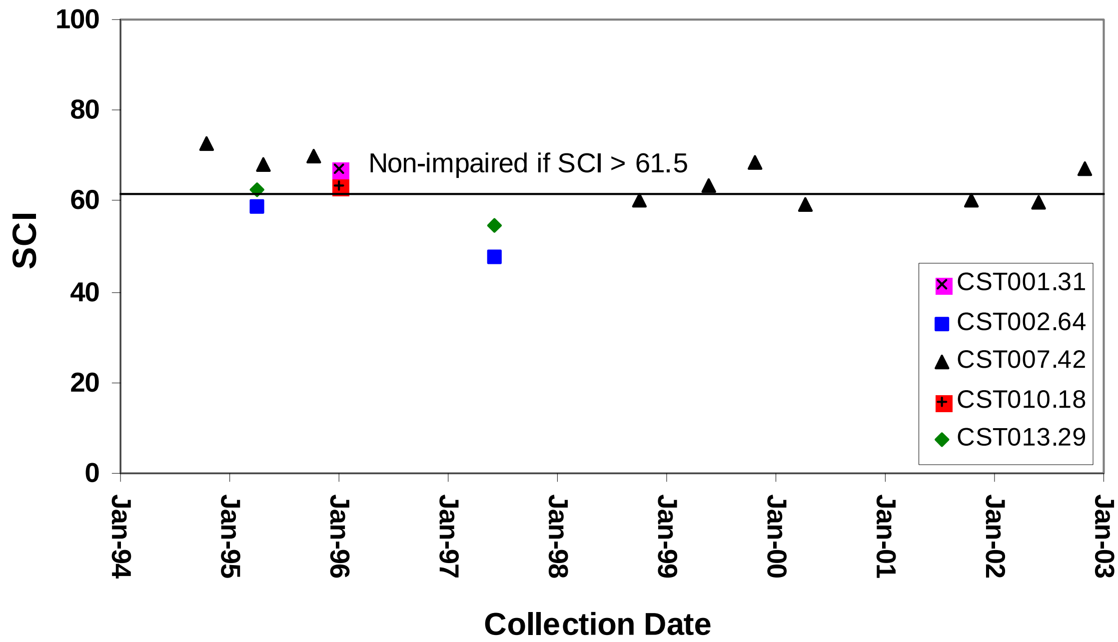

Figure 6.4 Results from biological monitoring on Christians Creek

Figure 6.4 shows that the SCI scores for Christians Creek over the past eight years have been close to the non-impaired cutoff value (61/5) with two of the last three scores slightly less than the cutoff at Station CST007.42. The results using the SCI were essentially identical to results using the RBPII; Christians Creek is classified as impaired.

SCI scores for Moffett Creek, as with the RBPII, clearly indicate impaired conditions. The SCI scores at Moffett Creek Station MFT005.11 are both below the non-impaired cutoff value and two of the last three scores at Station MFT006.24 were also below the cutoff value.

Table 6.37 Summary of benthic data from Moffett Creek.

Station	Date	Richness	EPT	% Ephem	% PT-H	% Scraper	% Chiron	% 2Dom	% MFBI	SCI
MFT005.11	10/16/00	59.1	54.5	14.7	42.3	45.7	60.8	68.7	68.7	51.8
MFT005.11	09/24/01	77.3	54.5	3.4	49.7	38.5	59.7	61.8	70.5	51.9
							MFT005.11 Mean SCI			51.9
MFT006.24	10/20/94	81.8	54.5	14.3	82.5	20.2	87.5	64.9	76.7	60.3
MFT006.24	05/10/95	77.3	63.6	19.4	61.2	49.5	80.2	95.7	80.8	66.0
MFT006.24	10/10/95	31.8	9.1	0.0	0.0	100.0	0.0	40.2	69.1	31.3
MFT006.24	05/08/97	81.8	72.7	49.9	57.3	46.1	81.6	100.0	83.7	71.7
MFT006.24	10/14/97	59.1	54.5	3.1	100.0	12.2	90.6	49.0	74.1	55.3
MFT006.24	10/06/98	54.5	36.4	14.7	74.1	66.1	56.9	49.1	73.7	53.2
							MFT006.24 Mean SCI			60.3

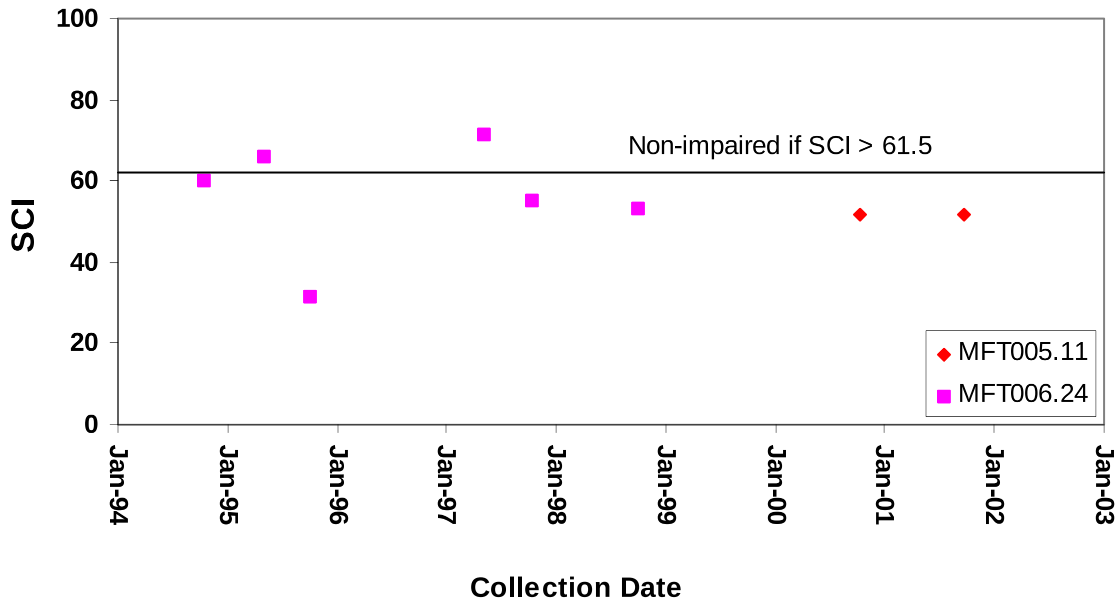

Figure 6.5 Results from biological monitoring on Moffett Creek

SCI scores for the Upper Middle River are shown in Table 6.38 and are far below the cutoff, indicating severely impaired conditions. Not surprisingly, the result is the same using the RBPII.

Table 6.38 Summary of benthic data from the Upper Middle River.

Station	Date	Richness	EPT	% Ephem	% PT-H	% Scraper	% Chiron	% 2Dom	% MFBI	SCI
MDL066.05	05/28/02	63.6	18.2	3.2	0.0	8.3	49.6	49.5	51.6	30.5
MDL066.47	05/28/02	59.1	27.3	0.7	0.0	6.6	77.3	62.0	46.8	35.0

7. TMDL ENDPOINT: STRESSOR IDENTIFICATION AND REFERENCE WATERSHED SELECTION

The first step in developing a TMDL is the establishment of measurable in-stream endpoints, which are used to evaluate the attainment of acceptable water quality. In-stream endpoints, therefore, represent the water quality goals that are to be achieved by implementing the load reductions specified in the TMDL. The endpoints for the Middle River watershed benthic impairments were developed using a reference watershed approach. Critical stressors were identified through analysis of ambient water quality data, toxicity tests, and habitat assessment.

7.1 Stressor Identification

7.1.1 Ambient Water Quality Data

Six general water quality parameters (temperature, dissolved oxygen, specific conductance, pH, alkalinity, and hardness) were analyzed to determine their impact as a source of stress for the benthic community. At the levels measured, the general water quality parameters are not sources of stress for the benthic community.

7.1.1.1 Temperature and Dissolved Oxygen

At the stations with multiple readings of three or more, the average temperatures remain well below 20 ^{o}C and dissolved oxygen (DO) levels were excellent at all stations, averaging above 9 mg/L with minimum values above 6 mg/L (Table 7.1). The two samples collected at station 1BCST000.13 were collected in July and September 2003. Temperature and DO are not stressors.

Table 7.1 Summary data for temperature and DO.

Station	n	Average Temperature (°C)	DO (mg/L) Min	Max	Avg	Stdev
1BMDL060.48	28	15.5	6.7	13.7	10.0	1.8
1BMDL061.07	31	13.8	7.0	14.0	10.3	2.1
1BMDL066.05	1	20.0	9.5	9.5	9.5	0.0
1BMDL066.47	1	19.5	9.2	9.2	9.2	0.0
1BCST000.13	2	24.2	8.0	8.9	8.5	0.6
1BCST007.42	3	19.3	7.4	12.3	9.1	2.7
1BCST012.32	111	13.4	7.2	15.4	10.6	2.2
1BCST016.48	2	15.6	8.1	11.4	9.8	2.3
1BCST021.76	111	14.1	6.2	15.1	10.3	1.7
1BMFT001.43	11	14.7	8.8	13.2	11.0	1.8
1BMFT006.20	44	14.4	6.0	14.2	10.4	2.2

7.1.1.2 Specific Conductance and pH

There is not much data for specific conductance in the impaired stream segments, but conductivity is in the normal range and well below 500 μmho/cm (Table 7.2). The pH in the impaired stream segments are close to ideal with average values ranging from 7.9 – 8.3, and minimum values at or above 6.1. There is less than a 10% occurrence of pH values exceeding 9 for each station. Specific conductance and pH levels are not stressors.

Table 7.2 Summary data for specific conductance and pH.

Station	n	Average Specific Conductance	pH Min	Max	Avg	Stdev
1BMDL060.48	28	216 (n=2)	7.4	8.6	8.0	0.3
1BMDL061.07	31	Not Available	7.1	8.7	8.0	0.3
1BMDL066.05	1	321	8.2	8.2	8.2	0.0
1BMDL066.47	1	335	8.2	8.2	8.2	0.0
1BCST000.13	2	456	8.3	8.3	8.3	0.0
1BCST007.42	3	464	8.1	8.4	8.2	0.2
1BCST012.32	206	259 (n=106)	6.1	9.5	8.2	0.5
1BCST016.48	2	340	7.8	8.3	8.1	0.4
1BCST021.76	116	340 (n=1)	6.5	8.8	8.0	0.3
1BMFT001.43	11	247 (n=1)	7.1	8.6	8.0	0.4
1BMFT006.20	28	Not Available	6.7	9.1	7.9	0.5

7.1.1.3 Alkalinity and Hardness

Data on alkalinity and hardness for the impaired stream segments are displayed in Table 7.3 and Table 7.4. Alkalinity provides protection against acidification of stream water and hardness diminishes the toxicity of heavy metals to aquatic organisms. The average values are typical for stream water in areas with limestone deposits. Alkalinity and hardness are not stressors.

Table 7.3 Summary data for alkalinity.

Station	n	Alkalinity (mg/L as $CaCO_3$) Min	Max	Avg	Stdev
1BMDL060.48	15	88.5	154.0	131.0	18.2
1BMDL061.07	30	32.8	163.0	120.0	29.1
1BCST012.32	176	9.0	555.0	247.0	34.2
1BCST021.76	101	21.2	208.4	220.7	26.6
1BMFT006.20	42	21.1	192.0	102.5	47.2

Table 7.4 Summary data for hardness.

Station	n	Hardness (mg/L as $CaCO_3$) Min	Max	Avg	Stdev
1BMDL060.48	22	85.7	171.0	131.3	19.6
1BMDL061.07	30	67.0	178.0	131.3	29.1
1BCST012.32	172	24.0	228.8	42.2	42.2
1BCST021.76	109	125.0	239.0	27.3	27.3
1BMFT001.43	7	59.2	203.0	148.9	56.9
1BMFT006.20	42	27.4	198.0	111.9	50.8

7.1.1.4 Nutrients

Nutrient enrichment in the impaired segments was assessed by analyzing data on nitrate, total phosphorus (TP), and total suspended solids (TSS). The data summaries are shown in Table 7.5–Table 7.7 for nitrate, TP and TSS, respectively. Nitrate levels, averaging approximately 1 mg/L, are not excessive. Total phosphorus (TP) is somewhat elevated at averages from 0.1 – 0.2 mg/L but is not considered excessive. TSS was included as an indicator of NPS pollution because nutrient adsorption to TSS is assumed to be the primary pathway for nutrient transport. The average TSS values are less than 40 mg/L, which are not excessive, but the maximum values (over 150 mg/L) at four stations indicate that large inputs of silt do occur, probably during stormwater runoff events.

Table 7.5 Summary data for nitrate.

Station	n	Nitrate (mg/L)			
		Min	Max	Avg	Stdev
1BMDL060.48	27	0.55	1.73	1.05	0.30
1BMDL061.07	30	0.41	1.83	1.09	0.31
1BCST012.32	231	0.15	5.04	1.87	0.57
1BCST021.76	112	0.04	3.50	1.67	0.46
1BMFT001.43	11	0.07	2.58	0.90	0.90
1BMFT006.20	42	0.18	1.90	0.94	0.47

Table 7.6 Summary data for TP.

Station	n	TP (mg/L)			
		Min	Max	Avg	Stdev
1BMDL060.48	27	0.01	0.20	0.07	0.05
1BMDL061.07	30	0.10	0.40	0.12	0.07
1BCST000.13	2	0.10	0.11	0.11	0.01
1BCST007.42	2	0.11	0.17	0.14	0.04
1BCST012.32	230	0.10	1.00	0.21	0.14
1BCST021.76	112	0.01	0.60	0.09	0.06
1BMFT001.43	11	0.01	0.04	0.02	0.01
1BMFT006.20	42	0.01	0.20	0.09	0.05

Table 7.7 Summary data for TSS.

Station	n	TSS (mg/L)			
		Min	Max	Avg	Stdev
1BMDL060.48	26	3.0	161.0	29.7	31.8
1BMDL061.07	30	3.0	380.0	40.1	67.5
1BCST000.13	2	5.0	15.0	10.0	7.1
1BCST007.42	3	3.0	18.0	11.0	7.5
1BCST012.32	234	1.0	321.0	24.1	41.5
1BCST021.76	114	3.0	560.0	31.6	56.7
1BMFT001.43	11	3.0	10.0	4.3	2.3
1BMFT006.20	42	2.0	32.0	5.6	6.4

Data from a diurnal DO study on the impaired streams are displayed in Figure 7.1 – Figure 7.3. There is a diurnal swing of 42% in the extent of oxygen saturation, from a minimum of 67% saturation to a maximum of 109% saturation in the Upper Middle River. The significant diurnal pattern indicates that nutrient enrichment has increased primary production in Middle River. However, the minimum DO level recorded for the Upper Middle River was 5.6 mg/L and is above the water quality standard for DO. The diurnal fluctuations for Christians Creek and Moffett Creek are not as great, and minimum DO levels are above the water quality standard for DO. Diurnal DO studies are conducted in impaired stream segments because the diurnal DO swing becomes more severe as nutrient levels increase. Excessive nutrient levels are probably not a major stressor but have the potential to impact the benthic community.

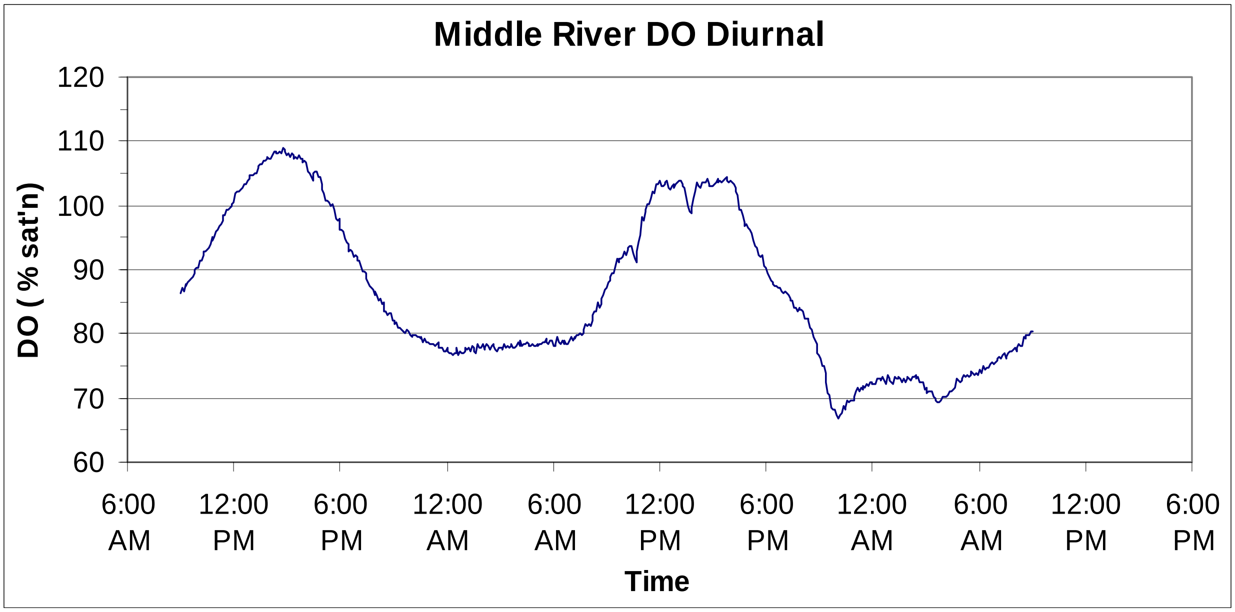

Figure 7.1 Diurnal DO Study on Middle River.

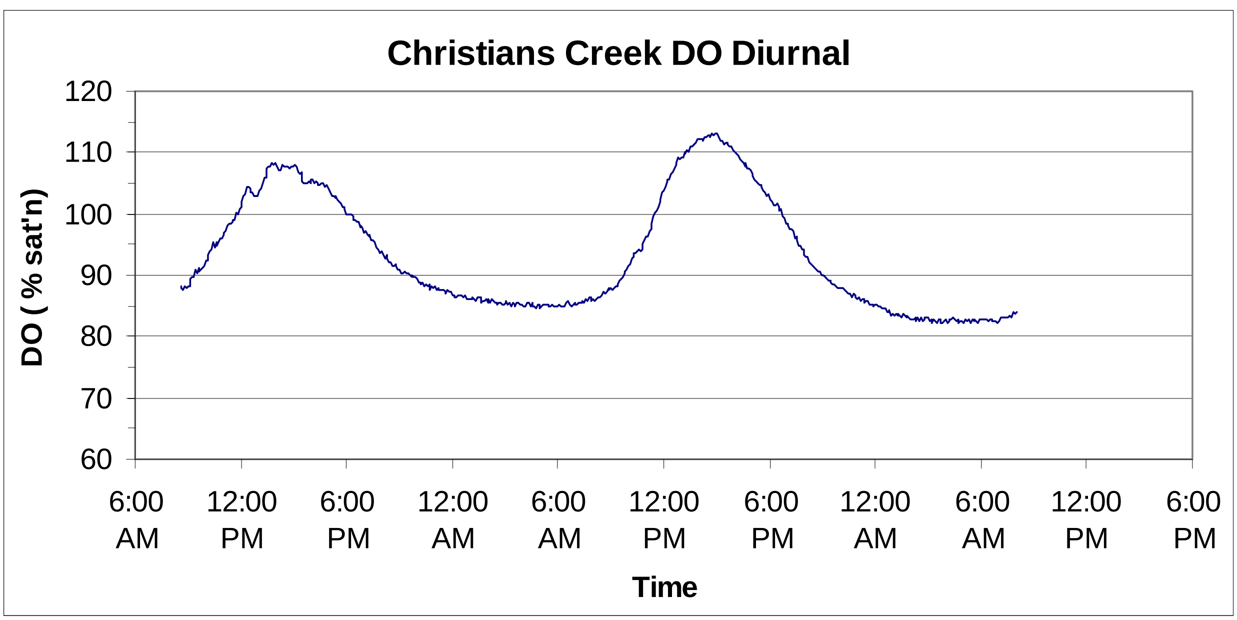

Figure 7.2 Diurnal DO Study on Christians Creek.

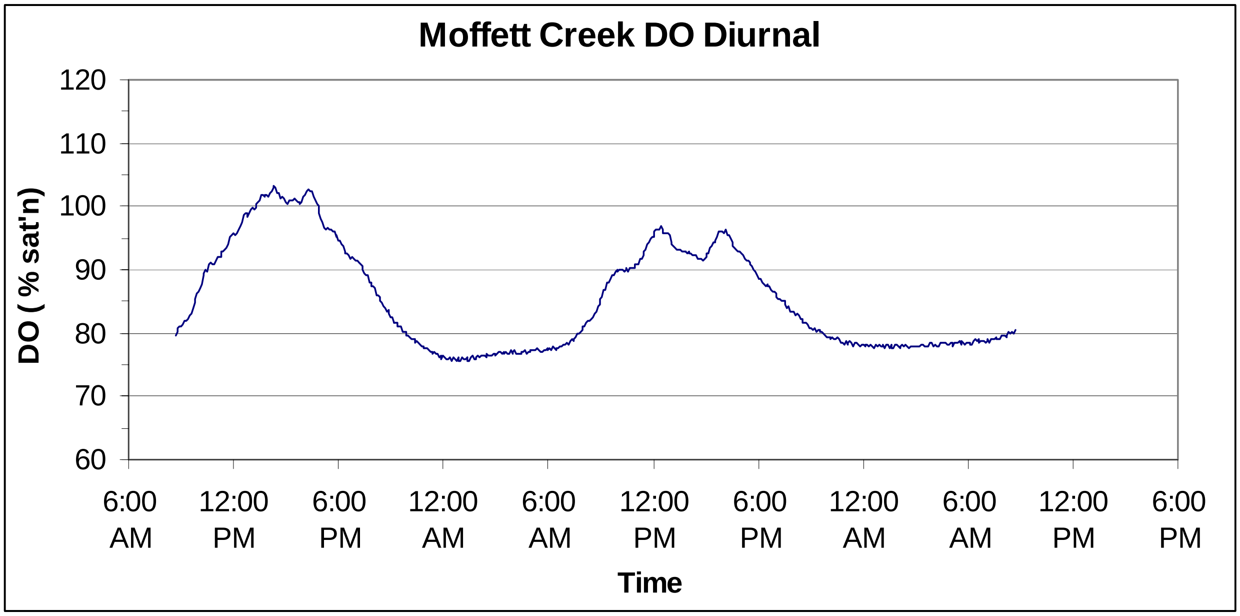

Figure 7.3 Diurnal DO Study on Moffett Creek.

7.1.1.5 Ammonia

Ammonia is both a nutrient and a toxicant, but was not detected (nd) in more than a third of the ambient water samples collected in the impaired segments (detection limit = 0.04 mg/L). The data summary is shown in Table 7.8. Ammonia was never measured above 0.42 mg/L, well below the chronic toxicity criteria for aquatic life. Ammonia is not a stressor.

Table 7.8 Summary data for ammonia.

Station	n	Ammonia (mg/L as N)			
		Min	Max	Avg	Stdev
1BMDL060.48	27 (10 nd)	0.04	0.14	0.06	0.03
1BMDL061.07	30 (14 nd)	0.04	0.18	0.06	0.03
1BCST000.13	2 nd	0.04	0.04	0.04	0.00
1BCST007.42	2 nd	0.04	0.04	0.04	0.00
1BCST012.32	136 (75 nd)	0.04	0.42	0.06	0.05
1BCST021.76	112 (69 nd)	0.04	0.12	0.05	0.02
1BMFT001.43	11 (9 nd)	0.04	0.07	0.04	0.01
1BMFT006.20	42 (33 nd)	0.04	0.08	0.04	0.01

7.1.1.6 Metals

Water samples from the Upper Middle River, Christians Creek, and Moffett Creek have not been analyzed for metals since 1982, but sediment samples have been collected. Three sediment samples from the Upper Middle River were collected, one at station 1BMDL060.48 (August 2000) and two at station 1BMDL061.07 (June 1992, July 1996), and analyzed for metals. Five sediment samples from Christians Creek were collected since 1991, two at station 1BCST012.32 (July 1991, July 1999) and three at station 1BCST021.76 (June 1992, July 1996, July 1999). Three sediment samples from Moffett Creek have been collected at station 1BMFT006.20 (June 1992, July 1996, August 2000). Antimony, beryllium, mercury, and thallium were not detected in any of the samples. Average concentrations of metals detected are shown in Table 7.9 for each stream. Concentrations were all well below the low and median NOAA Effects Range. Metal toxicity is not a stressor.

Table 7.9 Metals detected in stream sediment samples.

Metal	Average Sediment Concentration (mg/kg)			NOAA Effect Range (mg/kg)	
	Upper Middle River	Christians Creek	Moffett Creek	Low	Median
Arsenic	nd	6	6	8	70
Chromium	11	17	16	34	270
Copper	7	36	21	81	370
Lead	8	18	16	47	223
Nickel	9	14	20	21	52
Zinc	22	41	55	150	410

7.1.1.7 Toxic Organics

Water from the Upper Middle River, Christians Creek, and Moffett Creek was not analyzed for toxic organics after 1982, but the same sediment samples described in the preceding section were analyzed for a wide array of toxic organics: aldrin, chlordane, dieldrin, endrin, heptachlor, DDD, DDT, DDE, PCBs, and pentachlorophenol. Sediment quality guidelines developed by Long et al. (1995), based on data compiled from numerous studies in the United States that included sediment contaminant and biological effects information, were used in the analysis of toxic organics. From Long et al.'s study, the NOAA Effects Range-Median is the concentration equivalent to the 50th percentile of the compiled study data. According to that study, concentrations above the Effects Range-Median are “frequently” associated with adverse affects.

None of the toxic organics were at detectible levels in the sediment samples from the Upper Middle River, station 1BCST021.76 in Christians Creek, or Moffett Creek. Toxic organics are not stressors in these stream segments.

The sediment sample collected in July 1991 from station 1BCST012.32 was analyzed for toxic organics and did contain chlordane and PCBs at detectible levels. Chlordane was detected at 1000 µg/kg, much higher than the NOAA's Effects Range – Median of 6 µg/kg. The PCBs value in the sediment sample was detected at 1000 µg/kg, which is also well above NOAA's Effects Range – Median of 180 µg/kg. Toxic organics are a potential stressor in Christians Creek but data from recent sediment samples are necessary to reach a more confident conclusion.

7.1.2 Water-Column Toxicity Tests

Chronic toxicity tests were performed in March 2003 on water collected from Lewis Creek at the Route 931 bridge (ambient station 1BLEW002.91), Moffett Creek at the Route 733 bridge (ambient station 1BMFT001.43), and the Upper Middle River at the Route 705 bridge (ambient station 1BMDL060.48), but the results were not conclusive (EPA, 2003). The tests included measuring survival and growth of fathead minnows (*Pimephales promelas*) and measuring survival and reproduction of a small "water flea" (*Ceriodaphnia dubia*).

In the survival/reproduction test using *Ceriodaphnia dubia*, there was not a significant statistical difference in either metric between the control group and the test group exposed to Middle River water. There was a significant difference in growth between the control group and test group of *Pimephales promelas*. However, the results are probably not indicative of a true biological effect for several reasons. First, the weight of fish in the test group was well above the minimum weight required for acceptable control treatments and typical for control treatments within this laboratory. Secondly, the control treatment, to which the test group was compared to determine an effect, exhibited greater growth than typically experienced in this laboratory. This greater than usual control response resulted in a statistical difference between control and test treatments, where the test treatment exhibited growth equivalent to control treatments in typical tests. Survival results (both as % survival and transformed % survival) for the fathead minnows are displayed in Table 7.10

Table 7.10 Results from Chronic Toxicity Tests with Fathead Minnows.

Group	Group Mean Weight (mg)	% Survival	% Survival Transformed*
Control	0.749	100	1.412
Lewis Creek	0.278	60	0.891
Moffett Creek	0.529	85	1.202
Middle River	0.468	77.55	1.099

*Transform: Arc Sin (Square Root (Y))

7.1.3 Habitat Conditions

7.1.3.1 Upper Middle River

Results from the habitat assessments for the Upper Middle River are displayed in Figure 7.4. Habitat assessments have been carried out on the Upper Middle River at two stations; 1BMDL066.05 and 1BMDL066.47, both near the headwaters. The stations bracket Cockran Spring, rated as moderately impaired, and organic solids were identified as the stressor. Only the most recent survey was available in the EDAS database. The reference site was Strait Creek (Station 1ASTC004.27) in Highland County and the assessment results vary considerably from metric to metric.

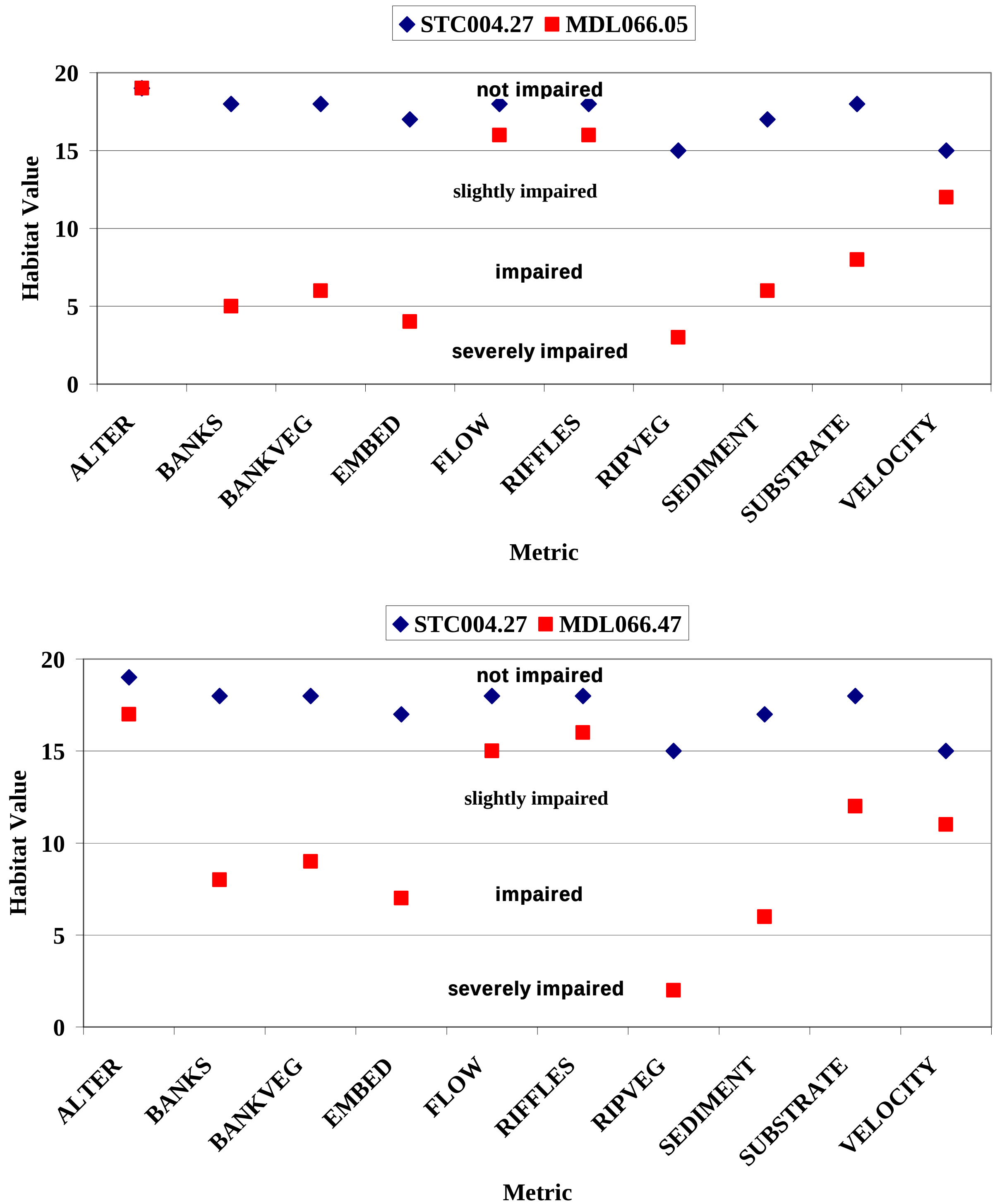

Figure 7.4 Results from the habitat assessment for the Upper Middle River.

At both stations, the stream channel was found to be in good physical condition with little alteration of the channel, good flow, and with adequate riffles and velocity. There was a difference in substrate score between the two stations. The upstream station substrate was only slightly impaired but the downstream station substrate was impaired. The decreasing substrate quality is typically a result of silt inputs and probably caused by solids from Cockran Spring. Embeddedness was greater at the downstream station as well and is a strong indicator of excessive siltation. Scores from the other metrics were not satisfactory. At Station 1BMDL066.05, the following habitat metrics compared poorly to the reference station:

BANKS (Bank Stability) – This metric measures whether banks are eroded or have a high potential for erosion. The Middle River monitoring station 1BMDL066.05 was rated poor for this metric. This means that 60 – 100% of the streambank has evidence of erosion. Erosion is an important source of sediment deposition in the stream.

BANKVEG (Bank Vegetative Protection) – This metric is indicative of the type and quality of bank vegetation. For example trees have root systems that can protect the bank from erosion. The lack of proper streambank vegetation is another indication of erosion potential. This metric was rated as marginal for Upper Middle River at the 1BMDL066.05 monitoring station.

EMBED (Embeddedness) – Is a measure of extent to which the suitable habitat is covered or sunken into sediment. Therefore, a low embeddedness score indicates a significant loss of habitat due to sediment deposition. Upper Middle River had a poor rating for this metric, indicating gravel, cobble and boulder in the riffle area is more than 75% surrounded by fine sediment at 1BMDL066.05.

RIPVEG (Riparian Vegetative Zone Width) – Is a measure of the width of the natural riparian zone. A healthy riparian zone acts as a buffer for pollutants in runoff from the land, helps prevent erosion, and provides habitat. Upper Middle River scored poorly on this metric as well, meaning that the riparian zone width was less than 20 feet at 1BMDL066.05.

SEDIMENT (Sediment Deposition) – A metric that measures the amount of sediment deposition in the pool areas of the stream. Upper Middle River had a marginal score for this metric at 1BMDL066.05. This indicates that 30 – 50% of the pool bottom is affected by sediment.

SUBSTRATE (Epifaunal Substrate/Available Cover) – Provides a measure of the relative quantity and quality of available habitat in the stream for benthic macroinvertebrates. Upper Middle River had a marginal score indicating that only 20 – 40% of a stable mix of suitable habitat exists at 1BMDL066.05. Scores this low are often indicative of substrate that is constantly disturbed or has been removed.

At Station 1BMDL066.47, the habitat metrics that compared poorly to the reference station include:

> **BANKS** (Bank Stability) – The Upper Middle River was rated marginal for this metric at 1BMDL066.47. This means that 30-60% of the streambank has evidence of erosion.
>
> **BANKVEG** (Bank Vegetative Protection) – This metric was rated as marginal for Upper Middle River at the 1BMDL066.47 monitoring station.
>
> **EMBED** (Embeddedness) – Upper Middle River had a marginal rating for this metric at 1BMDL066.47. More than 50 - 75% of the gravel, cobble and boulder in the riffle area are surrounded by fine sediment.
>
> **RIPVEG** (Riparian Vegetative Zone Width) – Upper Middle River scored poorly on this metric as well, meaning that the riparian zone width was less than 20 feet at 1BMDL066.47.
>
> **SEDIMENT** (Sediment Deposition) – Upper Middle River had a marginal score for this metric at 1BMDL066.47. This indicates that 30 – 50% of the pool bottom is affected by sediment.

The habitat and biological metrics clearly indicate that solids deposition is a significant problem. MapTech personnel have also made site visits to the Upper Middle River area and report that there is very little riparian vegetation and that the streambanks are eroded. Furthermore, the monitoring station sites are characterized by pasture, and livestock have full access to the stream.

7.1.3.2 Habitat Conditions in Christians Creek

Results from the habitat assessments are displayed in Figure 7.5. Habitat assessments have been carried out in Christians Creek at 1BCST007.42 (Route 795 bridge) since October 1994 (10 surveys). Several reference sites have been used, but the one used most frequently was the Cowpasture River (Station 2CWP050.66) located in Bath County. Total habitat scores were very good, ranging from 116 – 171 (Average = 141). In general, the trend shows improvement in habitat scores throughout the 1990s. The stream channel in Christians Creek was in good physical condition with little alteration of the channel, had good flow, and had adequate riffles and velocity. The only metric that was consistently impaired was riparian vegetation.

1BCST007.42 scored marginally on this metric, meaning that the riparian zone width was 20 – 40 feet.

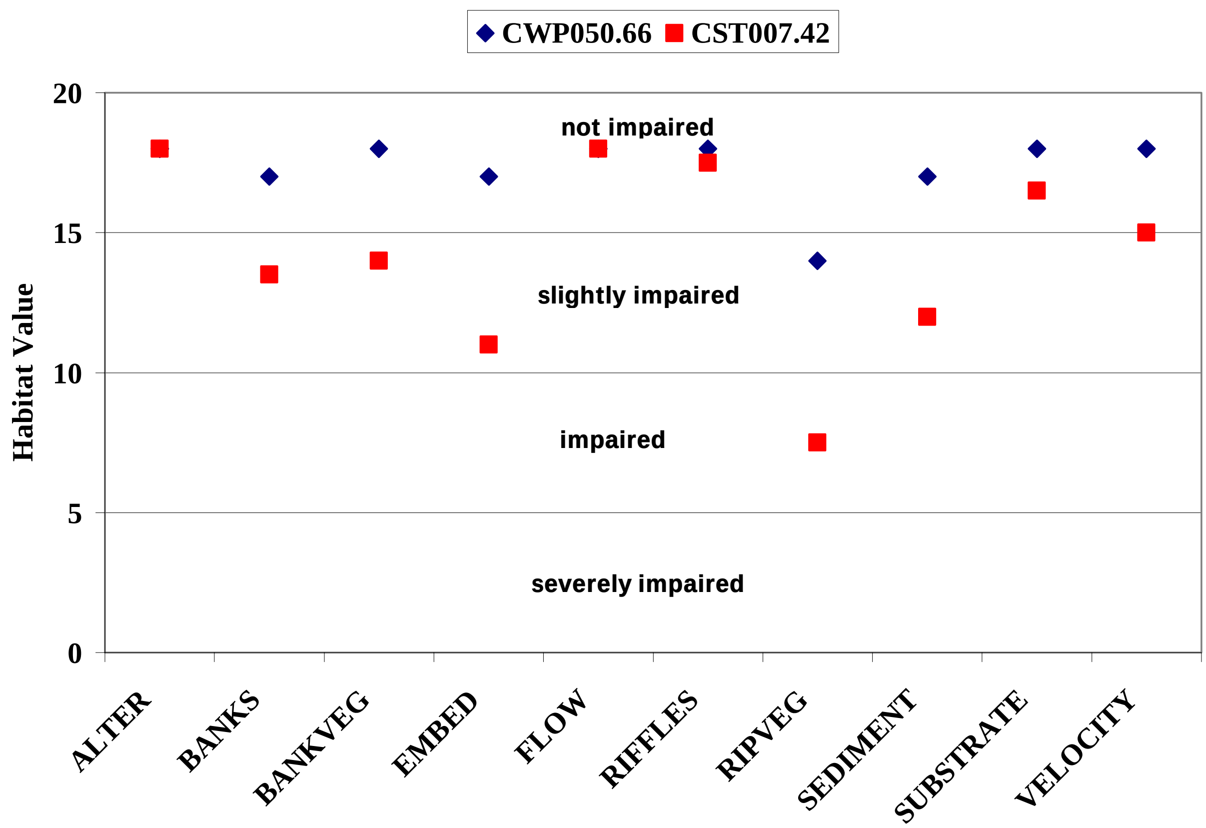

Figure 7.5 Average results from the habitat assessment for Christians Creek.

The only other metrics that indicated problems in Christians Creek were bank stability and bank vegetative protection. The low scores for these metrics were primarily in the early 1990s and they improved considerably over the sampling period. Average scores for embeddedness and sediment deposition were 12 and 13, respectively. Only embeddedness fell below the impaired cutoff score of 10 on one occasion (9 in November, 2002). Therefore, sediment deposition may be a minor stressor at this monitoring station. However, the biological metrics indicate that the impact of sediment deposition is minimal. One of the MAIS metrics, % Haptobenthos, is a good indicator of sediment problems at times because sediment eliminates habitat for clingers and crawlers, which require a coarse, clean bottom. The average score for Christians Creek was 72, which compared very favorably to the Cowpasture River reference station 78.

7.1.3.3 Habitat Conditions in Moffett Creek

Results from the habitat assessments for Moffett Creek are displayed in Figure 7.6. Habitat assessments were carried out in Moffett Creek at two stations, 1BMFT006.24 and 1BMFT005.11 since the fall of 1994. The original monitoring station, 1BMFT006.24, was abandoned in the spring of 1999 due to access issues. A new station site was located just over one mile downstream, 1BMFT005.11. The sampling for this assessment includes six surveys at station 1BMFT006.24 and three at station 1BMFT005.11. The results for each station will be discussed separately. The reference site for both stations was Strait Creek (Station 1ASTC004.27) in Highland County. At both stations, the stream channel was in good physical condition with little alteration of the channel, good flow, and with adequate riffles. Velocity scores were often marginal at station 1BMFT005.11 but good at 1BMFT006.24. Both stations had an average total habitat score of 109 (<120 is considered poor) but there were minor differences between them. At Station 1BMFT006.24, the following habitat metrics compared poorly to the reference station:

> **BANKS** (Bank Stability) – Moffett Creek at monitoring station 1BMFT006.24 was rated marginal for this metric. This means that 30 - 60% of the streambank has evidence of erosion. Erosion is an important source of sediment deposition in the stream.
>
> **BANKVEG** (Bank Vegetative Protection) –This metric was rated as marginal for Moffett Creek at the 1BMFT006.24 monitoring station, indicating that only 50 – 70% of the streambank is protected by vegetation.
>
> **RIPVEG** (Riparian Vegetative Zone Width) – Moffett Creek at 1BMFT006.24 had a marginal average score on this metric as well, meaning that the riparian zone width was only 20 - 40 feet.
>
> **SEDIMENT** (Sediment Deposition) – Moffett Creek at 1BMFT006.24 had a marginal average score for this metric. This indicates that 30 – 50% of the pool bottom is affected by sediment.

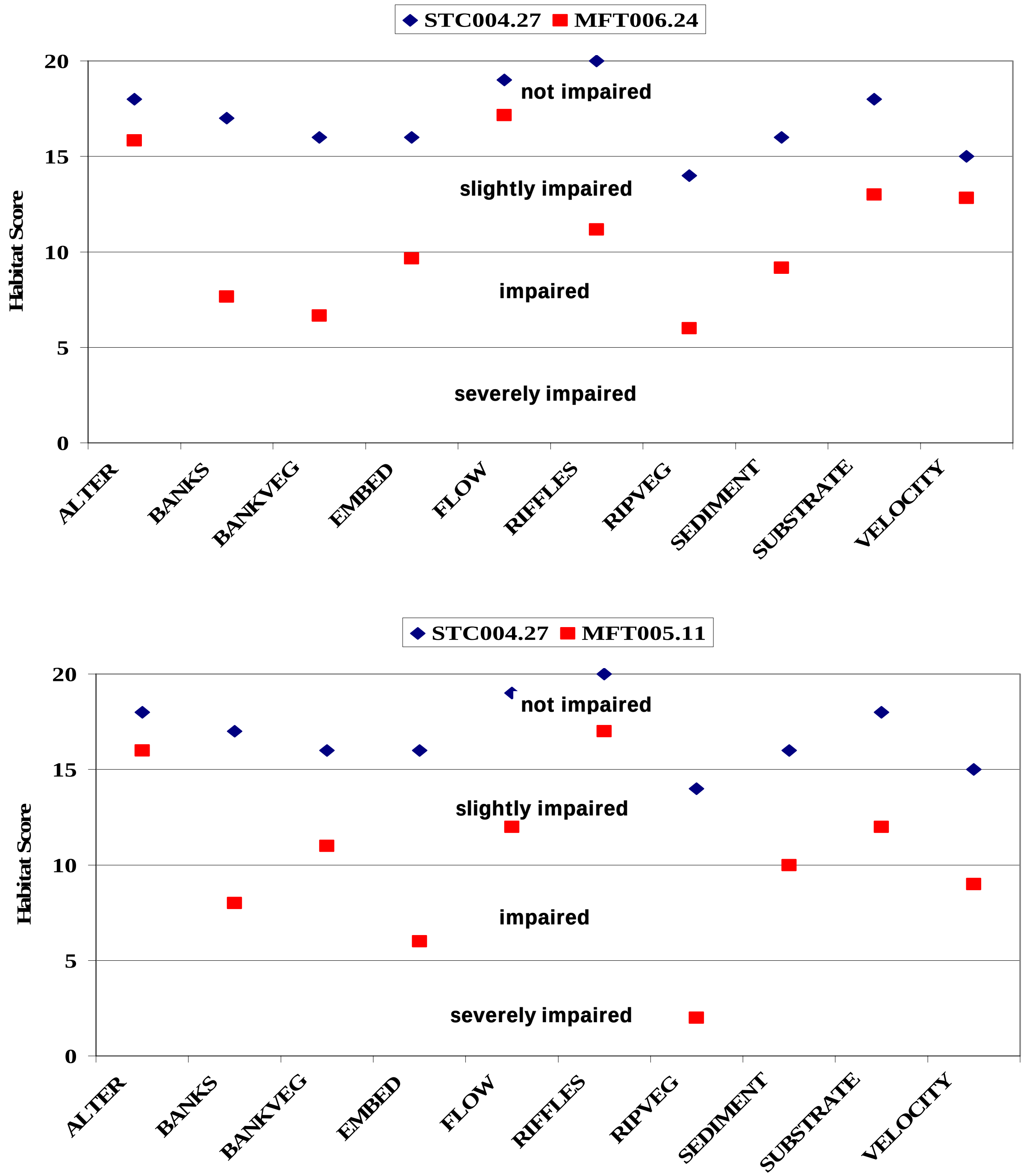

Figure 7.6 Results from the habitat assessment for Moffett Creek.

At Station 1BMFT005.11, the following habitat metrics compared poorly to the reference station:

> **BANKS** (Bank Stability) – Moffett Creek at monitoring station 1BMFT005.11 was rated marginal for this metric. This means that 30 - 60% of the streambank has evidence of erosion. Erosion is an important source of sediment deposition in the stream.
>
> **RIPVEG** (Riparian Vegetative Zone Width) – Moffett Creek at 1BMFT005.11had a poor average score for this metric as well, meaning that the riparian zone width was less than 20.
>
> **EMBED** (Embeddedness) – Moffett Creek at 1BMFT005.11had a marginal average rating for this metric, indicating that gravel, cobble and boulder in the riffle area is more than 75% surrounded by fine sediment.
>
> **VELOCITY** (Velocity/Depth Combinations) – Patterns of velocity and depth are crucial to high-gradient streams. There are four distinct patterns: (1) slow-deep, (2) slow-shallow, (3) fast-deep, (4) fast-shallow. Moffett Creek at 1BMFT005.11 had a marginal average score for this metric, which indicates that only two of the four flow regimes was present.

In addition, the sediment average score at 1BMFT005.11 was 10, which is the cutoff value between slightly impaired and impaired conditions. Even though there were some slight differences, the habitat metrics with average scores below 10 indicate that sediment is a significant problem in Moffett Creek. Eroding streambanks, sediment deposition in pool areas, and embeddedness are all indicators of excessive siltation. The benthic metrics also indicate that sediment is contributing to the impairments. MFBI is often an indicator of fine organic solids. Moffett Creek at station 1BMFT006.24 had an average score of 5.64 (>5.56 is considered poor) and a maximum score of 9.97 in October 1998. Moffett Creek at station 1BMFT005.11 had an average score of 5.27 and a maximum value of 6.36 in March 2003. This indicates that Moffett Creek has consistently high levels of fine organic particulate matter and, periodically, there are extreme amounts.

7.1.4 Landuse

Landuses along the first-order stream corridors in the Upper Middle River watershed, the Christians Creek watershed, and the Moffett Creek watershed are shown in Figure 7.7 through Figure 7.9, respectively. Landuse in the corridors of first order streams has been analyzed because vegetative cover provides a combination of factors (*e.g.*, shading, deadfall, and a primary energy source for the aquatic community) that promote a healthy aquatic community. Of these factors, litterfall is the primary energy source for the aquatic communities found in freshwater streams and litterfall occurs primarily in the first order streams of a drainage system. Among those watersheds considered as potential reference watersheds for benthic impairments in the Middle River Watershed, forest cover in the first order stream corridors ranged from 38%-87% of the total area. Based on a statistical analysis of the amount of forest cover on first order streams in impaired and non-impaired streams, the criterion for the minimal forest cover needed to support a diverse benthic community was set at 33%. First order stream corridors in the Upper Middle River and Christians Creek drainage are 23% and 18% forested, respectively, and lack of litter input is probably a stressor to the aquatic community in the Upper Middle River and Christians Creek.

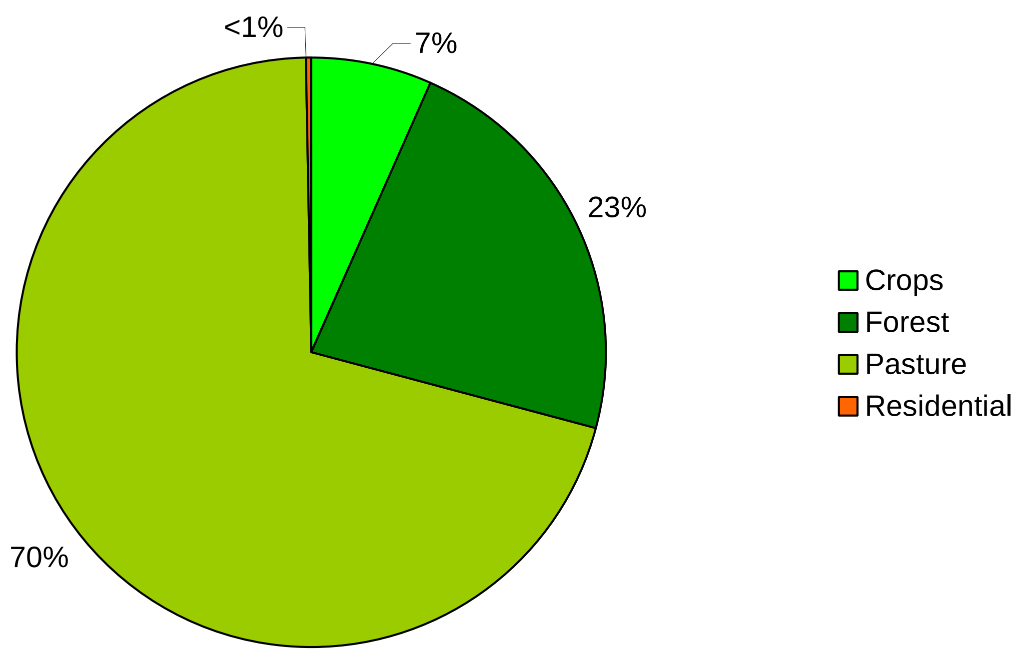

Figure 7.7 Landuse in the first order stream corridors of Upper Middle River.

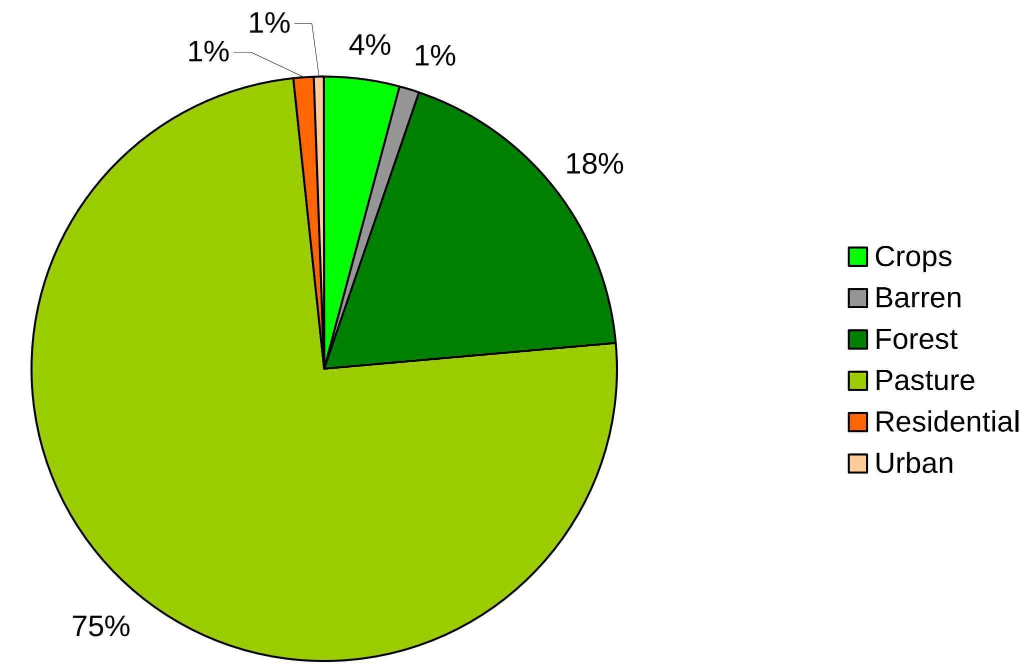

Figure 7.8 Landuse in the first order stream corridors of Christians Creek.

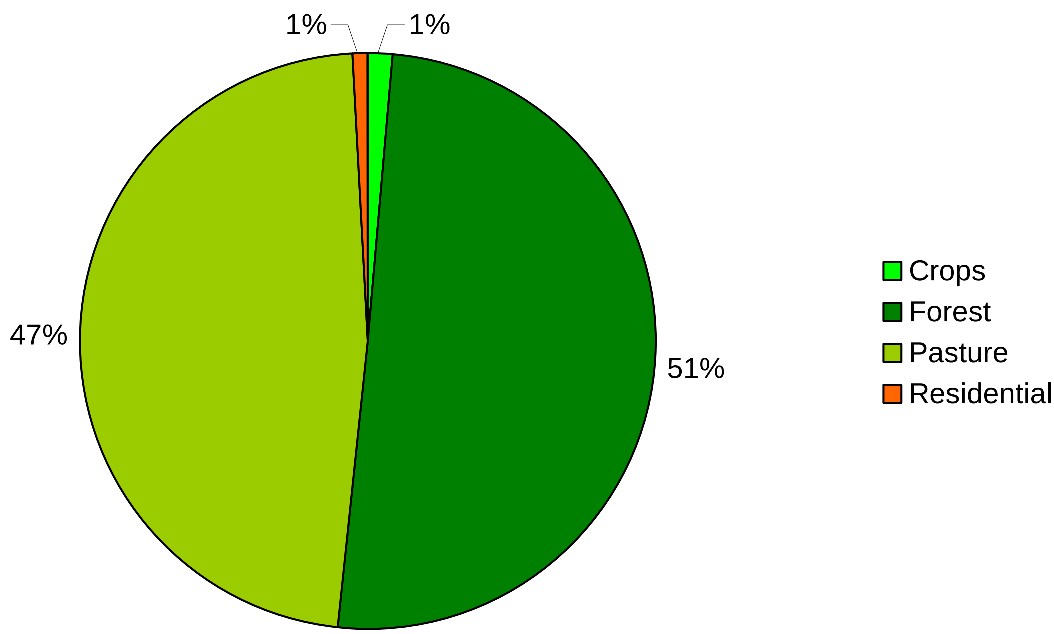

Figure 7.9 Landuse in the first order stream corridors of Moffett Creek.

7.1.5 Stressor Identification Summary

7.1.5.1 Upper Middle River

Three stressors on the aquatic life in the upper Middle River have been identified, two probable and one potential.

Probable stressors:

1) Excessive siltation leading to sedimentation, embeddedness, and loss of habitat.
2) Lack of litterfall to the first order streams in the upper Middle River watershed that results from a lack of forest cover in the riparian corridors.

Potential stressor:

3) Elevated nutrient levels.

The two probable stressors are interrelated and impacted by landuse in and around the riparian corridor of the Upper Middle River. The third stressor, thought to be less important, is nutrient inputs. The diurnal swings do not drive DO below the standard, but the swing is pronounced, and both total phosphorus and nitrate concentrations are found at elevated levels. It is anticipated that the TMDL for sediment will have beneficial impacts on the nutrient loads to the stream as well.

Sediment loads were considered the primary stressor for the Upper Middle River TMDL development. Sediment loads were modeled and an instream endpoint was established based on a reference watershed approach. In addition, implementation efforts should target first order stream corridors for riparian vegetation.

7.1.5.2 Christians Creek

The probable stressors on the aquatic life in Christians Creek have been identified as:

1) lack of litter fall to the first order streams in Christians Creek watershed that results from a lack of forest cover in the riparian corridors, and

2) sedimentation from riparian corridor and bank erosion (minor stressor).

The primary stressor on the aquatic life of Christians Creek was identified as lack of litter fall to the first order streams in the Christians Creek watershed from a lack of forest cover in the riparian corridors. A second minor stressor on the aquatic life in Christians Creek was identified as sedimentation from stream bank erosion. These two stressors are inexorably linked. A lack of riparian tree cover means that banks are likely unstable and susceptible to erosion because tree roots are not holding and maintaining bank soils. Based on input from VADEQ and EPA, a TMDL for sediment inputs from the riparian corridor of first order streams was developed to address these stressors. Sediment loads delivered from areas in the first-order stream corridor, including the stream channel, were modeled and an instream input was established on a reference watershed approach. Implementing best management practices that establish riparian tree cover will increase leaf fall and decrease bank erosion and sedimentation.

One matter of concern in Christians Creek is the presence of toxic organics (chlordane and PCBs) that have been found in sediments from the stream. However, there is insufficient data to confirm that these pollutants are currently impacting the aquatic community.

7.1.5.3 Moffett Creek

The stressor on the aquatic life in Moffett Creek has been identified as

1) Excessive siltation leading to sedimentation, embeddedness, and loss of habitat.

Sediment loads were considered the primary stressor for the Moffett Creek TMDL development. Sediment loads were modeled and an instream endpoint was established based on a reference watershed approach.

7.2 Reference Watershed Selection

A reference watershed approach was used to estimate the necessary load reductions that are needed to restore a healthy aquatic community and allow the streams in the Middle River watershed to achieve their designated uses. The reference watershed approach is based on selecting a non-impaired watershed in the same eco-region as the impaired watershed that has similar landuse, soils, and stream characteristics. The modeling process uses load rates in the non-impaired watershed as a target for load reductions in the impaired watershed. The impaired watershed is modeled to determine the current load rates and determine what reductions are necessary to meet the load rates of the non-impaired watershed.

Fourteen potential reference watersheds were initially selected based on non-impairment status, stream order, and eco-region (Figure 7.10). From the fourteen selected watersheds, individual reference watersheds were selected for Upper Middle River, Christians Creek, and Moffett Creek watersheds based on comparative watershed size, landuse, and slope. The General Standard TMDL for Lewis Creek will be addressed in a separate report in order to consider the Superfund site within the Lewis Creek watershed.

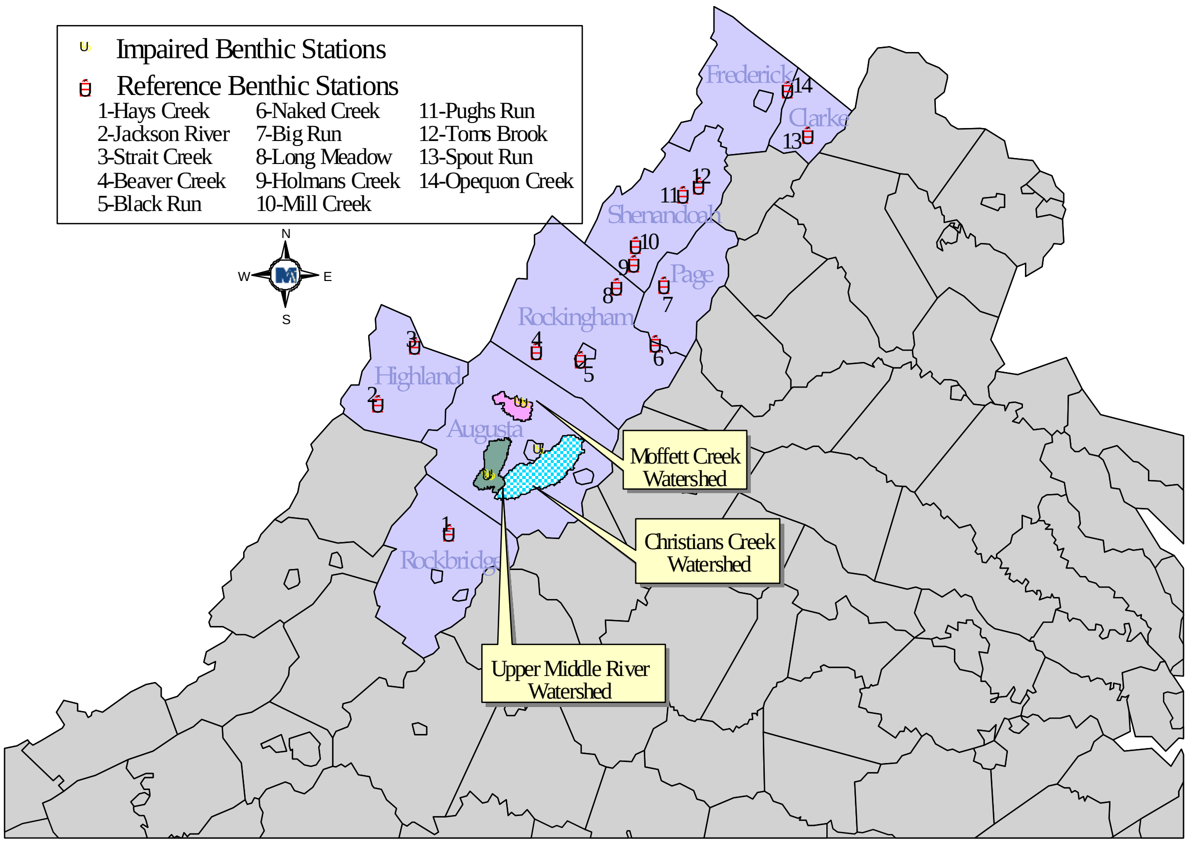

Figure 7.10 Potential reference watersheds.

7.2.1 Upper Middle River

Hays Creek watershed in Rockbridge County was selected as the reference watershed for Upper Middle River. Table 7.11 and Figure 7.11 show the comparison of the landuse in the impaired watershed and the reference watershed. Figure 7.12 shows the location of the impaired watershed and the reference watershed within the Central Appalachian Ridges and Valleys eco-region. Figure 7.13 shows the comparison of the slopes in the impaired watershed and the reference watershed.

Table 7.11 Upper Middle River and Hays Creek watershed landuse comparison.

Landuse	Upper Middle River	Hays Creek
Barren	<1%	<1%
Forest	36%	52%
Crops	6%	2%
Pasture	56%	46%
Residential/Urban	<1%	<1%
Total Acreage	30,423	50,933

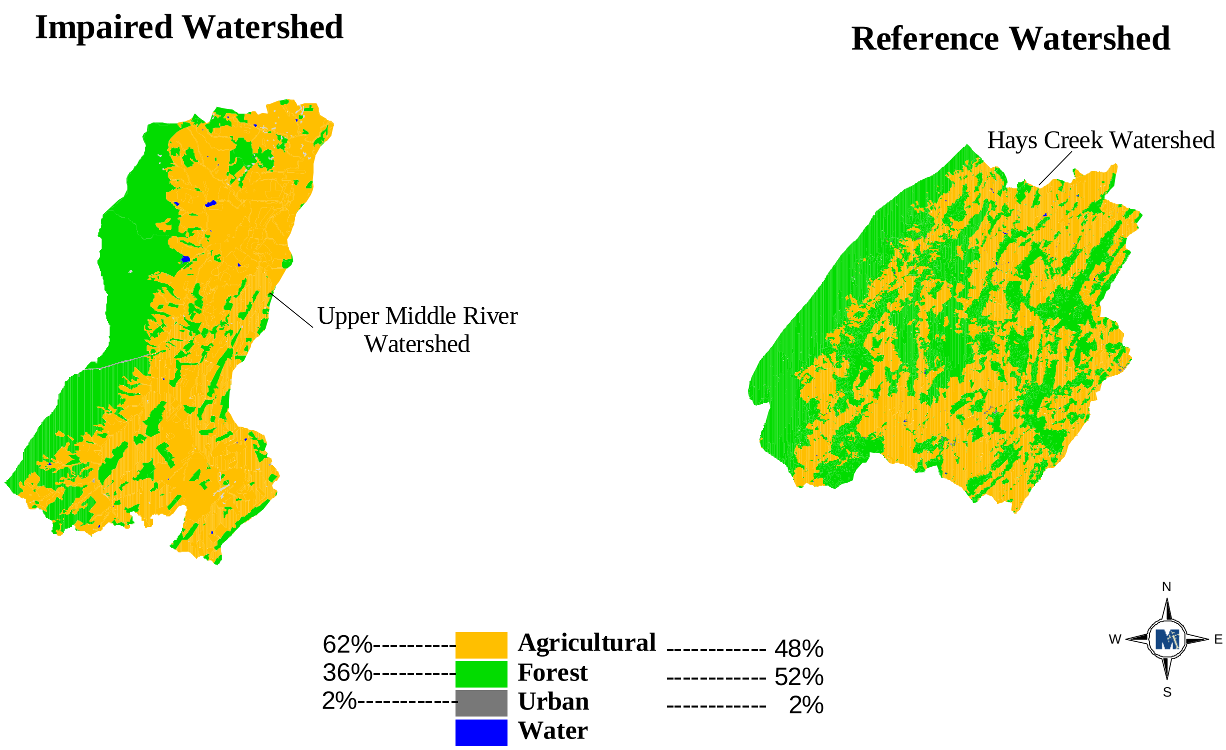

Figure 7.11 Upper Middle River and Hays Creek watershed landuse comparison.

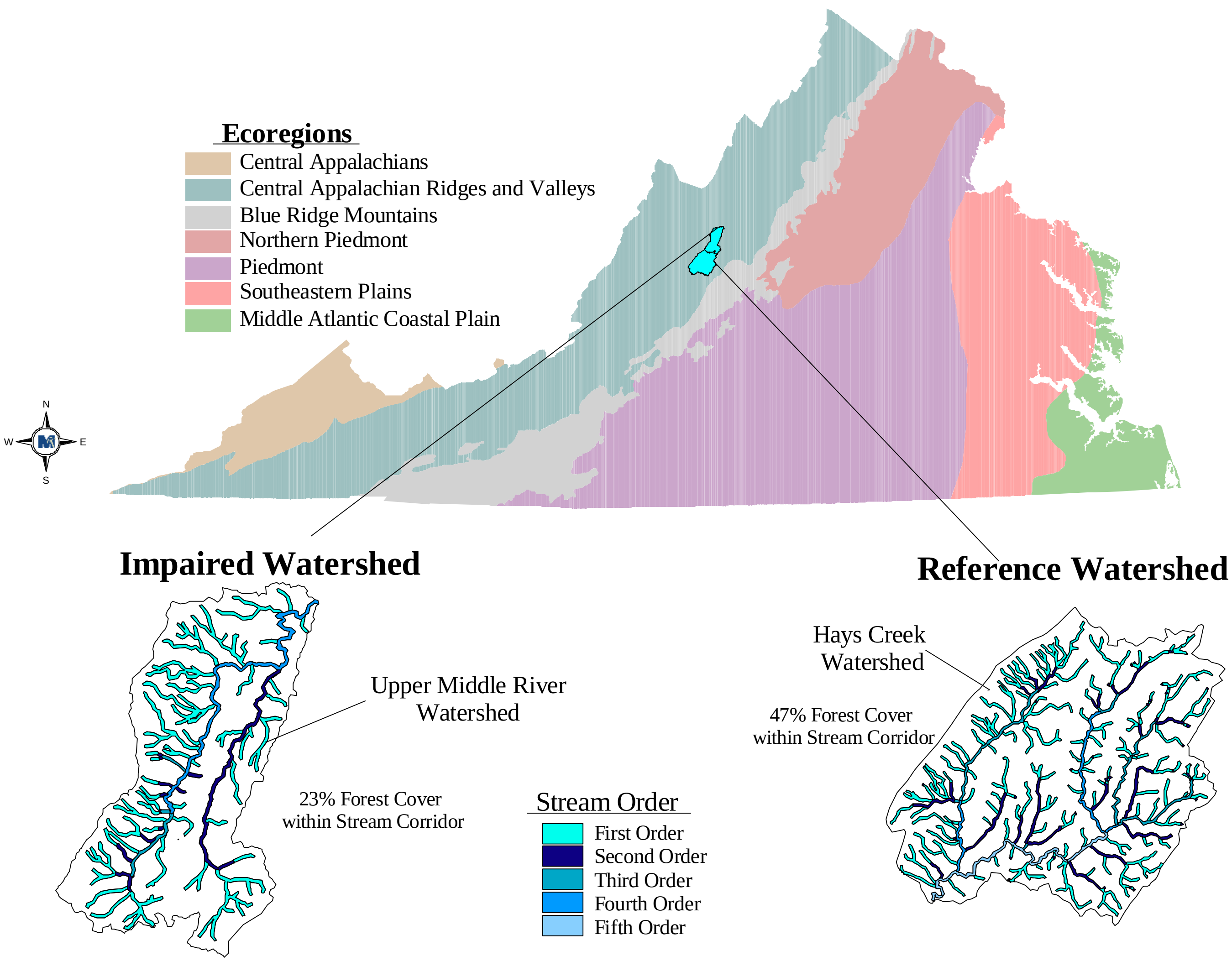

Figure 7.12 Location of Upper Middle River and Hays Creek watersheds.

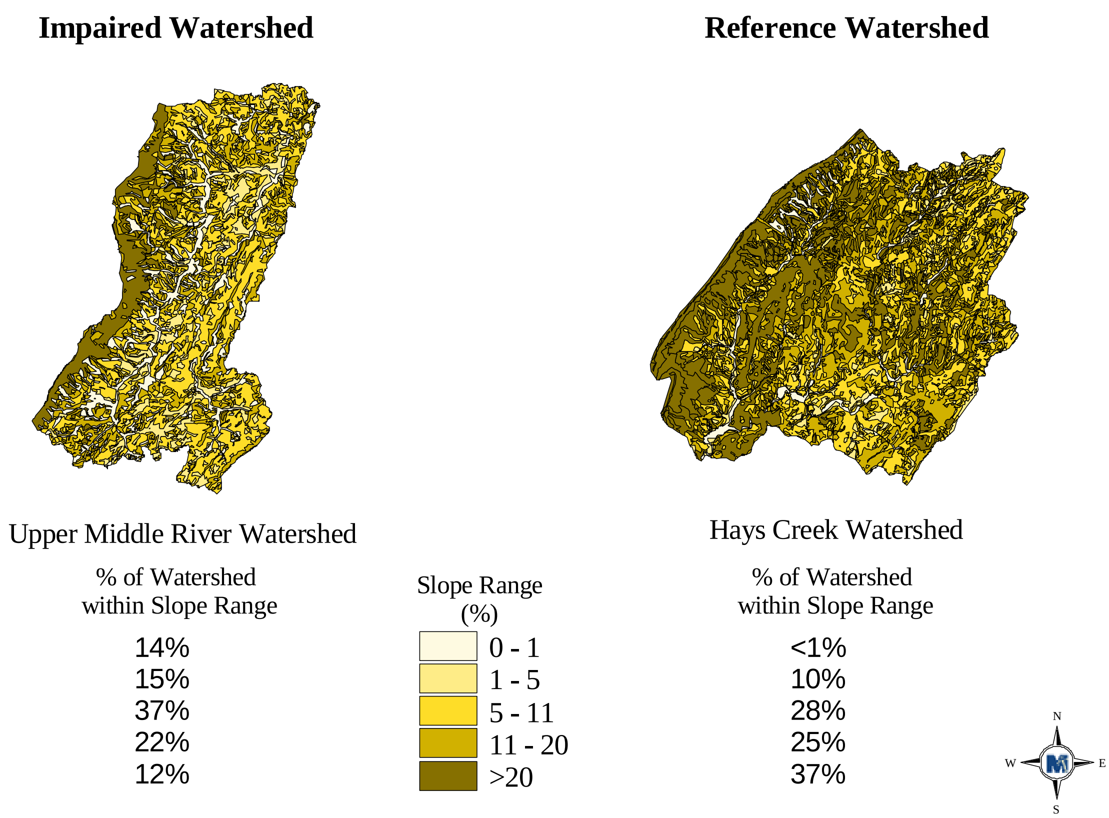

Figure 7.13 Upper Middle River and Hays Creek watershed slope comparison.

7.2.2 Christians Creek

The upper Opequon Creek watershed in Frederick County was selected as the reference watershed for Christians Creek. Table 7.12 and Figure 7.14 show the comparison of the landuse in the impaired watershed and the reference watershed. Figure 7.15 shows the location of the impaired watershed and the reference watershed within the Central Appalachian Ridges and Valleys eco-region. Figure 7.16 shows the comparison of the slopes in the impaired watershed and the reference watershed.

Table 7.12 Christians Creek and Opequon Creek watershed landuse comparison.

Landuse	Christians Creek	Opequon Creek
Barren	1%	1%
Forest	26%	33%
Crops	8%	5%
Pasture	56%	51%
Residential/Urban	9%	10%
Total Acreage	68,844	62,192

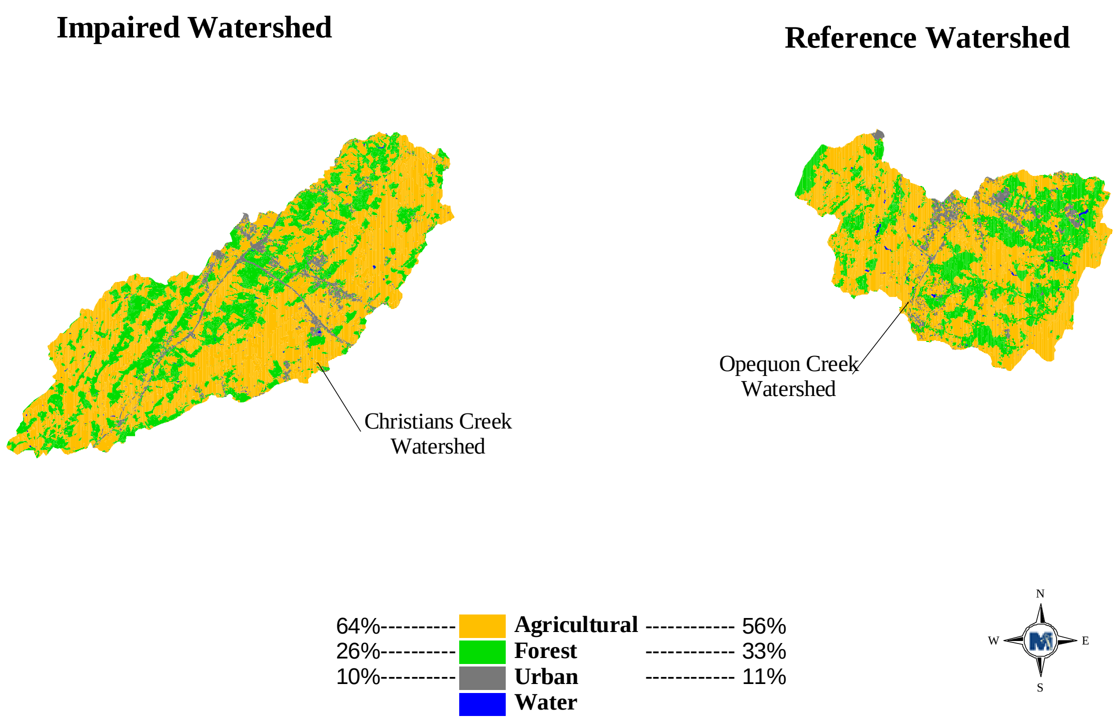

Figure 7.14 Christians Creek and Opequon Creek watershed landuse comparison.

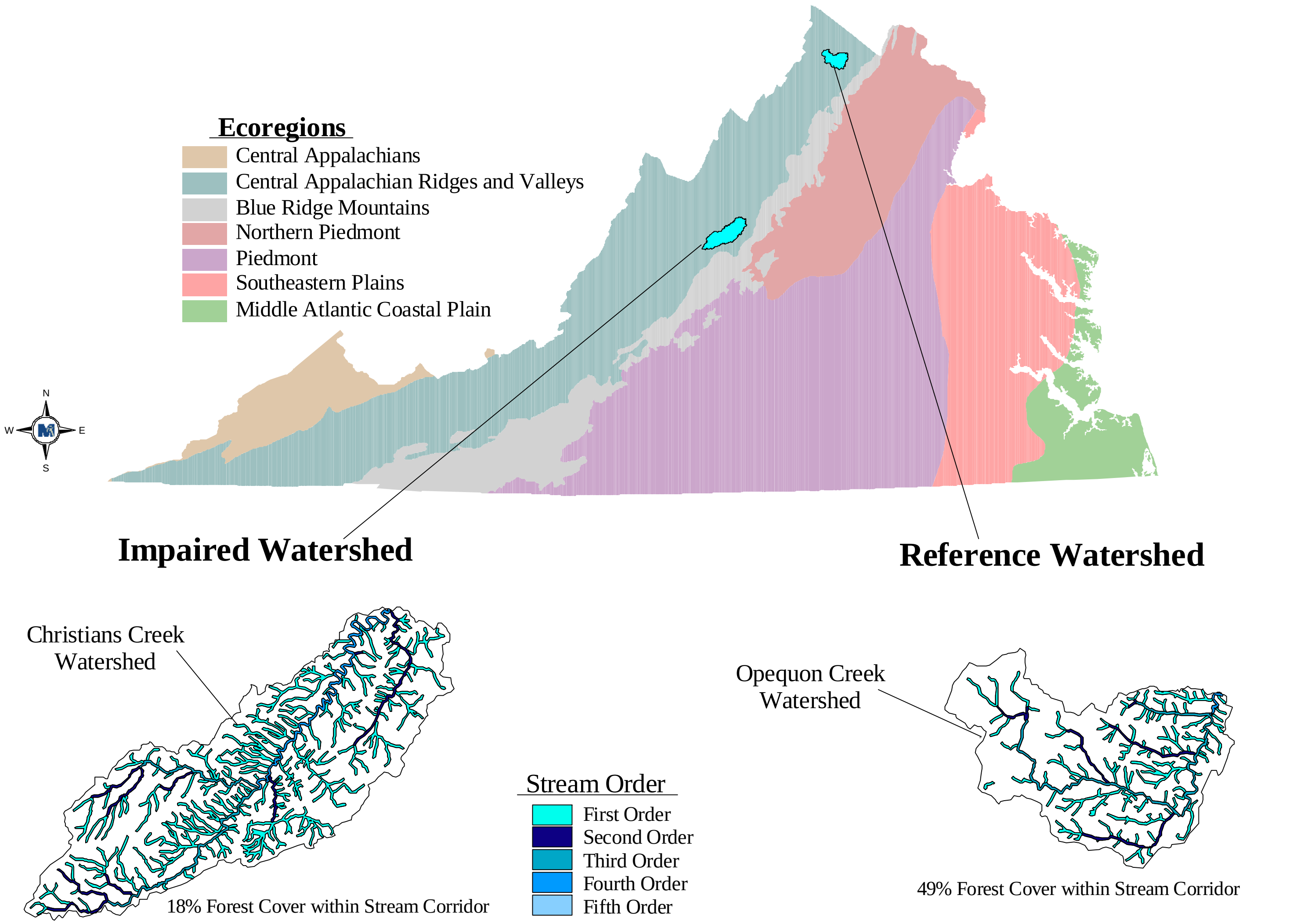

Figure 7.15 Location of Christians Creek and Opequon Creek watershed.

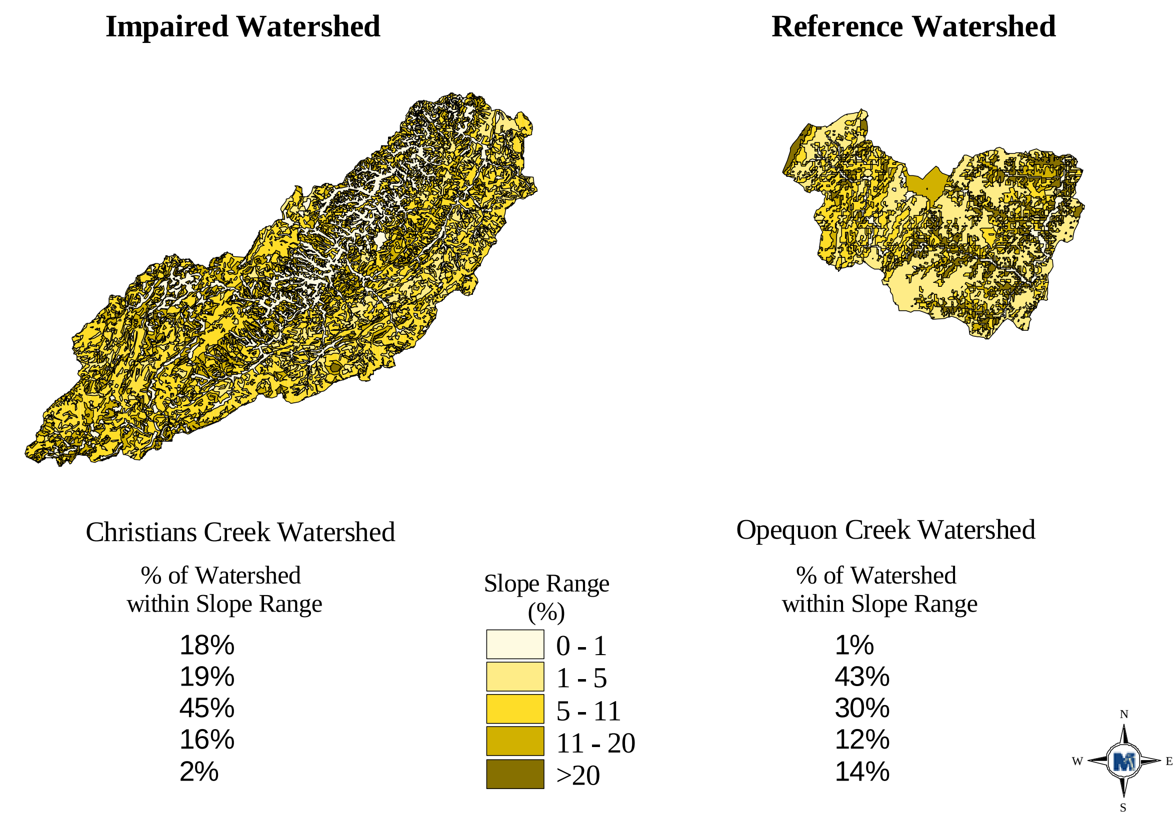

Figure 7.16 Christians Creek and Opequon Creek watershed slope comparison.

7.2.3 Moffett Creek

Mill Creek watershed in Shenandoah County was selected as the reference watershed for Moffett Creek. Table 7.13 and Figure 7.17 show the comparison of the landuse in the impaired watershed and the reference watershed. Figure 7.18 shows the location of the impaired watershed and the reference watershed within the Central Appalachian Ridges and Valleys eco-region. Figure 7.19 shows the comparison of the slopes in the impaired watershed and the reference watershed.

Table 7.13 Moffett Creek and Mill Creek watershed landuse comparison.

Landuse	Moffett Creek	Mill Creek
Barren	0%	0%
Forest	50%	59%
Crops	5%	2%
Pasture	44%	38%
Residential/Urban	1%	1%
Total Acreage	16,996	25,452

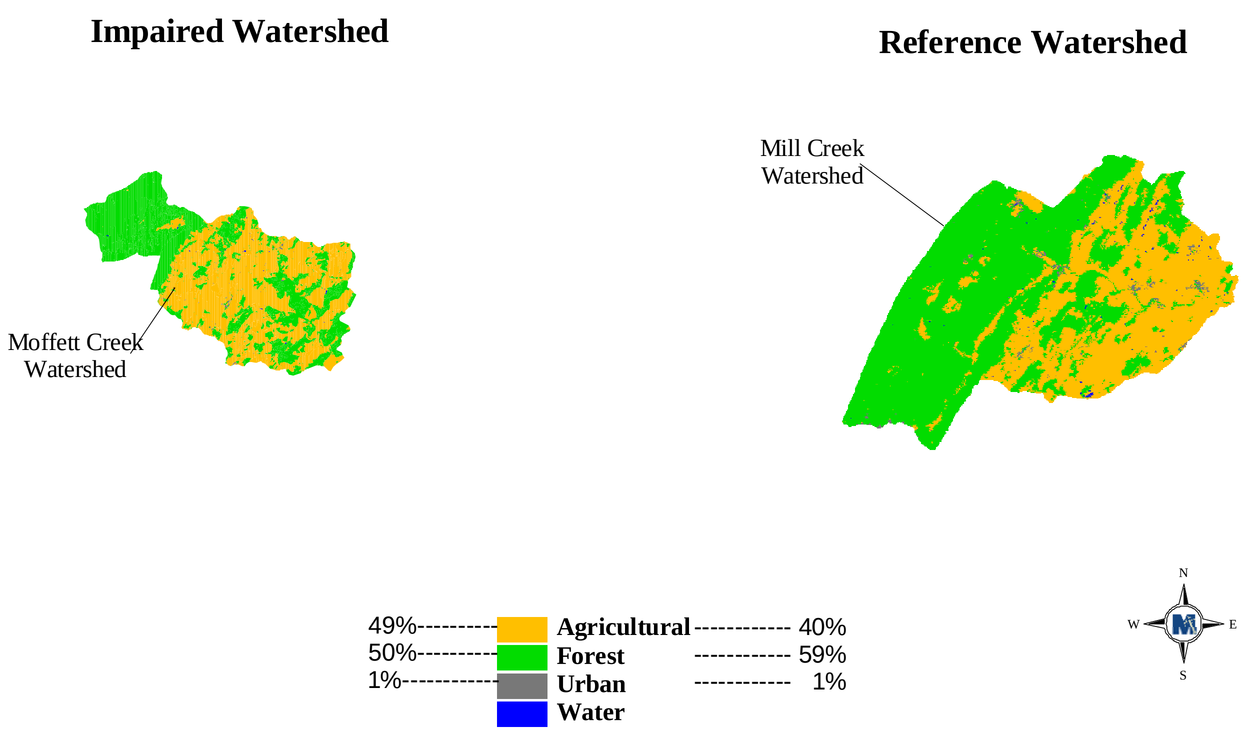

Figure 7.17 Moffett Creek and Mill Creek watershed landuse comparison.

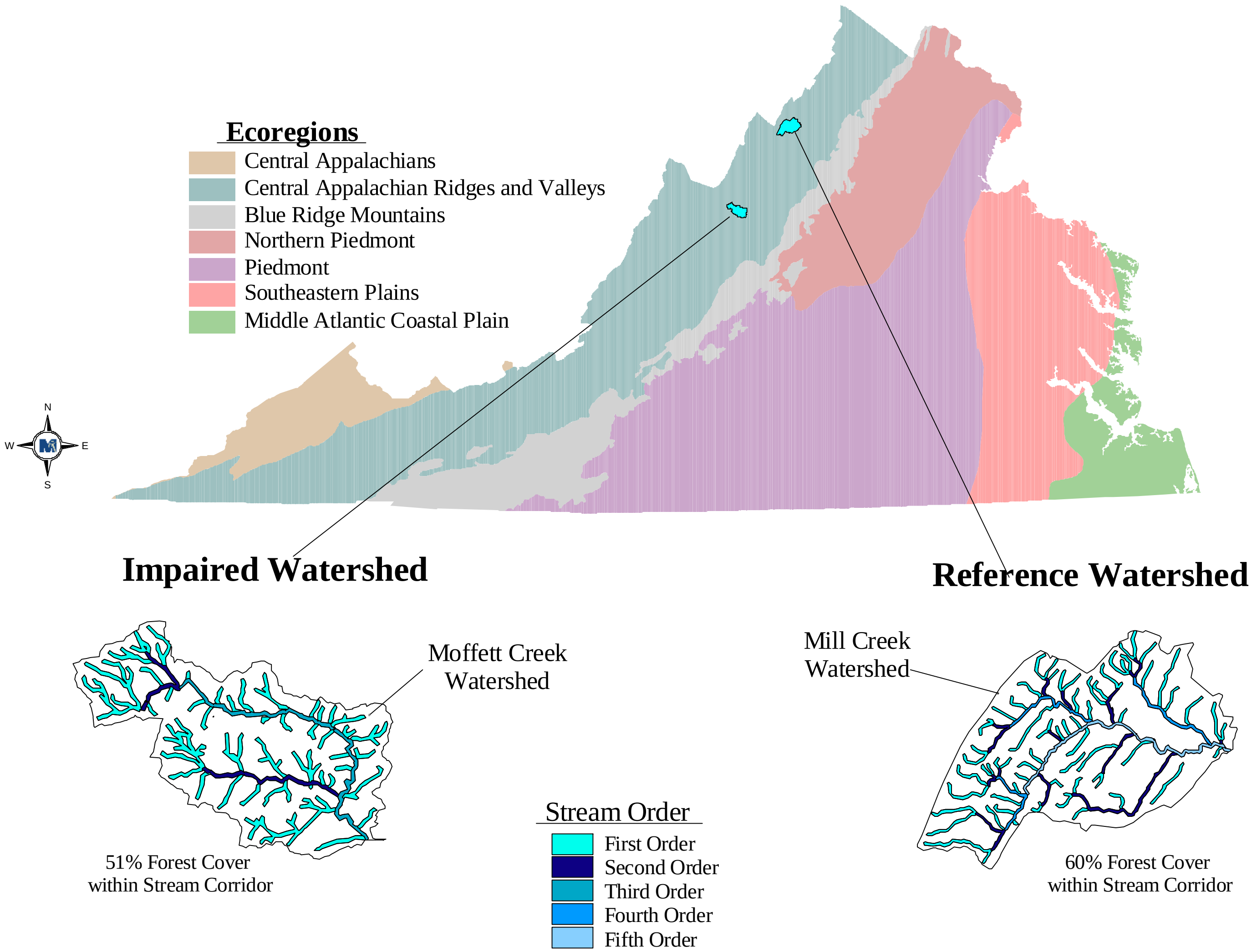

Figure 7.18 Location of Moffett Creek and Mill Creek watersheds.

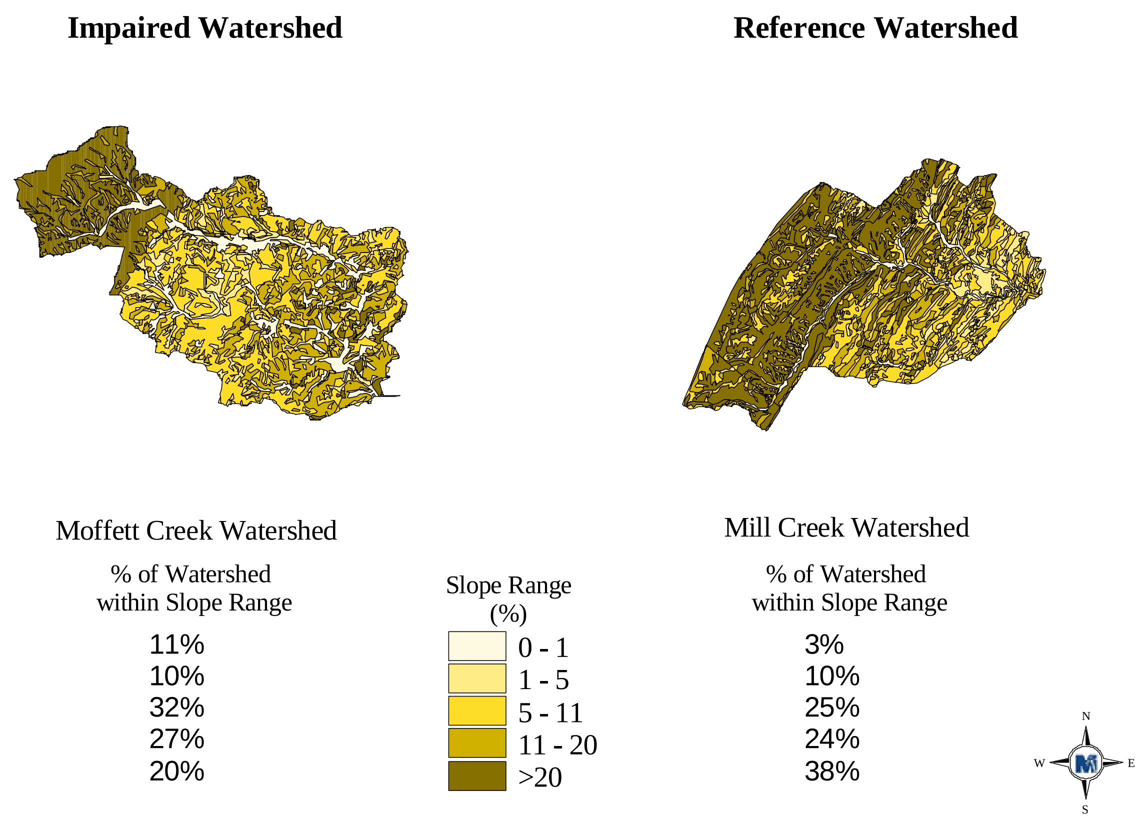

Figure 7.19 Moffett Creek and Mill Creek watershed slope comparison.

8. MODELING PROCEDURE

A reference watershed approach was used in this study to develop benthic TMDLs for sediment for Christians Creek, Moffett Creek and the Upper Middle River watersheds. As noted in Section 7.0, sediment was identified as the primary stressor for watersheds Moffett Creek and Upper Middle River watersheds. The analysis also strongly suggested that Christians Creek was not impaired and only limitedly impacted by sediment. A watershed model was used to simulate sediment loads from potential sources in both the impaired and reference watersheds. The model used in this study was the *Visual Basic*^{TM} version of the Generalized Watershed Loading Functions (GWLF) model with modifications for use with ArcView (Evans et al., 2001). The model also included modifications made by Yagow et al., 2002 and BSE, 2003. Numeric endpoints were based on unit-area loading rates calculated for respective reference watersheds. The TMDLs were then developed for the impaired watersheds based on these endpoints and the results from load allocation scenarios.

8.1 Model Framework Selection

The GWLF model was developed at Cornell University (Haith and Shoemaker, 1987; Haith, et al., 1992) for use in ungaged watersheds. It was chosen for this study as the model framework for simulating sediment. GWLF is a continuous simulation spatially lumped model. It operates on a daily time step for water balance calculations and monthly calculations for sediment and nutrients from a daily water balance. In addition to runoff and sediment, the model simulates dissolved and attached nitrogen and phosphorus loads delivered to streams from watersheds with both point and nonpoint sources of pollution. The model considers flow input from both surface and groundwater. Landuse classes are used as the basic unit for representing variable source areas. The calculation of nutrient loads from septic systems, stream-bank erosion from livestock access, and the inclusion of sediment and nutrient loads from point sources are also supported. Runoff is simulated based on the Soil Conservation Service's Curve Number method (SCS, 1986). Erosion is calculated from a modification of the Universal Soil Loss Equation (Schwab et al., 1983; Wischmeier and Smith, 1978). Sediment estimates use a delivery ratio based on a function of watershed area and erosion estimates from the modified USLE. The sediment transported depends on the transport capacity of runoff.

For execution, GWLF uses three input files for weather, transport, and nutrient loads. The weather file contains daily temperature and precipitation for the period of record. Data are based on a water year typically starting in April and ending in September. The transport file contains input data related to hydrology and sediment transport. The nutrient file contains primarily nutrient values for the various landuses, point sources, and septic system types, but does include urban sediment buildup rates.

8.2 Model Setup

Watershed data needed to run GWLF used in this study were generated using GIS spatial coverage, local weather data, streamflow data, literature values, and other data. Watershed boundaries for the three impaired stream segments and selected reference watersheds were delineated from USGS 7.5 minute digital topographic maps using GIS techniques. The impaired watersheds were delineated from the downstream extent of the respective segment impairments.

8.3 Source Assessment

Three source areas were identified as the primary contributors to sediment loading in the impaired watersheds that are the focus of this study – Surface runoff, Point sources, and Streambank erosion. The sediment process is a continual process but is often accelerated by human activity. An objective of the TMDL process is to minimize the acceleration of the sediment process. This section describes predominant sediment source areas, model parameters, and input data needed to simulate sediment loads.

8.3.1 Channel and Streambank Erosion

An increase in impervious land without appropriate stormwater control, increases runoff volume and peaks and leads to greater channel erosion potential. It has been well documented that livestock with access to streams can significantly alter the physical dimensions of streams through trampling and shearing (Armour, et al., 1991; Clary and Webster, 1990; Kaufman and Kruger, 1984). Increasing the bank full width decreases stream depth, increases sediment, and adversely affects aquatic habitat (USDI, 1998). All of the watersheds have significant livestock production.

8.3.2 Point Sources for TSS Loads

Fine sediments are included in total suspended solids (TSS) loads that are permitted for various facilities with industrial and construction VPDES permits. Sediment loads from industrial and construction permitted sites are included in the waste load allocation (WLA) component of the TMDL, in compliance with 40 CFRξ130.2(h).

8.4 Source Representation – Input Requirements

As described in Section 8.1, the GWLF model was developed to simulate runoff, sediment and nutrients in ungaged watersheds based on landscape conditions such as landuse/land cover, topography, and soils. In essence, the model uses a form of the hydrologic units (HU) concept (Li, 1972; England, 1970) to estimate runoff and sediment from different pervious areas (HUs) in the watershed. In the GWLF model, the nonpoint source load calculation for sediment is affected by landuse activity (*e.g.*, farming practices, topographic parameters, soil characteristics, soil cover conditions, stream channel conditions, livestock access, and weather). The model uses landuse categories as the mechanism for defining homogeneity of source areas. This is a variation of the HU concept, where homogeneity in hydrologic response or nonpoint source pollutant response would typically involve the identification of soil landuse topographic conditions that would be expected to give a homogeneous response to a given rainfall input. A number of parameters are included in the model to index the affect of varying soil-topographic conditions by landuse entities. A description of model parameters is given in Section 8.4.1 followed by a description of how parameters and other data were calculated and/or assembled.

8.4.1 Description of Model Input Parameters

The following description of GWLF model input parameters was taken from a TMDL Draft report prepared by BSE, 2003:

Hydrologic Parameters

Watershed Related Parameter Descriptions

- *<u>Unsaturated Soil Moisture Capacity (SMC):</u> The amount of moisture in the root zone, evaluated as a function of the area-weighted soil type attribute – available water capacity.*

- *<u>Recession Coefficient (/day):</u> The recession coefficient is a measure of the rate at which streamflow recedes following the cessation of a storm, and is approximated by averaging the ratios of streamflow on any given day to that on the following day during a wide range of weather conditions, all during the recession limb of each storm's hydrograph.*
- *<u>Seepage Coefficient (/day):</u> The seepage coefficient represents the amount of flow lost to deep seepage.*

Running the model for a 3-month period prior to the chosen period during which loads were calculated initialized the following parameters.

- *<u>Initial unsaturated storage (cm):</u> Initial depth of water stored in the unsaturated (surface) zone.*

- *<u>Initial saturated storage (cm):</u> Initial depth of water stored in the saturated zone.*

- *<u>Initial snow (cm):</u> Initial amount of snow on the ground at the beginning of the simulation.*

- *<u>Antecedent Rainfall for each of 5 previous days (cm):</u> The amount of rainfall on each of the five days preceding the first day in weather files.*

Month Related Parameter Descriptions

- *<u>Month</u>: Months were ordered, starting with April and ending with March – in keeping with the design of the GWLF model and its assumption that stored sediment is flushed from the system at the end of each Apr-Mar cycle. Model output was modified in order to summarize loads on a calendar year basis.*

- *<u>ET CV:</u> Composite evap-transpiration cover coefficient, calculated as an area-weighted average from landuses within each watershed.*

- *<u>Hours per Day:</u> mean number of daylight hours.*

- *<u>Erosion Coefficient:</u> This a regional coefficient used in Richard's equation for calculating daily erosivity. Each region is assigned separate coefficients for the months October-March, and for April-September.*

Sediment Parameters

Watershed-Related Parameter Descriptions

- *<u>Sediment Delivery ratio:</u> The fraction of erosion – detached sediment – that is transported or delivered to the edge of the stream, calculated as the inverse function of watershed size (Evans et al., 2001).*

Landuse-Related Parameter Descriptions

- *<u>USLE K-factor:</u> The soil erodibility factor was calculated as an area weighted average of all component soil types.*

- *<u>USLE LS-factor:</u> This factor is calculated from slope and slope length.*

- *<u>USLE C-factor:</u> The vegetative cover factor for each landuse was evaluated following GWLF manual guidance and Wischmeier and Smith (1978).*

- *<u>Daily sediment build-up rate on impervious surfaces</u>: The daily amount of dry deposition deposited from the air on impervious surfaces on days without rainfall, assigned using GWLF manual guidance.*

Streambank Erosion Parameter Descriptions (Evans, 2002)

- *<u>% Developed Land:</u> Percentage of the watershed with urban-related landuses- defined as all land in MDR, HDR, and COM land-uses, as well as the impervious portions of LDR.*

- *<u>Animal density:</u> Calculated as the number of beef and dairy 1000-lb equivalent animal units (AU) divided by watershed area in acres.*

- *<u>Stream length:</u> Calculated as the total stream length of natural stream channel, in meters. Excludes the non-erosive hardened and piped sections of the stream.*

- *<u>Stream length with livestock access:</u> calculated as the total stream length in the watershed where livestock have unrestricted access to streams, resulting in streambank trampling in meters.*

8.4.2 Streamflow and Weather data

Daily streamflow data obtained from USGS gauging stations were used to calibrate hydrologic parameters in the GWLF model are given in Table 8.1. Precipitation and temperature data were obtained from a web site created by BSE, 2002 to facilitate the use of the GWLF model (Table 8.2). Rainfall from a group of nearby stations was Theissen weighted to provide a single record. Access to the database is through the Virginia Hydrologic Units code.

Table 8.1 USGS gaging stations used in GWLF models.

Watersheds	USGS station site number	USGS gage location	Data Period
Christians Creek	01624800	Christians Creek near Fishersville, VA	4/1/1992–9/30/1997
Mills Creek	01632900	Smith Creek near New Market, VA	4/1/1992–9/30/1997
Hays Creek	02022500	Kerrs Creek near Lexington, VA	4/1/1992–9/30/1997
Opequon Creek	01615000	Opequon Creek near Berryville, VA	4/1/1992–9/30/1997

Table 8.2 Weather station used in GWLF models.

Watersheds	Weather Stations (station_id, location, Thiessen weights)	Data Type	Data Period
Opequon Creek	**Station id**: 449186 **Location**: Winchester 7 SE **Thiessen weight:** 0.3322; **Station id:** 449181 **Location**: Winchester Winc **Thiessen weight**: 0.6604; **Station id:** 440670 **Location**: Berryville **Thiessen weights**: 0.0074	**Daily Precipitation & Temperature**	4/1/1992–9/30/1997
Hays Creek	**Station id**: 445685, **Location**: Montebello,1 SE **Thiessen weight**: 0.0327**;** **Station id:** 444876, **Location:** Lexington **Thiessen weight:** 0.3515; **Station id:** 443470: **Location:** Goshen **Thiessen weight:** 0.1811; **Station id:** 442064: **Location:** Craigsville 2 S; **Thiessen weight:** 0.0108 **Station id:** 443470 **Location:** Kerrs Creek 6 WNW **Thiessen weight:** 0.424	**Daily Precipitation & Temperature**	4/1/1992–9/30/1997
Mill Creek	**Station id:** 449263 **Location:** Woodstock 2, NE; **Thiessen weight:** 0.1763 **Station id:** 448448: **Location:** Timberville 3 E. **Thiessen weight:** 0.8209	**Daily Precipitation & Temperature**	4/1/1992–9/30/1997
Moffett Creek	**Station id:** 448975 **Location:** West Augusta **Thiessen weight:** 0.4019 **Station id:** 448062 **Location:** Staunton sewage plant **Thiessen weight:** 0.5981	**Daily Precipitation & Temperature**	4/1/1992–9/30/1997

8.4.3 Landuse/landcover classes

Landuse classes were used as the basic response unit for performing runoff and erosion calculations and summarizing sediment transport. Landuse coverage was obtained from VADCR and Multi-Resolution Land Characteristics (MRLC) data (EPA, 1992).

Although both VADCR and MRLC landuse coverage were available for the impaired watersheds only MRLC data was available for the reference watersheds. To be consistent, MRLC data was used for both the impaired and reference watersheds. The landuse categories were consolidated from VADCR and/or MRLC classifications as given in Table 8.3. Urban landuse categories (*i.e.*, low density residential, middle density residential, high density residential, and commercial/industrial/transportation) were further subdivided into a pervious and an impervious component. The percentage of impervious and pervious area for urban categories was assigned from data provided in VADCR's online 2002 NPS Assessment Database (VADCR, 2002).

Table 8.3 Landuse-Categories for TMDL Analysis.

TMDL Landuse Categories	MRLC Landuse Categories	VADCR Landuse Categories
Low Density Residential	Low Density Residential (21)	Low Density Residential (111) Wooded Residential (118)
Medium Density Residential		Medium Density Residential (112) Mobile Home Park (115) Farmstead (241) Waste Storage Pit (242)
High Density Residential	High Density Residential (22)	High Density Residential (113)
Commercial	Commercial (23) Industrial (23) Transportation (23)	Commercial & Services (12) Industrial (13) Transportation (14)
Transitional	Barren - transitional (33) Barren/Bare Rock (31) Barren Gravel Pits (32)	Barren (7) Harvested Forest (44) Confined feeding Op. (231) Mixed Urban/Transitional (16)
Forest	Deciduous Forest (41) Evergreen Forest (42) Upland - Mixed Forest (43) Woody Wetlands (91) Shrubland (51)	Forest (4)
Urban Grass	Urban Grass (85)	Open Urban (18)
Pasture - Overgrazed	Pasture/Hay (81)	Overgrazed Pasture (2,123)
Pasture - Unimproved	Pasture/Hay (81)	Unimproved Pasture (2122)
Pasture - Improved	Grasslands (71) Pasture/Hay (81) Herbaceous Wetlands(92) Orchards/vineyards (61)	Improved Pasture (2121) Ornamentals/orchards/nurseries (22)
Cropland	Row Crops (82) Small grain (83) Cultivated Fallow (84)	Cropland (211)
Water	Water (5)	Water (11)

The pasture/hay category was subdivided into three sub-categories (*i.e.,* overgrazed pasture, unimproved pasture, and improved pasture). The percentage of the pasture/hay acreage that was assigned to each category was obtained from local sources. Cropland was also sub-divided into two sub-categories (*i.e.*, low tillage and high tillage). The percentage assigned to each cropland sub-category was obtained from VADCR's online database (VADCR, 2002) and local information. Landuse distributions for impaired and reference watersheds are given in Table 8.4. Landuse acreage for reference watersheds are adjusted up or down by the ratio of impaired watershed to reference watershed maintaining the original landuse distribution.

The weighted C-factor for each landuse category was estimated following guidelines given in Wischmeier and Smith, 1978, GWLF User's Manual (Haith et al., 1992), and Kleene, 1995. Where multiple landuse classifications were included in the final TMDL classification (*e.g.*, pasture/hay), each classification was assigned a C-factor and an area weighted C-factor calculated.

Table 8.4 Landuse distributions for impaired and reference watersheds.

Landuse Category	Christians Creek (ha)	Opequon Creek (Adjusted) (ha)	Moffett Creek (ha)	Mills Creek (Adjusted) (ha)	Upper Middle River (ha)	Hays Creek (Adjusted) (ha)
Low Density Residential (pervious)	304.32	291.60	10.36	23.73	20.55	10.91
Medium Density Residential (pervious)	0.00	0.00	0.00	0.00	0.00	0.00
High density Residential (pervious)	1.98	25.10	0.00	0.00	0.00	0.77
Commercial (pervious)	271.31	82.47	0.35	0.40	0.00	0.00
Transitional	113.71	198.93	0.44	12.86	28.46	8.00
Forest	8,294.38	4,599.58	3,253.09	4,090.65	4,592.51	6,368.16
Urban Grass	0.00	35.31	0.00	0.00	0.00	0.00
Overgrazed Pasture	80.84	36.86	502.71	520.07	1,065.74	0.00
Unimproved Pasture	1,889.02	861.18	1,173.00	780.11	2,486.73	1,427.29
Improved Pasture	14,736.79	6,718.32	1,675.72	1300.18	3,552.48	4,281.88
High Tillage	294.04	345.37	50.83	75.12	111.04	36.80
Low Tillage	1,147.33	264.83	202.06	44.88	433.29	157.90
Low Density Residential (impervious)	343.17	171.26	2.75	22.80	5.46	4.24
Medium Density Residential (impervious)	0.00	0.00	0.00	0.00	0.00	0.00
High density Residential (impervious)	2.23	14.74	0.00	0.00	0.00	0.30
Commercial (impervious)	305.95	48.43	0.09	.38	0.00	0.00
Water	50.89	40.78	6.78	12.14	20.78	8.09

8.4.4 Sediment Parameters

Sediment parameters include USLE parameters K, LS, C, and P, sediment delivery ratio, and buildup and loss functions for impervious surfaces. The product of USLE parameters, KLSCP, is entered as input to GWLF. The K factor relates to a soil's inherent erodibility and affects the amount of soil erosion from a given field. Soils data for Christians Creek, Moffett Creek, and the Upper Middle River was obtained from the Soil Survey Geographic (SSURGO) database for Virginia, the Augusta County soil survey (SCS, 1977), and Shanholtz et. al., 1988. The area-weighted average K-factor by landuse category was calculated using GIS procedures. Land slope was obtained from soil data as the average of the slope range given for each soil-mapping unit. For example a range of 2-7 percent would be 4.5. Earlier studies in the VirGIS program suggest that the slope ranges in soil surveys in general provided a better approximation than slopes calculated from Digital Elevation Models (DEMs). The length of slope was obtained from VirGIS Interim Reports (Shanholtz et al., 1988). Lengths of slope values for much of Virginia were developed during the VirGIS program in cooperation with local SCS Office personnel. The area-weighted average slope and length slope by landuse category were calculated from area-weighted slope and length slope with GIS procedures. The area- weighted LS factor was calculated for each landuse category using procedures recommended by Wischmeier and Smith (1978).

Soils data for the Hays Creek reference watershed was obtained from the Soil Survey Geographic (SSURGO) database for Augusta County (SCS, 2004), the Augusta County soil survey (SCS, 1977), VirGIS database (VADCR, 1992) for Rockbridge County, and VirGIS Interim Reports (Shanholtz et al., 1988; Shanholtz et al., 1993). Soils data for the Mill Creek reference watershed were obtained from the State Soil Geographic (STATSGO) database for Shenandoah County, the SSURGO database for Rockingham County. Soils data for Opequon Creek reference watershed were obtained from the VirGIS database (VADCR, 1992) and County Soil Surveys for Frederick (SCS, 1987) and Clarke (SCS, 1982) Counties. The area-weighted parameters, K and LS, for the reference watersheds were calculated following the procedures outlined for the impaired watersheds.

8.4.5 Pervious and Impervious Surfaces

Four TMDL categories define urban landuse/land cover (Table 8.3). Each urban area was sub-dived into pervious areas (USLE sediment algorithm applies) and impervious areas where an exponential buildup-washoff algorithm applies based on percentage pervious and impervious calculated from data obtained from VADCR's 2002 NPS Assessment Landuse/Land cover Database (VADCR, 2002).

Daily sediment build-up rate on impervious surfaces, which represents the daily amount of dry deposition from the air on days without rainfall, was assigned using GWLF manual (Haith, et al. 1992) guidance. For this study, the values used by BSE, 2003 were assigned as the daily build up rate.

8.4.6 Sediment Delivery Ratio

The sediment delivery ratio specifies the percentage of eroded sediment delivered to surface water and is empirically based on watershed size. The sediment delivery ratios for impaired and reference watersheds were calculated as an inverse function of watershed size (Evans et al., 2001).

8.4.7 SCS Runoff Curve

The runoff curve number is a function of soil type, antecedent moisture conditions, and cover and management practices. The runoff potential of a specific soil type is indexed by the Soil Hydrologic Group (HG) code. Each soil-mapping unit is assigned HG codes that range in increasing runoff potential from A to D. The soil HG code was given a numerical value of 1 to 4 to index HG codes A to D, respectively. An area-weighted average HG code was calculated for each landuse/land cover from soil survey data using GIS techniques. Runoff curve numbers (CN) for soil HG codes A to D were assigned to each landuse/land cover condition for antecedent moisture condition II following GWLF guidance documents and SCS, 1986 recommended procedures. The runoff CN for each landuse/land cover condition then were adjusted based on the numerical area-weighted soil HG codes.

8.4.8 Parameters for Channel and Streambank Erosion

Parameters for streambank erosion include animal density, total length of streams with livestock access, total length of natural stream channel, percent of developed land, mean stream depth, and watershed area. The animal density was calculated by dividing the number of livestock (beef and dairy) by watershed area in acres. The number of animal units (1000 pound per animal) was obtained from Virginia Agricultural Statistics. The number of dairy and beef animals for the County in which the impairment or reference watershed was located was distributed to the watershed by the ratio of watershed area to county area. Potential livestock access was estimated with GIS techniques. An estimate of the actual length of access area impacted by livestock was estimated at 2% of the potential length. The total length of the natural stream channel was estimated with GIS techniques from USGS NHD hydrography coverage as the distance of continuous streams. The length of hardened channel was estimated as 20% of the total stream length. The mean stream depth was estimated as a function of watershed area.

8.5 Point Source TSS Loads

Permitted loads were calculated as the maximum annual modeled runoff times the area governed by the permit times a maximum TSS concentration of 100 mg/l (Table 8.5). The modeled runoff for industrial stormwater dischargers was calculated for both pervious and impervious commercial sediment source areas. The calculations involved calculating a weighted maximum runoff value for commercial areas by multiplying the maximum annual modeled runoff depth from pervious commercial times the percentage of commercial area that is pervious and adding to the maximum annual modeled runoff depth from commercial impervious areas multiplied by the percentage of impervious commercial areas. The weighted maximum runoff (cm) from commercial areas is multiplied times the permit area (ha) times permitted concentration (TSS/mg/L) times 0.00010001 to get permit load in T/yr. For construction permit dischargers, the modeled runoff was taken as the maximum annual runoff depth (cm) for transitional landuses.

Table 8.5 VPDES point source facilities and permitted TSS load.

Permit ID	Name	Max. Design Discharge (MGD)	Modeled Runoff (cm)	Disturb Area (ha)	TSS (mg/L)	TSS (T/yr)
Christians Creek Impairment						
VA0020427	Riverheads High School STP	0.016	-			Inactive
VA0022292	Brookwood STP	0.039	-			Inactive
VA0022306	ACSA-Staunton Plaza, STP	0.200	-			Inactive
VA0025291	Fishersville STP	2.000	-	-	36	99.483
VA0086738	Petroleum Coop-Aug. Co.	0.0288	Not Permitted for TSS			
VA0089061	Woodlawn Village Mobile Home Park	0.015	-	-	117	2.425
VA0089362	Greenville STP VA0089362/VA0090417	0.039	Inactive			
VA0090417	Greenville WWTP	0.250	-	-	45	15.545
VAG401896	Victory Worship Center	0.001	-	-	30	0.041
VAG401967	Amoco/Deno's Food Mart	0.001	-	-	30	0.041
VAG401969	Private Residence	0.001	-	-	30	0.041
VAG401960	Private Residence	0.001	-	-	30	0.041
VAG401959	Private Residence	0.001	-	-	30	0.041
VAG401449	Private Residence	0.001	-	-	30	0.041
VAG401443	Private Residence	0.001	-	-	30	0.041
VAG401195	Private Residence	0.001	-	-	30	0.041
VAG401082	Private Residence	0.001	-	-	30	0.041
VAG401979	Private Residence	0.001	-	-	30	0.041
VAG408038	Private Residence	0.001	-	-	30	0.041
VAR100595	Pilot Travel Center 96	-	19.4	4.047	100	0.785
VAR100580	Project #U000-132-105, C501, B602	-	19.4	4.856	Inactive	
VAR100583	Project #0871-007-317, M502, D686, B697	-	19.4	2.104	Inactive	
VAR100635	Project #0642-007-293, M502 et al	-	19.4	2.428	Inactive	
VAR102392	Countryside Development Co LC – Windward Point	-	19.4	31.364	100	6.085
VAR101656	Shields Construction Company	-	19.4	37.232	100	7.224
VAR101657	Teaberry Green	-	19.4	4.330	100	0.840
VAR101710	VDOT Verona – 0262 007 101 L801	-	19.4	2.772	100	0.538
VAR101719	Augusta County Commercial Center – Phase I	-	19.4	9.308	100	1.806
VAR101725	Harley Crossing	-	19.4	4.614	100	0.895
VAR101780	VDOT Verona – 0635 007 S83 N501	-	19.4	0.482	100	0.094
VAR051334	FedEx Freight East, Inc. - Staunton	-	65.08	2.023	60	0.790
VAR051405	Augusta Regional Landfill		19.4	42.000	100	8.148
	Total					**145**
Moffett Creek Impairment						
VAR100622	Project #0728-007-P79, N501	-	19.4	2.428	Inactive	
	Total					**0.0**
Upper Middle River Impairment						
VA0060917	Camp Shenandoah STP	0.0029	-	-	45	0.180
VA0091219	Casta Line Trout Farms	1.840				1.175*
	Total					**1.36**

* This load was calculated from a mximum monthly average of 3.22 kg/day. This permitted load results from the TMDL developed for Cockran Spring.

8.6 Stream Characteristics

The GWLF model does not support flow routing. An empirical relationship developed by Evans, et al., 2001 and modified by BSE, 2003 requires total watershed stream length of the natural channel and total watershed stream length with livestock access. Total watershed stream length in meters was calculated using GIS procedures from USGS NHD hydrography coverage, excluding intermittent streams. This calculation excludes the non-erosive hardened and piped sections of the stream. The potential total stream length with livestock access was calculated with GIS procedures from the MRLC landuse and hydrography coverage. The unrestricted livestock access was estimated as 2 percent of the potential total stream length with livestock access. The mean depth of the natural channel was calculated as a function of watershed area.

8.7 Selection of a Representative Modeling Period

The selection of the modeling period was based on two factors; availability of streamflow data and the need to represent critical hydrological conditions and seasonal variability. A discussion of analysis conducted to select a representative period is given in Section 4.0.

8.8 Hydrologic Model Calibration Process

Although the GWLF model was originally developed for use in ungaged watersheds, calibration was performed to insure that hydrology was being simulated reasonably accurately. This process was considered necessary to minimize errors in sediment simulations due to potential gross errors in hydrology. The models parameters were set based on available soils, landuse, and topographic data. Parameters that were adjusted during calibration included the evapo-transpiration cover coefficient, recession coefficient, seepage coefficient, and unsaturated soil moisture capacity.

Model calibrations were performed for reference watersheds Hays Creek, Mill Creek, and Opequon Creek. One calibration was performed for the impaired watersheds and assumed to be applicable to all three. The model for Christians Creek, Moffett Creek and Upper Middle River was calibrated using the mean daily flow from USGS Station Number 01624800 for the period April 1992 through September 1997. Precipitation and temperature data were obtained from a website maintained by the Biological Systems Engineering Department for automated creation of weather data for GWLF in the State of Virginia. The hydrologic unit code (HUP) is used to access the data (Table 8.2). The final calibration results are given in Figure 8.1 and 8.2 with goodness of fit statistics given in Table 8.6. The model for Opequon Creek was calibrated using USGS Station #01615000 for the period April 1992 through September 1997. Precipitation and temperature data stations are give in Table 8. The final calibration results are displayed in Figure 8.3 and Figure 8.4 for the calibration period with statistics showing the goodness of fit given in Table 8.6. Reference watershed Hays Creek did not have an observed stream flow station located within the watershed boundary. USGS Station #02022500 located nearby and precipitation and temperature data stations listed in Table 8.2 was used to calibrate hydrologic model parameters for Hays Creek (Figure 8.5 and Figure 8.6). The final calibration for Hays Creek is given in Figure 8.4 with statistics showing goodness of fit given in Table 8.6. Reference watershed Mill Creek also did not have a stream flow station located within the watershed boundary. USGS Station #01632900 located nearby, with precipitation and temperature data from Table 8.2, was used to calibrate the Mill Creek model. The final calibration for Hays Creek is given in Figure 8.7 and Figure 8.8 with statistics showing goodness of fit given in Table 8.6.

Model calibrations were considered good to excellent for total runoff volume. Monthly fluctuations were variable but still considered reasonably good considering the general simplicity of GWLF. Results were also consistent with other applications of GWLF in Virginia (*e.g.,* Tetra Tech, 2001 and BSE, 2003).

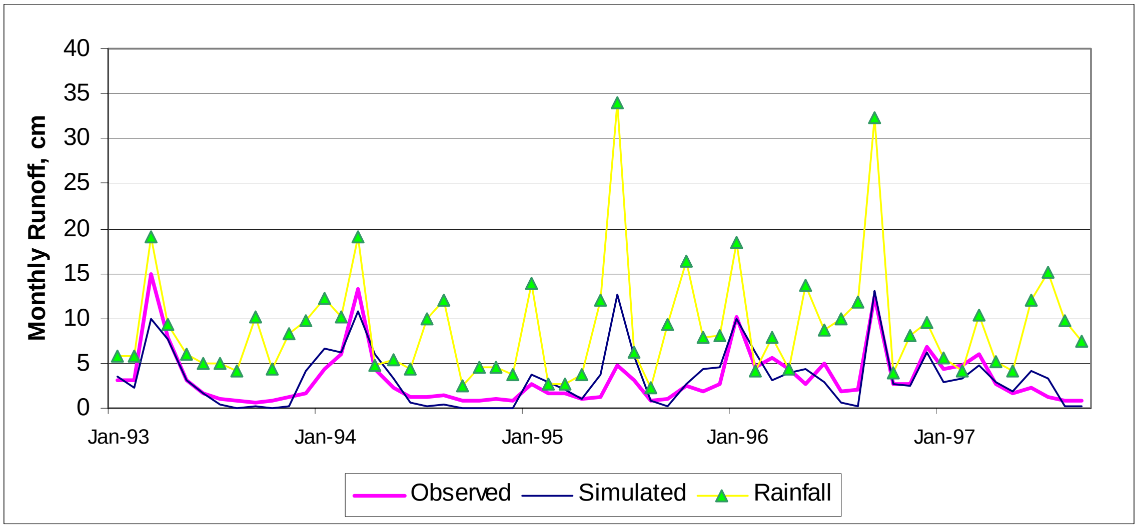

Figure 8.1 Comparison of Monthly Simulated and Observed Flow for Christians Creek Watershed.

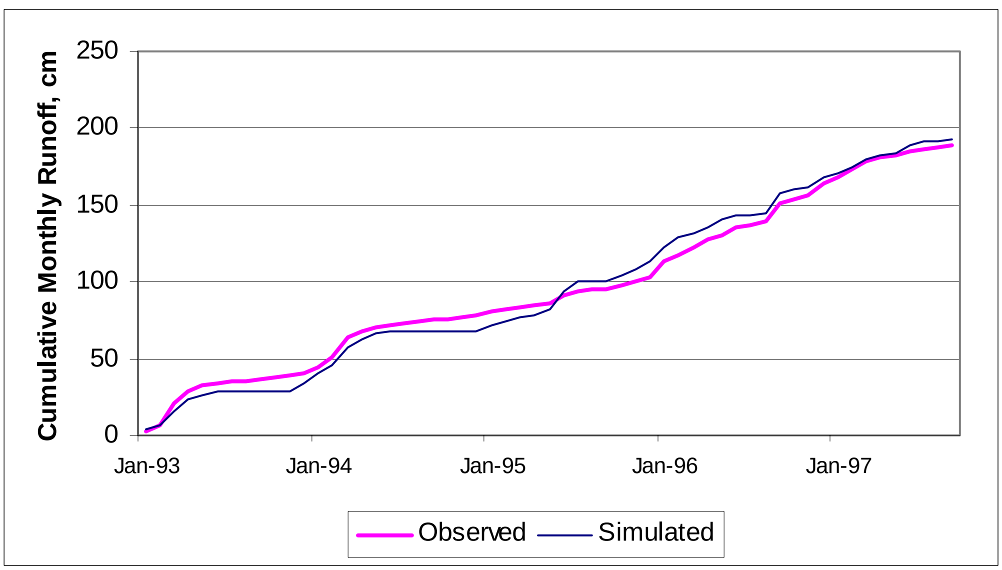

Figure 8.2 Comparison of Cumulative Monthly Simulated and Observed Flow for Christians Creek.

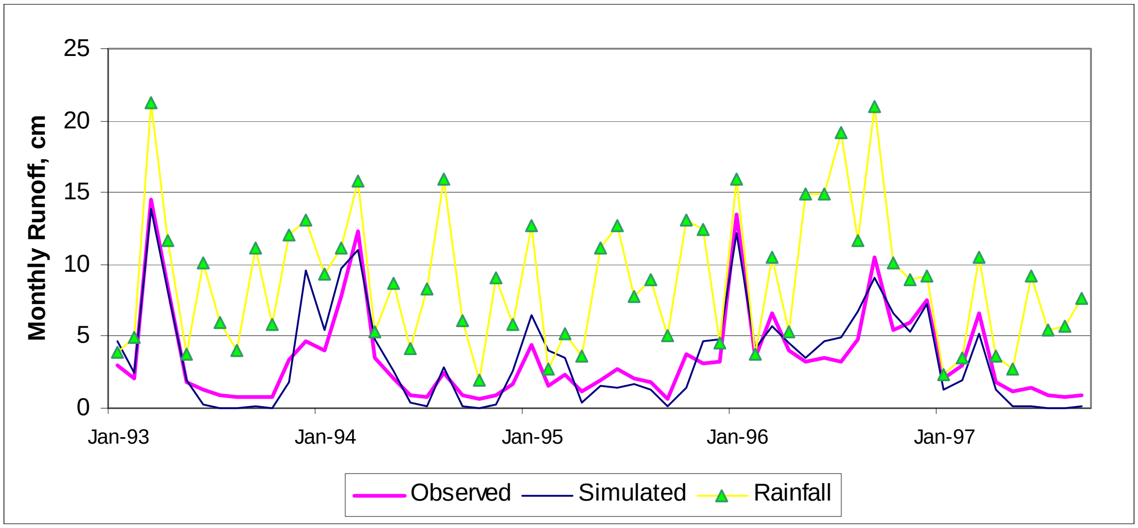

Figure 8.3 Comparison of Monthly Simulated and Observed Flow for Opequon Creek Watershed.

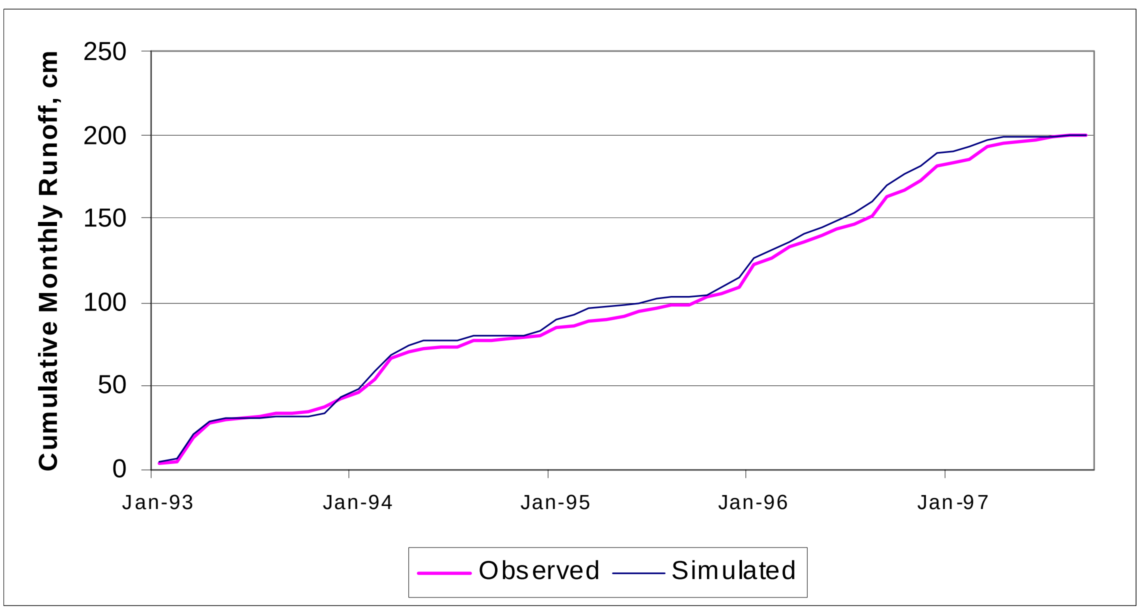

Figure 8.4 Comparison of Cumulative Monthly Simulated and Observed Flow for Opequon Creek.

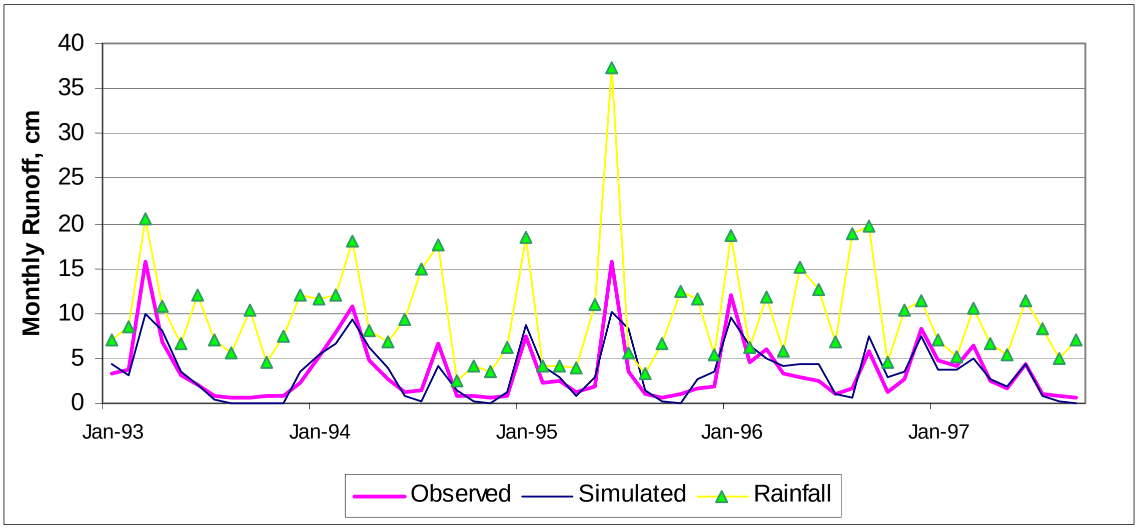

Figure 8.5 Comparison of Monthly Simulated and Observed Flow for Hays Creek Watershed.

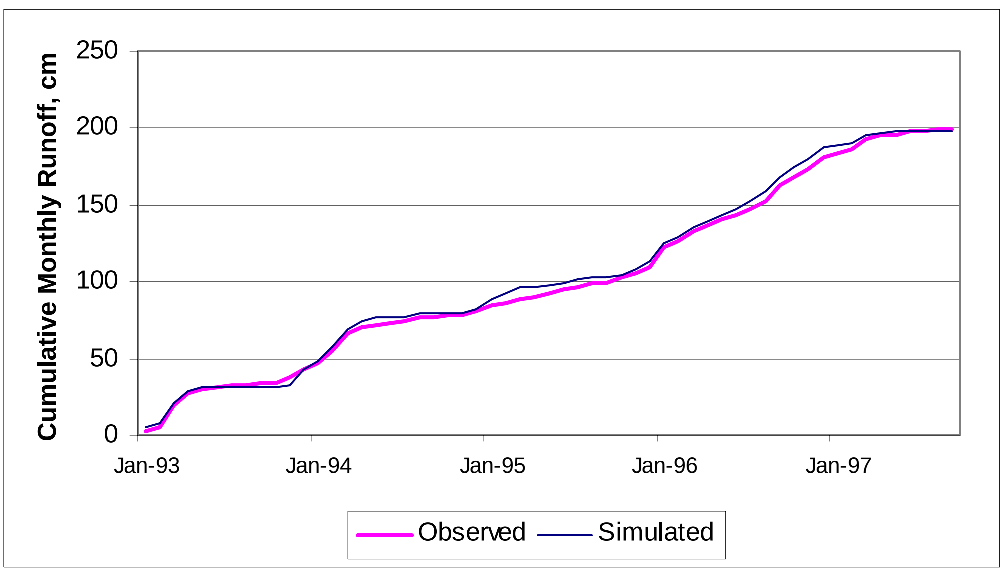

Figure 8.6 Comparison of Cumulative Monthly Simulated and Observed Flow for Hays Creek.

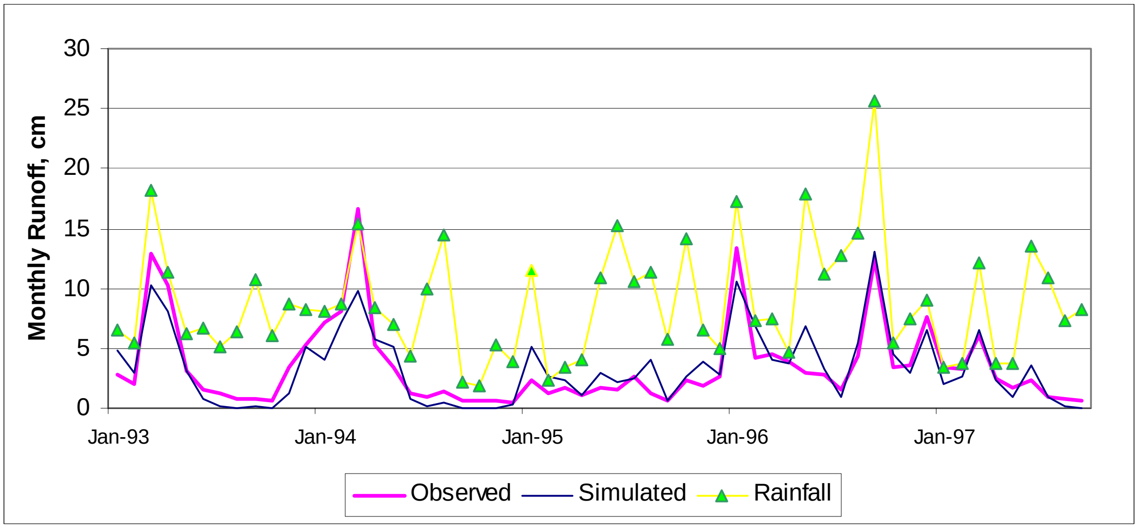

Figure 8.7 Comparison of Monthly Simulated and Observed Flow for Mill Creek Watershed.

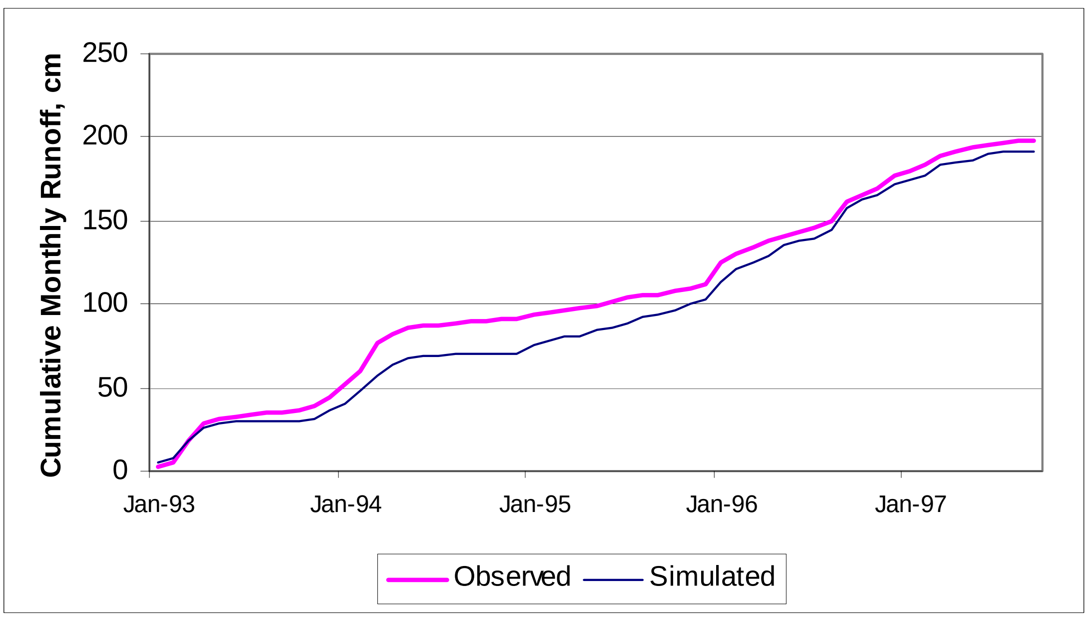

Figure 8.8 Comparison of Cumulative Monthly Simulated and Observed Flow for Mill Creek.

Table 8.6 GWLF flow calibration statistics.

Watershed	Simulation Period	R^2 (Correlation) value	Total Volume Error
Christians Creek	4/1/92 –9/30/97	0.84	2.1%
Opequon Creek	4/1/92 –9/30/97	0.93	-0.4%
Hays Creek	4/1/92 –9/30/97	0.89	-2.2%
Mill Creek	4/1/92 –9/30/97	0.89	-3.4%

8.9 Existing Conditions

A listing of parameters from the GWLF Transport input files that were finalized during hydrologic calibration for existing conditions are given in Appendix D, Tables D.1 through Table D.12. Watershed parameters are listed in Table D.1 for Moffett Creek and reference watershed Mill Creek, in Table D.5 for Upper Middle River and reference watershed Hays Creek, and in Table D.9 for Christians Creek and reference watershed Opequon Creek. Monthly evaporation cover coefficients are listed in Appendix D, Table D.2 for Moffett Creek and reference watershed Mill Creek, in Table D.6 for Upper Middle River and reference watershed Hays Creek, and in Table D.10 for Christians Creek and reference watershed Opequon Creek. Landuse parameters are listed in Appendix D, Table D.3 for Moffett Creek and reference watershed Mill Creek, in Table D.7 for Upper Middle River and reference watershed Hays Creek, and in Table D.11 for Christians Creek and reference watershed Opequon Creek. Area adjustments for reference watershed Mill Creek are given in Appendix D, Table D.4, Table D.8 for reference watershed Hays Creek, and Table D.12 for reference watershed Opequon Creek.

8.9.1 Moffett Creek

The existing sediment loads were modeled for Moffett Creek and Mill Creek and adjusted for agricultural BMPs applied to both watersheds as identified in the Virginia Agricultural BMP database (Appendix D, Table D.1). The agricultural BMP database provides the type of BMP, acres benefited, sheet and rill erosion and gully erosion reduction. The total sediment reduction was calculated by multiplying the total erosion times the delivery ratio for the respective watersheds. An efficiency factor was calculated based on the existing sediment load from agricultural land. The existing sediment loads for individual agricultural categories were adjusted for BMPs (Table 8.7). The target TMDL load for Moffett Creek is the average annual load (4,067) from the area-adjusted Mill Creek watershed under existing conditions (Table 8.7).

Table 8.7 Existing sediment loads for Moffett Creek and reference watershed Mill Creek.

Sediment Sources	Moffett Creek		Mill Creek (Area adjusted)	
	(T/yr)	(T/ha)	(T/yr)	(T/ha)
LDR-PER	0.381	0.037	0.957	0.040
MDR-PER	0.000	0.000	0.000	0.000
HDR-PER	0.000	0.000	0.000	0.000
COM-PER	0.003	0.009	0.012	0.029
Transitional	1.174	2.668	33.773	2.625
Forest	177.686	0.055	77.181	0.019
Urban Grass	0.000	0.000	0.000	0.000
Pasture 1	3,968.402	7.894	1,754.536	3.374
Pasture 2	3,675.741	3.134	920.536	1.180
Pasture 3	741.016	0.442	251.635	0.194
High Tillage	501.434	9.865	710.389	7.439
Low Tillage	517.459	2.561	105.782	2.353
LDR-IMP	0.573	0.208	4.789	0.210
MDR-IMP	0.000	0.000	0.000	0.000
HDR-IMP	0.000	0.000	0.000	0.000
COM-IMP	0.009	0.074	0.383	0.080
Channel Erosion	5.389	--	786.169	--
NPS Load	**9,589**		**4,067**	
Point Source Load	0.0	0.0	0.0	0.0
Watershed Totals	**9,589**		**4,067**	

8.9.2 Upper Middle River

The existing sediment loads modeled for the Upper Middle River impairment and reference watershed Hays Creek are listed in Table 8.8. The existing sediment loads for individual agricultural categories were adjusted for BMPs following the same procedures that were used for Moffett Creek and area-adjusted Mill Creek. The target TMDL load for Upper Middle River is the average annual load (6,316) from the area-adjusted Hays Creek watershed under existing conditions (Table 8.8).

Table 8.8 Existing sediment loads for Upper Middle River and Reference watershed Hays Creek.

Sediment Sources	Upper Middle River (t/yr)	Upper Middle River (t/ha)	Hays Creek (Area adjusted) (t/yr)	Hays Creek (Area adjusted) (t/ha)
LDR-PER	0.737	0.036	0.474	0.043
HDR-PER	0.000	0.000	0.024	0.031
COM-PER	0.000	0.000	0.000	0.000
Transitional	188.777	6.634	69.177	8.644
Forest	173.249	0.038	341.300	0.054
Pasture 1	4,886.925	4.585	0.000	0.000
Pasture 2	4,554.314	1.831	4,439.110	3.110
Pasture 3	913.404	0.257	1,799.240	0.420
High Tillage	714.515	6.435	377.238	10.251
Low Tillage	724.021	1.671	407.198	2.579
LDR-IMP	1.164	0.213	0.913	0.215
MDR-IMP	0.000	0.000	0.000	0.000
HDR-IMP	0.000	0.000	0.019	0.064
COM-PER	0.000	0.000	0.000	0.000
Channel Erosion	4.648	--	19.345	--
NPS Load	**12,162**		**6,316**	
Point Source Load	1.36		0.0	
Watershed Totals	**12,163**		**6,316**	

8.9.3 Christians Creek

The primary stressor on the aquatic life of Christians Creek was identified as lack of litter fall to the first order streams in the Christians Creek watershed from a lack of forest cover in the riparian corridors. A second minor stressor on the aquatic life in Christians Creek was identified as sedimentation from stream bank erosion. Corridor analyses were conducted on the Middle River impairments and potential reference watersheds. These results strongly suggest that an abundance of tree cover on first order streams was important to a healthy stream biological community. The analysis also established that a 33 to 38% forest cover is an approximate threshold between a healthy community and a community showing signs of stress. The cover index for first order stream corridors for Christians Creek was 23, suggesting that an improvement in the riparian buffer would significantly benefit the biological community. As a result of these and previous analysis, the TMDL analysis focused on a 330-foot wide corridor centering on first order streams. The existing loads for the Christians Creek impairment is 7,447 T/yr including sediment delivered from the first order corridor and stream channel erosion. The existing loads for area-adjusted Opequon Creek is 6,107 T/yr including sediment delivered from the first order corridor and stream channel erosion. These results provide some indication that the slightly impaired status of Christians Creek is related to the stream corridor. The existing conditions for the first order stream corridor are shown at the bottom of Table 8.9 and will be used to construct the Christians Creek benthic TMDL.

Table 8.9 Existing sediment loads from first-order stream corridors for Christians Creek and Reference watershed Opequon Creek.

Sediment Sources	Christians Creek		Opequon Creek	
	(T/yr)	(T/ha)	(T/yr)	(T/ha)
LDR-PER-COR	0.003	0.025	1.827	0.084
MDR-PER-COR	0.000	0.000	0.000	0.000
HDR-PER-COR	0.000	0.000	0.0038	0.007
COM-PER-COR	0.006	0.006	0.1768	0.048
Transitional-COR	0.000	0.000	0.165	0.735
Forest-COR	1.281	0.0152	15.779	0.052
Urban Grass-COR	0.000	0.0000	0.214	0.021
Pasture 1-COR	54.286	1.301	7.285	4.495
Pasture 2-COR	44.872	0.461	74.278	1.962
Pasture 3-COR	9.613	0.069	90.525	0.306
High Tillage –COR	10.795	4.858	105.144	8.189
Low Tillage-COR	8.395	1.259	41.247	4.190
LDR-IMP-COR	0.021	0.205	2.757	0.216
MDR-IMP-COR	0.000	0.000	0.000	0.000
HDR-IMP-COR	0.000	0.0000	0.072	0.217
COM-IMP-COR	0.060	0.205	0.465	0.205
Channel Erosion-COR	7,173.120	**--**	5,767.353	**--**
NPS Load	**7,302**		**6107**	
Point Source - Load	145		0.0	
Total - Cor	**7,447**		**6,107**	

9. ALLOCATION

Total Maximum Daily Loads (TMDLs) consist of waste load allocations (WLAs, point sources) and load allocations (LAs, nonpoint sources) including natural background levels. Additionally, the TMDL must include a margin of safety (MOS) that either implicitly or explicitly accounts for uncertainties in the process (*e.g.*, landuses cover factors). The definition is typically denoted by the expression.

TMDL = WLAs + LAs + MOS

The TMDL becomes the amount of a pollutant that can be assimilated by the receiving water body and still achieve water quality standards. For sediment, the TMDL is expressed in terms of metric tons or metric tons per hectare.

This section describes the development of benthic TMDLs for sediment for three impaired stream segments using a reference watershed approach. The model was calibrated for hydrology and run for existing conditions over the five-year period April 1992 through September 1997. The average annual sediment load from the respective TMDL reference watersheds- area adjusted- was used to define the TMDL load for each impaired watershed. The target reduction load was calculated as the TMDL minus WLA a 10% explicit MOS. Since WLA is included in the calculation of the target reduction load, the existing watershed load (impaired watershed) only includes the nonpoint source loads plus stream channel loads. A sensitivity analysis was performed to determine the impact of uncertainties in input parameters.

9.1 Sensitivity Analysis

Sensitivity analyses were conducted to assess the sensitivity of the model to changes in hydrologic and water quality parameters as well as to assess the impact of unknown variability in source allocation (*e.g.,* seasonal and spatial variability of crop cover conditions, runoff curve number, etc.). Sensitivity analyses were run on the watershed parameters listed in Table 9.1. For a given simulation, the model parameters in Table 9.1 were set at the base value except for the parameter being evaluated. Each parameter was evaluated through 10 and 50 percentage changes, from the base value. Results are listed in Table 9.2. The results show that the model is extremely sensitive to parameter changes resulting in major changes in either runoff or sediment. For example, decreases in the runoff curve number (*i.e.*, with a base value of 65) resulted in little change in channel erosion; however, the channel erosion output was extremely sensitive to increases in the curve number. The results tend to reiterate the importance of carefully evaluating conditions in the watershed and following a systematic protocol in establishing values for model parameters.

Table 9.1 Base watershed parameter values used to determine hydrologic and sediment response.

GWLF Watershed Parameter	Units	Base Value
Recession Coefficient	Day^{-1}	0.384
Seepage Coefficient	Day^{-1}	0.02
Unsaturated Water Capacity	(cm)	10
Erosivity Coefficient (April – September)		0.26
Erosivity Coefficient (October - March)		0.06
% developed land	(%)	10%
Livestock density	(AU/ac)	0.1785
Area weighted soil erodibility (K-factor)		0.28
Area weighted runoff curve number		65
Total Stream Length	(m)	684590
Mean Channel Depth	(m)	1.5

Table 9.2 Sensitivity of model response to change in selected parameters.

Model Parameter	Parameter Change	% Change in Runoff	% Change in Sediment Load	% Change in Channel Sediment Load
Recession Coefficient	-50	-50	-4.76	-11.4
Recession Coefficient	-10	-3	-0.06	-1.71
Recession Coefficient	10	3	9.6	1.92
Recession Coefficient	50	50	19	4.57
Seepage Coefficient	-50	17.1	0.06	0.002
Seepage Coefficient	-10	2.94	0.08	0.001
Seepage Coefficient	10	-2.74	-0.08	-0.001
Seepage Coefficient	50	-12.1	-0.35	-0.002
Unsaturated Water Capacity	-50	7.89	0.298	0.002
Unsaturated Water Capacity	-10	1	2.6	0.001
Unsaturated Water Capacity	10	-1	-2.5	-0.001
Unsaturated Water Capacity	50	4.2	-0.1	-0.002
Erosivity Coefficient (April – September)	-50	Insensitive	-39.7	-49
Erosivity Coefficient (April – September)	-10	Insensitive	-9.5	-11.9
Erosivity Coefficient (April – September)	10	Insensitive	9.58	11.2
Erosivity Coefficient (April – September)	50	Insensitive	48	51.6
% developed land	-50	Insensitive	insensitive	Insensitive
% Developed land	-10	Insensitive	Insensitive	Insensitive
% Developed land	10	Insensitive	Insensitive	Insensitive
% Developed land	50	Insensitive	Insensitive	Insensitive
No. of livestock	-50	Insensitive	Insensitive	Insensitive
No. of livestock	-10	Insensitive	Insensitive	Insensitive
No. of livestock	10	Insensitive	Insensitive	Insensitive
No. of livestock	50	Insensitive	Insensitive	Insensitive
Area weighted soil erodibility	-50	Insensitive	-50	Insensitive
Area weighted soil erodibility	-10	Insensitive	-10	Insensitive
Area weighted soil erodibility	10	Insensitive	10	Insensitive
Area weighted soil erodibility	50	Insensitive	10	55000
Area weighted runoff curve number	-50	-4.02	-1.20	Insensitive
Area weighted runoff curve number	-10	-1.5	-3.70	Insensitive
Area weighted runoff curve number	10	1.5	3.87	10700
Area weighted runoff curve number	50	4.02	1.23	143200
Total Stream Length	-50	Insensitive	Insensitive	-49
Total Stream Length	-10	Insensitive	Insensitive	-11.9
Total Stream Length	10	Insensitive	Insensitive	11.2
Total Stream Length	50	Insensitive	Insensitive	51.6
Mean Channel Depth	-50	Insensitive	Insensitive	-49
Mean Channel Depth	-10	Insensitive	Insensitive	-8.9
Mean Channel Depth	10	Insensitive	Insensitive	11.2
Mean Channel Depth	50	Insensitive	Insensitive	51.6

9.2 Moffett Creek Benthic TMDL

The Moffett Creek benthic TMDL was developed for sediment, with Mill Creek as the reference watershed. The area of Mill Creek was reduced by the ratio of the reference watershed area to the impaired area. After adjustment by the factor 0.6678, the Mill Creek reference watershed area equaled the Moffett Creek watershed area (6878 ha). Landuse acreage for Mill Creek was reduced while maintaining the original landuse distribution.

The target TMDL sediment load for Moffett Creek is the average annual sediment load from the area-adjusted Mill Creek watershed under existing conditions (Table 9.3). The TMDL for Moffett Creek includes three components – waste load allocations (WLA) from point sources, the load allocation from nonpoint sources (LA), and a margin of safety (MOS). The margin of safety was explicitly set to 10% to account for uncertainty in developing benthic TMDLs. The WLA was calculated as the sum of all permitted point source discharges. The LA was calculated as the target TMDL load minus the WLA load minus the MOS.

Table 9.3 TMDL for Moffett Creek Impairment

Impairment	WLA (T/yr)	LA (T/yr)	MOS (T/yr)	TMDL (T/yr)
Moffett Creek	0	**3,660**	407	4,067

9.2.1 Future Growth

The Augusta County Comprehensive Plan forecasts 1,000 to 2,000 acres for urban development and another 4,000 to 10,000 acres for rural development over the next 20-years. Rural residential development ranges from one dwelling per 2 acres to one dwelling per 5 acres with no development zones. Urban development is recommended not to exceed 3 dwellings per gross acre. Based on the expected growth, and assuming that rural development would be somewhat proportional to the area of the Moffett Creek watershed to total area of Augusta County the expected number of rural dwellings would be 60. Assuming development is on 5-acre lots, a typical trend, a total of 300 acres would be impacted. Based on this scenario, projected future sediment loads for Moffett

Creek are expected to be insignificant and a TMDL modeling run was considered unnecessary.

9.2.2 Sediment Load Reductions for Moffett Creek Impairment

The reduction required to meet the TMDL from existing conditions in Moffett Creek are given in Table 9.4. A review of existing conditions given in Table 8.7 shows that most reductions must come from the agricultural sediment source categories. The pastureland category (pasture 1, pasture 2, and pasture 3) exceeds the reference watershed targets by a factor of three. For allocation scenarios, the agricultural sub-categories for pastureland and cropland have been combined into two categories (*i.e.*, cropland and pastureland) in Table 9.5. For this situation, the majority of the reduction must come from pastureland. Reductions could be achieved through pasture improvement, better pasture management, or less intensive grazing. Two sediment reduction alternatives are presented in Table 9.5. Sediment reduction Alternative 1 requires a 66% reduction in sediment loads from pastureland and 40% reduction in sediment loads from cropland. In Alternative 2, a 70.9% reduction in sediment loads from pastureland is required to achieve the sediment standard established by reference watershed Mill Creek.

Table 9.4 Required sediment reductions for Moffett Creek Impairment.

Load Summary	Moffett Creek (T/yr)	Reductions Required (T/yr)	Reductions Required (% of existing load)
Existing Load	9,589	5,929	61.8
TMDL	3,864		
Target Modeling Load	**3,660**		

Table 9.5 TMDL sediment reductions for Moffett Creek Impairment.

Sediment Source Categories	Existing Condition (T/yr)	Sediment Load Reductions Alternative 1 (%)	Alternative 1 (T/yr)	Alternative 2 (%)	Alternative 2 (T/yr)
LDR-PER	0.381	0	0.381		0.381
HDR-PER	0.000	0	0.000		0.000
COM-PER	0.003	0	0.003		0.003
Transitional	1.174	0	1.174		1.174
Forest	177.686	0	177.686		177.686
Urban Grass	0.000	0	0.000		0.000
Pastureland	**8,385**	**66.0**	**2,851**	**70.9**	**2,440**
Cropland	**1,019**	**40.0**	**611**		1,018.893
LDR-IMP	0.573	0	0.573		0.573
HDR-IMP	0.000	0	0.000		0.000
COM-IMP	0.009	0	0.009		0.009
Channel Erosion	5.389	0	5.389		5.389
WLA	0.000	0	0.000		0.000
Total	**9,589**		**3,647**		**3,644**
Target Allocation Load (TMDL-MOS-WLA)			**3,660**		**3,660**

9.3 Upper Middle River Benthic TMDL

The Upper Middle River benthic TMDL was developed for sediment, with Hays Creek as the reference watershed. The area of Hays Creek was reduced by the ratio of the reference watershed area to the impaired area. After adjustment by the factor 0.5973, the Hays Creek reference watershed area equaled the Moffett Creek watershed area (12,312 ha). Landuse acreage for Hays Creek was reduced while maintaining the original landuse distribution.

The target TMDL load for Upper Middle River is the average annual load from the area-adjusted Hays Creek watershed under existing conditions (Table 9.6). The MOS was explicitly set to 10% to account for uncertainty in developing benthic TMDLs. The WLA was calculated as the sum of all permitted point source discharges. The LA was calculated as the target TMDL load minus the WLA load minus the MOS.

Table 9.6 TMDL for Upper Middle River Impairment.

Impairment	WLA (T/yr)	LA (T/yr)	MOS (T/yr)	TMDL (T/yr)
Upper Middle River	1.355	**5,683**	632	6,316
VA0060917	*0.180*			
VA0091219	*1.175*			

9.3.1 Future Growth

Future growth in the Upper Middle River watershed, which is very rural, was analyzed in the same manner as it was for Moffett Creek. Assuming development is on five-acre lots, a total of 500 acres would be impacted. Based on this scenario, projected future sediment loads for Upper Middle River are expected to be insignificant, and a TMDL modeling run was considered unnecessary.

9.3.2 Sediment Load Reductions for Upper Middle River Impairment

The reduction required to meet the TMDL from existing conditions in Upper Middle River are given in Table 9.7. A review of existing conditions given in Table 8.8 shows that most reductions must come from the agricultural or forestry sediment source categories. The pastureland category (pasture 1, pasture 2, and pasture 3) exceeds the reference watershed targets by a factor of two. For allocation scenarios, the agricultural sub-categories for pastureland and cropland have been combined into two categories cropland and pastureland in Table 9.8. For this situation, the majority of the reduction must come from pastureland and cropland. Reductions could be achieved through pasture improvement, better pasture management, less intensive grazing, and minimum tillage operations, during timber harvesting. Two sediment reduction alternatives are presented in Table 9.8. Sediment reduction Alternative 1 requires a 56.5% reduction in sediment loads from pastureland, and a 53% reduction in sediment loads from cropland. In Alternative 2, a 64% reduction in sediment loads from pastureland is required to achieve the sediment standard established by reference watershed Hays Creek.

Table 9.7 Required sediment reductions for Upper Middle River Impairment.

Load Summary	Upper Middle River (T/yr)	Reductions Required (T/yr)	Reductions Required (% of existing load)
Existing Load	12,162	6,479	53.3
TMDL	6,316		
Target Modeling Load	**5,683**		

Table 9.8 TMDL sediment reductions for Upper Middle River Impairment.

Sediment Source Categories	Existing Conditions	Sediment Load Reductions			
		Alternative 1		Alternative 2	
	(T/yr)	(%)	(T/yr)	(%)	(T/yr)
LDR-PER	0.737		0.737		0.737
HDR-PER	0.000		0.000		0.000
COM-PER	0.000		0.000		0.000
Transitional	188.777		188.777		188.777
Forest	173.249		173.249		173.249
Pastureland	**10,355**	**56.5**	**4,504**	**64**	**3,728**
Cropland	**1,439**	**53.0**	**676**		1,438.536
LDR-IMP	1.164		1.164		1.164
HDR-IMP	0.000		0.000		0.000
COM-PER	0.000		0.000		0.000
Channel Erosion	4.648		4.648		4.648
WLA	115.000		115.000		115.000
Totals	**12,162**		**5,664**		**5,650**
Target Allocation Load (TMDL-MOS-WLA)			**5,683**		**5,683**

9.4 Christians Creek Benthic TMDL

The Christians Creek benthic TMDL was developed for sediment, with Opequon Creek as the reference watershed. The area of Opequon Creek was increased by the ratio of the impaired watershed area to the reference watershed area. After adjustment by the factor 2.029, the Opequon Creek reference watershed area equaled the Christians Creek watershed area (27,861ha). Landuse acreage for Opequon Creek was increased while maintaining the original landuse distribution. As noted in earlier discussion, the benthic TMDL for sediment was developed for a 330-foot corridor centering on first order streams.

The target TMDL load for Christians Creek is the average annual load from the area-adjusted Opequon Creek watershed under existing conditions (Table 9.9). The MOS was explicitly set to 10% to account for uncertainty in developing benthic TMDLs. The WLA was calculated as the sum of all permitted point source discharges. The LA was calculated as the target TMDL load minus the WLA load minus the MOS.

Table 9.9 TMDL for Christians Creek Impairment.

Impairment	WLA (T/yr)	LA (T/yr)	MOS (T/yr)	TMDL (T/yr)
Christians Creek	**145**	5,406	617	6,168
VA0020427	*Inactive*			
VA0022292	*Inactive*			
VA0022306	*Inactive*			
VA0025291	*99.483*			
VA0086738	*Not P. for TSS*			
VA0089061	*2.425*			
VA0089362	*Inactive*			
VA0090417	*15.545*			
VAG401896	*0.041*			
VAG401967	*0.041*			
VAG401969	*0.041*			
VAG401960	*0.041*			
VAG401959	*0.041*			
VAG401449	*0.041*			
VAG401443	*0.041*			
VAG401195	*0.041*			
VAG401082	*0.041*			
VAG401979	*0.041*			
VAG401038	*0.041*			
VAR100595	*0.785*			
VAR100580	*Inactive*			
VAR100583	*Inactive*			
VAR100635	*Inactive*			
VAR102392	*6.085*			
VAR101656	*7.224*			
VAR101657	*0.840*			
VAR101710	*0.538*			
VAR101719	*1.806*			
VAR101725	*0.895*			
VAR101780	*0.094*			
VAR051334	*0.790*			
VAR051405	*8.148*			

9.4.1 Future Growth

The Augusta County Comprehensive Plan forecasts 1,000 to 2,000 acres for urban development and another 4,000 to 10,000 acres for rural development over the next 20 years. Rural residential development ranges from one dwelling per 2 acres to one dwelling per 5 acres with no development zones. Urban development is recommended not to exceed 3 dwellings per gross acre. Based on the expected growth, and assuming that rural development would be somewhat proportional to the area of the Christians Creek watershed to the total area of Augusta County, the expected number of rural dwellings would be 220. Assuming development is on 5-acre lots, a typical trend, a total of 1100 acres would be impacted with 12 acres being impervious. Since Christians Creek is near Urban Service Areas, that are expected to have sufficient capacity to support expected development over the next twenty years, some urban development would be expected. Assuming that urban development occurs based on the above proportionality, 1100 acres would be expected to convert to high density residential or some form of commercial development. Based on the above assumptions, the two future development scenarios were modeled. The first scenario assumes that 1100 acres will convert from forestry and pasture to low density residential. The second scenario assumes that the same acreage will be converted to commercial landuse. The results are summarized in Table 9.10 for first order stream corridor.

Table 9.10 Projected future sediment loads for Christians Creek Impairment.

Scenario	% Landuse change				Loads
	Pasture	Forest	LDR	HDR/ COM	First Order Stream Corridor (T/yr)
Projected Future Load (LDR)	-3.28	-6.7	168.0		7,310
Projected Future Load (HDR/COM)	-3.28	-6.7		269.0	7,381
Existing Load	0	0	0	0	7,447

The future development load resulted in a maximum increase of 4% to the total watershed load. A slight reduction (less than 1%) was noted in the first order steam corridor. This was expected because the change was not targeted specifically to the corridor where zoning generally restricts development in the flood plain. Since the watershed sediment load for future conditions still remains well below the corresponding sediment load from the reference watershed, and the sediment load for the stream corridor was not significantly impacted (Table 9.10), projected future loads were not included into sediment load allocations required to meet the TMDL established for the first order stream corridor.

9.4.2 Sediment Load Reductions for Christians Creek Impairment

The reductions required to meet the TMDL from future conditions in Christians Creek are given in Table 9.11. Grouping nonpoint source loads into agriculture, urban and forestry facilitated the development of TMDL allocation scenarios (Table 9.12). The predominant sediment load is from the stream channel. To meet the target-modeling load, a 25.9% overall sediment reduction will be required (Table 9.11). Two alternatives are presented in Table 9.12. In Alternative 1, the required sediment reduction is allocated to the stream channel. In Alternative 2, allocations are also made to pastureland and cropland within the 330-foot stream corridor. Alternatives to achieve sediment load reductions could include streamside fencing, streambank stabilization, stormwater management from urban areas, improved pasture management in the stream corridor zone, etc.

Table 9.11 Required sediment reductions for Christians Creek Impairment.

Load Summary	Christians Creek (T/yr)	Reductions Required (T/yr)	Reductions Required (% of existing load)
Projected Future Load (LDR)	7,165	1,751	24.0
Projected Future Load (COM)	7,236	1,822	25.0
Existing Load	**7,302**	**1,888**	**25.9**
TMDL	6,168		
WLA	145		
MOS	617		
Target Modeling Load	**5,406**		

Table 9.12 TMDL sediment load reductions for Christians Creek Impairment.

Sediment Source Categories	Existing Load (T/yr)	Sediment Load Reductions Alternative 1 (%)	Alternative 1 (T/yr)	Alternative 2 (%)	Alternative 2 (T/yr)
LDR-PER-COR	0.003		0.003		0.003
HDR-PER-COR	0.000		0.000		0.000
COM-PER-COR	0.006		0.006		0.006
Transitional-COR	0.000		0.000		0.000
Forest-COR	1.281		1.281		1.281
Pastureland	108.771		108.771	**50**	**54.4**
Cropland	19.190		19.190	**50**	**9.6**
LDR-IMP-COR	0.021		0.021		0.021
HDR-IMP-COR	0.000		0.000		0.000
COM-IMP-COR	0.060		0.060		0.060
Channel Erosion-COR	**7,173**	**28.4**	**5,139**	**27.5**	**5,200**
NPS + Channel	7,302		5,268		5,265
WLA	145		145		145
Totals	**7,447**		**5,413**		**5,410**
Target Allocation Load (TMDL-MOS-WLA)			**5,414**		**5,414**
		TMDL	6,168.00		6,168.000

PART IV: IMPLEMENTATION AND PUBLIC PARTICIPATION

10. 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 meeting water quality standards. This report represents the culmination of that effort for the bacteria and benthic impairments in the Middle and Upper South River watersheds. The second step is to develop a TMDL implementation plan. The final step is to implement the TMDL implementation plan, and to monitor stream water quality to determine if water quality standards are being attained.

Once a TMDL has been approved by the civilian State Water Control Board and then EPA, measures must be taken to reduce pollution levels in the stream. These measures, 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 recent *Guidance Manual for Total Maximum Daily Load Implementation Plans*, published in July 2003 and available upon request from the VADEQ and VADCR TMDL project staff. This document is also available on the VADEQ web site: http://www.deq.state.va.us/tmdl/implans/ipguide.pdf. With successful completion of implementation plans, Virginia will be well on the way to restoring impaired waters and enhancing the value of this important resource. Additionally, development of an approved implementation plan will improve a locality's chances for obtaining financial and technical assistance during implementation.

10.1 Staged Implementation

In general, Virginia intends for the required reductions to be implemented in an iterative process that first addresses those sources with the largest impact on water quality. For example, in agricultural areas of the watershed, the most promising management practice to control bacteria and minimize streambank erosion is livestock exclusion from streams. This has been shown to be very effective in lowering bacteria concentrations in streams, both by reducing the direct cattle deposits and by providing additional riparian buffers. Reduced trampling and soil shear on streambanks by livestock has been shown to reduce bank erosion. Improved pasture management, including less intensive grazing, minimization of animal concentrations by frequent movement of winter feeding areas, improving pasture forages, etc, can significantly reduce soil loss from pasture areas. Reducing tillage operations, farming on the contour, strip cropping, maintaining a winter cover crop, etc., have been demonstrated as effective measure to reduce erosion from cropland agriculture.

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

In urban areas, reducing the human bacteria loading from leaking sewer lines could be accomplished through a sanitary sewer inspection and management program. Implementable BMPs appropriate for controlling urban wash-off from parking lots and roads 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 I scenarios are targeted at controllable, anthropogenic bacteria and sediment sources.

Stage I scenarios - Bacteria

The goal of the Stage I scenarios is to reduce the bacteria loadings from controllable sources, excluding wildlife. The Stage I scenarios were generated with the same model setup as was used for the TMDL allocation scenarios.

The Stage I scenario is intended to establish an approachable interim goal and determine the anticipated percentage of violations based on the modeled output. The Stage I allocations for the Middle River impairments require a 100% reduction in loads from sewer overflows and uncontrolled residential discharges (straight pipes), a 100% reduction in direct in-stream loads from livestock, 50% reduction in land-based loads from urban and agricultural sources, and a 0% reduction in all wildlife loads. The Stage I allocations for the South River impairment requires a 100% reduction in loads from sewer overflows and uncontrolled residential discharges (straight pipes), a 55% reduction in direct in-stream loads from livestock, 50% reduction in land-based loads from urban and agricultural sources, and a 0% reduction in all wildlife loads. Table 10.1 contains these reductions along with a projected percent of violation occurrence. Tables 10.2 through 10.7 detail the load reductions required for meeting the Stage I Implementation.

Table 10.1 Reduction percentages for the Stage I implementation.

Impairment	Percent Reduction in Loading from Existing Condition						Percent Violations	
	Direct Wildlife	NPS Wildlife	Direct Livestock	NPS Pasture / Livestock	Res./ Urban	Straight Pipe/ Sewer Overflow	GM > 126 cfu/ 100ml	Single Sample Exceeds 235 cfu/ 100ml
Upper Middle	0	0	100	50	50	100	0	6.9
Moffett Creek	0	0	100	50	50	100	53	17
Lewis Creek	0	0	100	50	50	100	38	53
Polecat Draft	0	0	100	50	50	100	2	5
Lower Middle	0	0	100	50	50	100	27	9
South River	0	0	55	50	50	100	26	12

Table 10.2 Land-based and Direct nonpoint source load reductions in the Upper Middle River impairment for Stage I allocation.

Source	Total Annual Loading for Existing Run (cfu/yr)	Total Annual Loading for Allocation Run (cfu/yr)	Percent Reduction
Land Based			
Residential	1.42E+14	7.12E+13	50
Commercial	6.02E+11	3.01E+11	50
Farmstead	1.88E+13	9.42E+12	50
Cropland	1.23E+16	6.15E+15	50
Livestock Access	7.70E+14	3.85E+14	50
Improved Pasture	1.01E+16	5.06E+15	50
Unimproved Pasture	2.24E+14	1.12E+14	50
Livestock Operations	6.89E+12	3.45E+12	50
Forest	1.12E+15	1.12E+15	0
Water	0.00E+00	0.00E+00	0
Direct			
Livestock	1.89E+14	0.00E+00	100
Wildlife	6.13E+13	6.13E+13	0
Straight Pipes and Sewer Overflows	1.33E+12	0.00E+00	100

Table 10.3 Land-based and Direct nonpoint source load reductions in the Moffett Creek impairment for Stage I allocation.

Source	Total Annual Loading for Existing Run (cfu/yr)	Total Annual Loading for Allocation Run (cfu/yr)	Percent Reduction
Land Based			
Residential	2.86E+13	1.43E+13	50
Commercial	2.68E+10	1.34E+10	50
Farmstead	1.18E+13	5.92E+12	50
Cropland	7.44E+15	3.72E+15	50
Livestock Access	2.58E+14	1.29E+14	50
Improved Pasture	3.61E+15	1.80E+15	50
Unimproved Pasture	4.01E+14	2.01E+14	50
Livestock Operations	4.31E+11	2.15E+11	50
Forest	3.88E+14	3.88E+14	0
Water	0.00E+00	0.00E+00	0
Direct			
Livestock	6.66E+13	0.00E+00	100
Wildlife	1.84E+13	1.84E+13	0
Straight Pipes and Sewer Overflows	3.07E+11	0.00E+00	100

Table 10.4 Land-based and Direct nonpoint source load reductions in the Lewis Creek impairment for Stage I allocation.

Source	Total Annual Loading for Existing Run (cfu/yr)	Total Annual Loading for Allocation Run (cfu/yr)	Percent Reduction
Land Based			
Residential	6.26E+14	3.13E+14	50
Commercial	5.91E+12	2.95E+12	50
Farmstead	3.38E+12	1.69E+12	50
Cropland	5.54E+15	2.77E+15	50
Livestock Access	2.23E+14	1.11E+14	50
Improved Pasture	2.29E+15	1.14E+15	50
Unimproved Pasture	1.66E+13	8.30E+12	50
Livestock Operations	5.35E+09	2.68E+09	50
Forest	1.70E+14	1.70E+14	0
Water	0.00E+00	0.00E+00	0
Direct			
Livestock	4.14E+03	0.00E+00	100
Wildlife	1.97E+13	1.97E+13	0
Straight Pipes and Sewer Overflows	4.39E+11	0.00E+00	100

Table 10.5 Land-based and Direct nonpoint source load reductions in the Polecat Draft impairment for Stage I allocation.

Source	Total Annual Loading for Existing Run (cfu/yr)	Total Annual Loading for Allocation Run (cfu/yr)	Percent Reduction
Land Based			
Residential	1.55E+13	7.76E+12	50
Commercial	0.00E+00	0.00E+00	50
Farmstead	2.63E+12	1.32E+12	50
Cropland	2.23E+15	1.11E+15	50
Livestock Access	8.84E+13	4.42E+13	50
Improved Pasture	1.41E+15	7.06E+14	50
Unimproved Pasture	4.80E+11	2.40E+11	50
Livestock Operations	7.91E+10	3.96E+10	50
Forest	3.47E+13	3.47E+13	0
Water	0.00E+00	0.00E+00	0
Direct			
Livestock	2.18E+13	0.00E+00	100
Wildlife	5.82E+12	5.82E+12	0
Straight Pipes and Sewer Overflows	6.15E+10	0.00E+00	100

Table 10.6 Land-based and Direct nonpoint source load reductions in the Lower Middle River impairment for Stage I allocation.

Source	Total Annual Loading for Existing Run (cfu/yr)	Total Annual Loading for Allocation Run (cfu/yr)	Percent Reduction
Land Based			
Residential	7.35E+13	3.68E+13	50
Commercial	1.45E+12	7.26E+11	50
Farmstead	1.06E+13	5.29E+12	50
Cropland	2.18E+16	1.09E+16	50
Livestock Access	6.45E+14	3.22E+14	50
Improved Pasture	9.52E+15	4.76E+15	50
Unimproved Pasture	1.26E+14	6.28E+13	50
Livestock Operations	8.57E+10	4.28E+10	50
Forest	2.34E+14	2.34E+14	0
Water	0.00E+00	0.00E+00	0
Direct			
Livestock	2.03E+14	0.00E+00	100
Wildlife	7.26E+15	7.26E+15	0
Straight Pipes and Sewer Overflows	1.93E+11	0.00E+00	100

Table 10.7 Land-based and Direct nonpoint source load reductions in the Upper South River impairment for Stage I allocation.

Source	Total Annual Loading for Existing Run (cfu/yr)	Total Annual Loading for Allocation Run (cfu/yr)	Percent Reduction
Land Based			
Residential	1.59E+14	7.96E+13	50
Commercial	1.12E+13	5.60E+12	50
Farmstead	1.23E+13	6.13E+12	50
Cropland	1.85E+15	9.23E+14	50
Livestock Access	2.80E+14	1.40E+14	50
Improved Pasture	3.04E+15	1.52E+15	50
Unimproved Pasture	7.09E+13	3.54E+13	50
Livestock Operations	3.30E+11	1.65E+11	50
Forest	7.80E+14	7.80E+14	0
Water	0.00E+00	0.00E+00	0
Direct			
Livestock	1.77E+15	7.97E+14	55
Wildlife	3.37E+13	3.37E+13	0
Straight Pipes and Sewer Overflows	2.57E+12	0.00E+00	100

Stage I scenarios – Sediment

The Stage I goal was to reduce sediment loads in Christians Creek, Moffett Creek, and Upper Middle River to within 40% of required target reductions. The Stage I implementation target reduction goals are as follows; Christians Creek impairment 6,169 T/yr (17% reduction), Moffett Creek impairment 6,032 T/yr (37% reduction), and Upper Middle River impairment 8,206 T/yr (33% reduction). The proposed management scenarios to achieve the Stage I water quality goals are summarized in Tables 10.8, 10.9, and 10.10 for Moffett Creek, Upper Middle River and Christians Creek, respectively.

An implementation scenario for benthic (sediment) could involve changes in landuse management and/or farm operations. For example, conversion from convention tillage operations to less intensive tillage such as no-till planting into grass, cover crop or corn stubble mulch. Other options could include improving pasture management, particularly on steep slopes, establishing a riparian buffer, exclusion of livestock from stream, and improved stormwater management from urban areas.

Table 10.8 Management scenarios with sediment reductions for Moffett Creek Impairment.

Sediment Source Categories	Management Scenarios	Area Affected (ha)	Existing Condition (T/yr)	Benefit (T/ha)	Implem. Condition (T/yr)
LDR-PER			0.381	0	0.381
HDR-PER			0.000	0	0.000
COM-PER			0.003	0	0.003
Transitional			1.174	0	1.174
Forest			177.686	0	177.686
Urban Grass			0.000	0	0.000
Pastureland	Pasture Improvement (rotational grazing, improved grasses, lower animal densities on steep slopes, reduce overgrazing by 90%) *38% Redustion in sediment loads.*	790	8,385.159	4.052	5,184.079
Cropland	High Tillage to Low Tillage (e.g. no-tillage), strip cropping, rotations) *36% Redustion in sediment loads.*	50	1,018.893	7.30	653.893
LDR-IMP			0.573	0	0.573
HDR-IMP			0.000	0	0.000
COM-IMP			0.009	0	0.009
Channel Erosion			5.389	0	5.389
WLA			0.000	0	0.000
Total			**9,589**		6,023
	Stage I Implementation Target (60% implementation)				6,032
	Target Allocation Load (TMDL-MOS-WLA)				3,660

Table 10.9 Management scenarios with sediment reductions for Upper Middle River Impairment.

Sediment Source Categories	Management Scenarios	Area Affected (ha)	Existing Condition (T/yr)	Benefit (T/ha)	Implem. Condition (T/yr)
LDR-PER			0.737	0	0.737
HDR-PER			0.000	0	0.000
COM-PER			0.000	0	0.000
Transitional			188.777	0	188.777
Forest			173.249	0	173.249
Pastureland	Pasture Improvement (rotational grazing, improved grasses, lower animal densities on steep slopes, reduce overgrazing by 90%) *30% Redustion in sediment loads.*	721	10,354.643	4.328	7,234.155
Cropland	High Tillage to Low Tillage (e.g. no-tillage), strip cropping, rotations) *66% Redustion in sediment loads.*	200	1,438.536	4.764	485.736
LDR-IMP			1.164	0	1.164
HDR-IMP			0.000	0	0.000
COM-IMP			0.000	0	0.000
Channel Erosion			4.648	0	4.648
WLA			1.355	0	1.355
Total			**12,162**		8,203
	Stage I Implementation Target (60% implementation)				8,206
	Target Allocation Load (TMDL-MOS-WLA)				5,683

Table 10.10 Management scenarios with sediment reductions for Christians Creek Impairment-Stream Corridor.

Sediment Source Categories	Management Scenarios	Area/Len. Affected (ha) : (m)	Existing Condition (T/yr)	Benefit (t/ha) : (T/m)	Implem. Condition (T/yr)
LDR-PER			0.003	0	0.003
HDR-PER			0.000	0	0.000
COM-PER			0.006	0	0.006
Transitional			0.000	0	0.000
Forest			1.281	0	1.281
Pastureland	Pasture Improvement (rotational grazing, improved grasses, lower animal densities on steep slopes, reduce overgrazing by 90%) *51% Redustion in sediment loads.*	45	108.771	1.232	53.331
Cropland	High Tillage to Low Tillage (e.g. no-tillage), strip cropping, rotations) *94% Redustion in sediment loads.*	5	19.190	3.598	1.200
LDR-IMP			0.021	0	0.021
HDR-IMP			0.000	0	0.000
COM-IMP			0.060	0	0.060
Channel Erosion	Improve riparian buffer, livestock exclusion, urban stormwater management *17% Redustion in sediment loads.*	7,550	7,173.120	0.16	5965.120
WLA			145	0	145
Total			**7,447**		**6,166**
	Stage I Implementation Target (60% implementation)				6,169
	Target Allocation Load (TMDL-MOS-WLA)				5,414

The development of the implementation plan is expected to be an iterative process, with monitoring data refining its final design. Subsequent refinements will be made as the progress toward meeting milestones and the expressed TMDL goals is assessed. As practices are implemented, periodic analyses of water quality conditions will be conducted to evaluate the progress toward meeting end goals.

10.2 Link to Ongoing Restoration Efforts

Implementation of this TMDL will be integrated into on-going water quality improvement efforts aimed at restoring water quality in the Middle River basin. Several BMPs known to be effective in controlling bacteria have also been identified for implementation as part of this effort. For example, management of on-site waste management systems, management of livestock and manure, and pet waste management are among the components of a nonpoint source implementation strategy.

10.3 Reasonable Assurance for Implementation

10.3.1 Follow-up Monitoring

VADEQ will continue monitoring the Middle River watershed in accordance with its ambient watershed monitoring program to evaluate reductions in fecal bacteria counts and the effectiveness of TMDL implementation in attainment of water quality standards.

Watershed monitoring stations are designed to provide complete coverage of every watershed in Virginia. Two of the major data users in the Commonwealth (the Department of Environmental Quality and the Department of Conservation and Recreation) have indicated that this is an important function for ambient water quality monitoring.

Watershed stations are located at the mouth and within the watershed, based on a census-siting scheme. The number of stations in the watershed is determined by the NPS priority ranking thus focusing our resources on known problem areas. Watersheds are monitored on a rotating basis such that, in the 6-year assessment cycle, all 493 watersheds are monitored. These stations will be sampled at a frequency of once every other month for a two-year period on a 6-year rotating basin basis.

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

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

Once developed, VADEQ will take TMDL implementation plans to the State Water Control Board (SWCB) for approval as the plan for implementing the pollutant allocations and reductions contained in the TMDLs. Also, VADEQ will request SWCB authorization to incorporate the TMDL implementation plan into the appropriate Water Quality Management Plan (WQMP) in accordance with the CWA's Section 303(e). 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 WQMPs. Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

10.3.3 Stormwater Permits

It is the intention of the Commonwealth that the TMDL will be implemented using existing regulations and programs. One of these regulations is the VPDES Permit Regulation (9 VAC 25-31-10 et seq.). Section 9 VAC 25-31-120 describes the requirements for stormwater discharges. Also, federal regulations state in 40 CFR §122.44(k) that National Pollutant Discharge Elimination System (NPDES) permit conditions may consist of *“Best management practices to control or abate the discharge of pollutants when:… (2) Numeric effluent limitations are infeasible…”*.

There are currently no MS4 permits in the Middle River watershed. For MS4/VPDES general permits, VADEQ expects revisions to the permittee’s Stormwater Pollution Prevention Plans to specifically address the TMDL pollutants of concern. VADEQ anticipates that BMP effectiveness would be determined through ambient in-stream monitoring. This is in accordance with recent EPA guidance (EPA Memorandum on

TMDLs and Stormwater Permits, dated November 22, 2002). If future monitoring indicates no improvement in stream water quality, the permit could require the MS4 to expand or better tailor its BMPs to achieve the TMDL reductions. However, only failing to implement the required BMPs would be considered a violation of the permit. VADEQ acknowledges that it may not be possible to meet the existing water quality standard because of the wildlife issue associated with a number of bacteria TMDLs (see section 10.3.5 below). At some future time, it may therefore become necessary to investigate the stream's use designation and adjust the water quality criteria through a Use Attainability Analysis. Any changes to the TMDL resulting from water quality standards changes would be reflected in the permittee's Stormwater Pollution Prevention Plan required by the MS4/VPDES permit.

Additional information on Virginia's Storm Water Phase 2 program and a downloadable menu of Best Management Practices and Measurable Goals Guidance can be found at http://www.deq.state.va.us/water/bmps.html.

10.3.4 Implementation Funding Sources

One potential source of funding for TMDL implementation is Section 319 of the Clean Water Act. Section 319 funding is a major source of funds for Virginia's Nonpoint Source Management Program. Other funding sources for implementation include the U.S. Department of Agriculture's Conservation Reserve Enhancement and Environmental Quality Incentive Programs, the Virginia State Revolving Loan Program, and the Virginia Water Quality Improvement Fund. 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.

10.3.5 Addressing Wildlife Contributions

In some streams for which TMDLs have been developed, water quality modeling indicates that, even after removal of all bacteria sources other than wildlife, the stream will not attain standards under all flow regimes at all times. As is the case for the Middle

River and Upper South River impairments, these streams may not be able to attain standards without some reduction in wildlife load. **Virginia and EPA are not proposing the elimination of wildlife to allow for the attainment of water quality standards.**

Although previous TMDLs for the Commonwealth have not addressed wildlife reductions in first stage goals, some localities have already introduced wildlife management practices. While managing overpopulations of wildlife remains as an option to local stakeholders, the reduction of wildlife or changing a natural background condition is not the intended goal of a TMDL.

To address this issue, Virginia proposed (during its recent 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 were approved by EPA and became effective in February 2004. Additional information can be found at http://www.deq.state.va.us/wqs/rule.html.

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

Based on the above, EPA and Virginia have developed a process to address the wildlife issue. First in this process is the development of a Stage I scenario such as those presented previously in this chapter. The pollutant reductions in the Stage I scenario are targeted only at the controllable, anthropogenic bacteria sources identified in the TMDL, setting aside control strategies for wildlife except for cases of overpopulations. During the implementation of the Stage I 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 I scenario to determine if the water quality standard is attained. This effort will also evaluate if the modeling assumptions were correct. If water quality standards are not being met, a UAA may be initiated to reflect the presence of naturally high bacteria levels due to uncontrollable sources. In some cases, the effort may never have to go to the UAA phase because the water quality standard exceedances attributed to wildlife in the model may have been very small and infrequent and within the margin of error.

11. PUBLIC PARTICIPATION

The development of the Middle River TMDLs was greatly benefited from public participation. Table 7.1 details the public participation throughout the project. The government kickoff meeting took place on October 29, 2002 at the VADCR-Shenandoah Watershed Office with 20 people attending. The purpose of this meeting was to inform the localities of the TMDL development process, and provide data for this study to the contractor.

The first public meeting was held at the Augusta County government offices in Verona on March 5, 2003 to discuss the process for TMDL development, available data, data needs and timeline for the project; 63 people attended. Copies of the presentation materials were available for public distribution. The meeting was public noticed in the *Virginia Register*. There was a 30 day-public comment period and no written comments were received.

A second public meeting was held at the Woodrow Wilson Rehabilitation Center in Fishersville on October 7, 2003 to discuss the fecal bacteria impairments (specifically, the source assessment input and hydrologic calibration); 33 people attended. Copies of the presentation materials were available for public distribution. The meeting was public noticed in the *Virginia Register*. There was a 30 day-public comment period and no written comments were received.

The third public meeting, held at the Augusta County Government Center in Verona, Virginia on December 3, 2003, focused specifically on the benthic impairments. This meeting focused on the TMDL development for the benthic impairments; 15 people attended. Discussion topics included stressor identification and reference watershed selection. The meeting was public noticed in the *Virginia Register*. There was a 30 day-public comment period and no written comments were received.

The fourth public meeting was held January 29, 2004. This was the final meeting for the General Standard (benthic) TMDLs in the Moffett Creek and Upper Middle River watersheds; 18 people attended. Sediment modeling results and allocations were presented at the fourth public meeting. The meeting was public noticed in the *Virginia Register*. Following the meeting, there was a 30 day-public comment period.

The fifth public meeting was held on March 25, 2004 to present the modeling results and allocations. This was the final meeting for the fecal bacteria TMDLs and the General Standard (benthic) TMDL in Christians Creek; 21 people attended. The meeting was public noticed in the *Virginia Register*. Following the meeting, there was a 30 day-public comment period and two sets of comments were received. VADEQ has responded to both sets of comments.

In addition to the public meetings, there were meetings held with farmers and the Headwaters Soil & Water Conservation District. These meetings were to educate the stakeholders on the TMDL process, to obtain data pertaining to the area, and to encourage public participation.

Table 11.1 Public participation during TMDL development for the Middle River watershed.

Date	Location	Attendance[1]	Format
3/5/03	Augusta County Government Center Board Room, Verona Virginia	63	Open to public at large
10/7/03	Woodrow Wilson Rehabilitation Center, Fishersville Virginia	33	Open to public at large
12/3/03	Augusta County Government Center Board Room, Verona Virginia	15	Open to public at large
1/29/04	Augusta County Government Center Board Room, Verona Virginia	18	Open to public at large
3/25/04	Augusta County Government Center Board Room, Verona Virginia	21	Open to public at large

[1]The number of attendants is estimated from sign up sheets provided at each meeting. These numbers are known to underestimate the actual attendance.

Public participation will continue to be critical during the implementation plan (IP) development process. The IP development will depend on the formation of a stakeholders' committee and open public meetings. Public participation is critical to promote reasonable assurances that the implementation activities will occur. A stakeholders' committee will have the expressed purpose of formulating the TMDL implementation plan. The committee will consist of, but not be limited to, representatives from the Department of Conservation and Recreation, Department of Environmental Quality, Department of Health, local agricultural community, local urban community, and local governments. This committee will have responsibility for identifying corrective actions that are founded in practicality, establish a time line to insure expeditious implementation, and set measurable goals and milestones for attaining water quality standards.

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GLOSSARY

Note: All entries in italics are taken from EPA (1998).

303(d). A section of the Clean Water Act of 1972 requiring states to identify and list water bodies that do not meet the states' water quality standards.

Allocations. *That portion of a receiving water's loading capacity attributed to one of its existing or future pollution sources (nonpoint or point) or to natural background sources. (A wasteload allocation [WLA] is that portion of the loading capacity allocated to an existing or future point source, and a load allocation [LA] is that portion allocated to an existing or future nonpoint source or to natural background levels. Load allocations are best estimates of the loading, which can range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting loading.)*

Ambient water quality. *Natural concentration of water quality constituents prior to mixing of either point or nonpoint source load of contaminants. Reference ambient concentration is used to indicate the concentration of a chemical that will not cause adverse impact on human health.*

Anthropogenic. *Pertains to the [environmental] influence of human activities.*

Antidegradation Policies. *Policies that are part of each states water quality standards. These policies are designed to protect water quality and provide a method of assessing activities that might affect the integrity of waterbodies.*

Aquatic ecosystem. *Complex of biotic and abiotic components of natural waters. The aquatic ecosystem is an ecological unit that includes the physical characteristics (such as flow or velocity and depth), the biological community of the water column and benthos, and the chemical characteristics such as dissolved solids, dissolved oxygen, and nutrients. Both living and nonliving components of the aquatic ecosystem interact and influence the properties and status of each component.*

Assimilative capacity. *The amount of contaminant load that can be discharged to a specific waterbody without exceeding water quality standards or criteria. Assimilative capacity is used to define the ability of a waterbody to naturally absorb and use a discharged substance without impairing water quality or harming aquatic life.*

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

Bacteria. *Single-celled microorganisms. Bacteria of the coliform group are considered the primary indicators of fecal contamination and are often used to assess water quality.*

Bacterial decomposition. *Breakdown by oxidation, or decay, of organic matter by heterotrophic bacteria. Bacteria use the organic carbon in organic matter as the energy source for cell synthesis.*

Bacterial source tracking (BST). A collection of scientific methods used to track sources of fecal contamination.

Benthic. *Refers to material, especially sediment, at the bottom of an aquatic ecosystem. It can be used to describe the organisms that live on, or in, the bottom of a waterbody.*

Benthic organisms. *Organisms living in, or on, bottom substrates in aquatic ecosystems.*

Best management practices (BMPs). *Methods, measures, or practices determined to be reasonable and cost-effective means for a landowner to meet certain, generally nonpoint source, pollution control needs. BMPs include structural and nonstructural controls and operation and maintenance procedures.*

Bioassessment. Evaluation of the condition of an ecosystem that uses biological surveys and other direct measurements of the resident biota. (2)

Biochemical Oxygen Demand (BOD). Represents the amount of oxygen consumed by bacteria as they break down organic matter in the water.

Biological Integrity. A water body's ability to support and maintain a balanced, integrated adaptive assemblage of organisms with species composition, diversity, and functional organization comparable to that of similar natural, or non-impacted habitat.

Biosolids. Biologically treated solids originating from municipal wastewater treatment plants.

Biometric. (Biological Metric) The study of biological phenomena by measurements and statistics.

Box and whisker plot. A graphical representation of the mean, lower quartile, upper quartile, upper limit, lower limit, and outliers of a data set.

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

Causal analysis. A process in which data and other information are organized and evaluated using quantitative and logical techniques to determine the likely cause of an observed condition. (2)

Causal association. A correlation or other association between measures or observations of two entities or processes which occurs because of an underlying causal relationship. (2)

Causal mechanism. The process by which a cause induces an effect. (2)

Causal relationship. The relationship between a cause and its effect. (2)

Cause. 1. That which produces an effect (a general definition).

2. A stressor or set of stressors that occur at an intensity, duration and frequency of exposure that results in a change in the ecological condition (a SI-specific definition). (2)

Channel. *A natural stream that conveys water; a ditch or channel excavated for the flow of water.*

Chloride. *An atom of chlorine in solution; an ion bearing a single negative charge.*

Clean Water Act (CWA). *The Clean Water Act (formerly referred to as the Federal Water Pollution Control Act or Federal Water Pollution Control Act Amendments of 1972), Public Law 92-500, as amended by Public Law 96-483 and Public Law 97-117, 33 U.S.C. 1251 et seq. The Clean Water Act (CWA) contains a number of provisions to restore and maintain the quality of the nation's water resources. One of these provisions is Section 303(d), which establishes the TMDL program.*

Coefficient of determination. Represents the proportion of the total sample variability around y that is explained by the linear relationship between *y* and *x*. (In simple linear regression, it may also be computed as the square of the coefficient of correlation *r.)* (3)

Concentration. *Amount of a substance or material in a given unit volume of solution; usually measured in milligrams per liter (mg/L) or parts per million (ppm).*

Concentration-based limit. *A limit based on the relative strength of a pollutant in a waste stream, usually expressed in milligrams per liter (mg/L).*

Concentration-response model. A quantitative (usually statistical) model of the relationship between the concentration of a chemical to which a population or community of organisms is exposed and the frequency or magnitude of a biological response. (2)

Conductivity. An indirect measure of the presence of dissolved substances within water.

Confluence. The point at which a river and its tributary flow together.

Contamination. *The act of polluting or making impure; any indication of chemical, sediment, or biological impurities.*

Continuous discharge. *A discharge that occurs without interruption throughout the operating hours of a facility, except for infrequent shutdowns for maintenance, process changes, or other similar activities.*

Conventional pollutants. *As specified under the Clean Water Act, conventional contaminants include suspended solids, coliform bacteria, high biochemical oxygen demand, pH, and oil and grease.*

Conveyance. A measure of the of the water carrying capacity of a channel section. It is directly proportional to the discharge in the channel section.

Cost-share program. *A program that allocates project funds to pay a percentage of the cost of constructing or implementing a best management practice. The remainder of the costs is paid by the producer(s).*

Cross-sectional area. *Wet area of a waterbody normal to the longitudinal component of the flow.*

Critical condition. *The critical condition can be thought of as the "worst case" scenario of environmental conditions in the waterbody in which the loading expressed in the TMDL for the pollutant of concern will continue to meet water quality standards. Critical conditions are the combination of environmental factors (e.g., flow, temperature, etc.) that results in attaining and maintaining the water quality criterion and has an acceptably low frequency of occurrence.*

Decay. *The gradual decrease in the amount of a given substance in a given system due to various sink processes including chemical and biological transformation, dissipation to other environmental media, or deposition into storage areas.*

Decomposition. *Metabolic breakdown of organic materials; the formation of by-products of decomposition releases energy and simple organic and inorganic compounds. See also* ***Respiration****.*

Designated uses. *Those uses specified in water quality standards for each waterbody or segment whether or not they are being attained.*

Deterministic model. *A model that does not include built-in variability: same input will always result in the same output.*

Dilution. *The addition of some quantity of less-concentrated liquid (water) that results in a decrease in the original concentration.*

Direct runoff. *Water that flows over the ground surface or through the ground directly into streams, rivers, and lakes.*

Discharge. *Flow of surface water in a stream or canal, or the outflow of groundwater from a flowing artesian well, ditch, or spring. Can also apply to discharge of liquid effluent from a facility or to chemical emissions into the air through designated venting mechanisms.*

Discharge Monitoring Report (DMR). *Report of effluent characteristics submitted by a municipal or industrial facility that has been granted an NPDES discharge permit.*

Discharge permits (under NPDES). *A permit issued by the U.S. EPA or a state regulatory agency that sets specific limits on the type and amount of pollutants that a municipality or industry can discharge to a receiving water; it also includes a compliance schedule for achieving those limits. The permit process was established under the National Pollutant Discharge Elimination System, under provisions of the Federal Clean Water Act.*

Dispersion. *The spreading of chemical or biological constituents, including pollutants, in various directions at varying velocities depending on the differential in-stream flow characteristics.*

Dissolved Oxygen (DO). The amount of oxygen in water. DO is a measure of the amount of oxygen available for biochemical activity in a waterbody.

Diurnal. *Actions or processes that have a period or a cycle of approximately one tidal-day or are completed within a 24-hour period and that recur every 24 hours. Also, the occurrence of an activity/process during the day rather than the night.*

DNA. Deoxyribonucleic acid. The genetic material of cells and some viruses.

Domestic wastewater. *Also called sanitary wastewater, consists of wastewater discharged from residences and from commercial, institutional, and similar facilities.*

Drainage basin. *A part of a land area enclosed by a topographic divide from which direct surface runoff from precipitation normally drains by gravity into a receiving water. Also referred to as a watershed, river basin, or hydrologic unit.*

Dynamic model. *A mathematical formulation describing and simulating the physical behavior of a system or a process and its temporal variability.*

Dynamic simulation. *Modeling of the behavior of physical, chemical, and/or biological phenomena and their variations over time.*

Ecoregion. A region defined in part by its shared characteristics. These include meteorological factors, elevation, plant and animal speciation, landscape position, and soils.

Ecosystem. *An interactive system that includes the organisms of a natural community association together with their abiotic physical, chemical, and geochemical environment.*

Effluent. *Municipal sewage or industrial liquid waste (untreated, partially treated, or completely treated) that flows out of a treatment plant, septic system, pipe, etc.*

Effluent guidelines. *The national effluent guidelines and standards specify the achievable effluent pollutant reduction that is attainable based upon the performance of treatment technologies employed within an industrial category. The National Effluent Guidelines Program was established with a phased approach whereby industry would first be required to meet interim limitations based on best practicable control technology currently available for existing sources (BPT). The second level of effluent limitations to be attained by industry was referred to as best available technology economically achievable (BAT), which was established primarily for the control of toxic pollutants.*

Effluent limitation. *Restrictions established by a state or EPA on quantities, rates, and concentrations in pollutant discharges.*

Empirical model. *Use of statistical techniques to discern patterns or relationships underlying observed or measured data for large sample sets. Does not account for physical dynamics of waterbodies.*

Endpoint. *An endpoint (or indicator/target) is a characteristic of an ecosystem that may be affected by exposure to a stressor. Assessment endpoints and measurement endpoints are two distinct types of endpoints commonly used by resource managers. An assessment endpoint is the formal expression of a valued environmental characteristic and should have societal relevance (an indicator). A measurement endpoint is the expression of an observed or measured response to a stress or disturbance. It is a measurable* *environmental characteristic that is related to the valued environmental characteristic chosen as the assessment endpoint. The numeric criteria that are part of traditional water quality standards are good examples of measurement endpoints (targets).*

Enhancement. *In the context of restoration ecology, any improvement of a structural or functional attribute.*

Erosion. The detachment and transport of soil particles by water and wind. Sediment resulting from soil erosion represents the single largest source of nonpoint pollution in the United States.

Eutrophication. The process of enrichment of water bodies by nutrients. Waters receiving excessive nutrients may become eutrophic, are often undesirable for recreation, and may not support normal fish populations.

Evapotranspiration. The combined effects of evaporation and transpiration on the water balance. Evaporation is water loss into the atmosphere from soil and water surfaces. Transpiration is water loss into the atmosphere as part of the life cycle of plants.

Existing use. *Use actually attained in the waterbody on or after November 28, 1975, whether or not it is included in the water quality standards (40 CFR 131.3).*

Fate of pollutants. *Physical, chemical, and biological transformation in the nature and changes of the amount of a pollutant in an environmental system. Transformation processes are pollutant-specific. Because they have comparable kinetics, different formulations for each pollutant are not required.*

Fecal Coliform. Indicator organisms (organisms indicating presence of pathogens) associated with the digestive tract.

Feedlot. *A confined area for the controlled feeding of animals. Tends to concentrate large amounts of animal waste that cannot be absorbed by the soil and, hence, may be carried to nearby streams or lakes by rainfall runoff.*

First-order kinetics. *The type of relationship describing a dynamic reaction in which the rate of transformation of a pollutant is proportional to the amount of that pollutant in the environmental system.*

Flux. *Movement and transport of mass of any water quality constituent over a given period of time. Units of mass flux are mass per unit time.*

General Standard. A narrative standard that ensures the general health of state waters. All state waters, including wetlands, shall be free from substances attributable to sewage, industrial waste, or other waste in concentrations, amounts, or combinations which contravene established standards or interfere directly or indirectly with designated uses of such water or which are inimical or harmful to human, animal, plant, or aquatic life (9VAC25-260-20). (4)

Geometric mean. A measure of the central tendency of a data set that minimizes the effects of extreme values.

GIS. Geographic Information System. A system of hardware, software, data, people, organizations and institutional arrangements for collecting, storing, analyzing and disseminating information about areas of the earth. (Dueker and Kjerne, 1989)

Ground water. *The supply of fresh water found beneath the earths surface, usually in aquifers, which supply wells and springs. Because ground water is a major source of drinking water, there is growing concern over contamination from leaching agricultural or industrial pollutants and leaking underground storage tanks.*

HSPF. Hydrological Simulation Program – Fortran. A computer simulation tool used to mathematically model nonpoint source pollution sources and movement of pollutants in a watershed.

Hydrograph. *A graph showing variation of stage (depth) or discharge in a stream over a period of time.*

Hydrologic cycle. *The circuit of water movement from the atmosphere to the earth and its return to the atmosphere through various stages or processes, such as precipitation, interception, runoff, infiltration, storage, evaporation, and transpiration.*

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.*

Hyetograph. *Graph of rainfall rate versus time during a storm event.*

IMPLND. An impervious land segment in HSPF. It is used to model land covered by impervious materials, such as pavement.

Indicator. *A measurable quantity that can be used to evaluate the relationship between pollutant sources and their impact on water quality.*

Indicator organism. *An organism used to indicate the potential presence of other (usually pathogenic) organisms. Indicator organisms are usually associated with the other organisms, but are usually more easily sampled and measured.*

Indirect causation. The induction of effects through a series of cause-effect relationships, so that the impaired resource may not even be exposed to the initial cause. (2)

Indirect effects. Changes in a resource that are due to a series of cause-effect relationships rather than to direct exposure to a contaminant or other stressor. (2)

Infiltration capacity. *The capacity of a soil to allow water to infiltrate into or through it during a storm.*

In situ. *In place; in situ measurements consist of measurements of components or processes in a full-scale system or a field, rather than in a laboratory.*

Interflow. Runoff that travels just below the surface of the soil.

Isolate. An inbreeding biological population that is isolated from similar populations by physical or other means.

Leachate. *Water that collects contaminants as it trickles through wastes, pesticides, or fertilizers. Leaching can occur in farming areas, feedlots, and landfills and can result in hazardous substances entering surface water, ground water, or soil.*

Limits (upper and lower). The lower limit equals the lower quartile – 1.5x(upper quartile – lower quartile), and the upper limit equals the upper quartile + 1.5x(upper quartile – lower quartile). Values outside these limits are referred to as outliers.

Loading, Load, Loading rate. *The total amount of material (pollutants) entering the system from one or multiple sources; measured as a rate in weight per unit time.*

Load allocation (LA). *The portion of a receiving waters loading capacity attributed either to one of its existing or future nonpoint sources of pollution or to natural background sources. Load allocations are best estimates of the loading, which can range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading. Wherever possible, natural and nonpoint source loads should be distinguished (40 CFR 130.2(g)).*

Loading capacity (LC). *The greatest amount of loading a water can receive without violating water quality standards.*

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 (CWA Section 303(d)(1)(C)). The MOS is normally incorporated into the conservative assumptions used to develop TMDLs (generally within the calculations or models) and approved by EPA either individually or in state/EPA agreements. If the MOS needs to be larger than that which is allowed through the conservative assumptions, additional MOS can be added as a separate component of the TMDL (in this case, quantitatively, a TMDL = LC = WLA + LA + MOS).*

Mass balance. *An equation that accounts for the flux of mass going into a defined area and the flux of mass leaving the defined area. The flux in must equal the flux out.*

Mass loading. *The quantity of a pollutant transported to a waterbody.*

Mathematical model. *A system of mathematical expressions that describe the spatial and temporal distribution of water quality constituents resulting from fluid transport and the one or more individual processes and interactions within some prototype aquatic ecosystem. A mathematical water quality model is used as the basis for waste load allocation evaluations.*

Mean. The sum of the values in a data set divided by the number of values in the data set.

Metrics. Indices or parameters used to measure some aspect or characteristic of a water body's biological integrity. The metric changes in some predictable way with changes in water quality or habitat condition.

MGD. Million gallons per day. A unit of water flow, whether discharge or withdraw.

Mitigation. *Actions taken to avoid, reduce, or compensate for the effects of environmental damage. Among the broad spectrum of possible actions are those that restore, enhance, create, or replace damaged ecosystems.*

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

Monitoring. *Periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or pollutant levels in various media or in humans, plants, and animals.*

Mood's Median Test. A nonparametric (distribution-free) test used to test the equality of medians from two or more populations.

Multivariate Regression. A functional relationship between 1 dependent variable and multiple independent variables that are often empirically determined from data and are used especially to predict values of one variable when given values of the others.

Narrative criteria. *Nonquantitative guidelines that describe the desired water quality goals.*

National Pollutant Discharge Elimination System (NPDES). *The national program for issuing, modifying, revoking and re-issuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements, under sections 307, 402, 318, and 405 of the Clean Water Act.*

Natural waters. *Flowing water within a physical system that has developed without human intervention, in which natural processes continue to take place.*

Nitrogen. An essential nutrient to the growth of organisms. Excessive amounts of nitrogen in water can contribute to abnormally high growth of algae, reducing light and oxygen in aquatic ecosystems.

Nonpoint source. *Pollution that 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.*

Numeric targets. *A measurable value determined for the pollutant of concern, which, if achieved, is expected to result in the attainment of water quality standards in the listed waterbody.*

Numerical model. Model that approximates a solution of governing partial differential equations, which describe a natural process. The approximation uses a numerical discretization of the space and time components of the system or process.

Nutrient. An element or compound essential to life, including carbon, oxygen, nitrogen, phosphorus, and many others: as a pollutant, any element or compound, such as phosphorus or nitrogen, that in excessive amounts contributes to abnormally high growth of algae, reducing light and oxygen in aquatic ecosystems.

Organic matter. *The organic fraction that includes plant and animal residue at various stages of decomposition, cells and tissues of soil organisms, and substances synthesized by the soil population. Commonly determined as the amount of organic material contained in a soil or water sample.*

Parameter. A numerical descriptive measure of a population. Since it is based on the observations of the population, its value is almost always unknown.

Peak runoff. *The highest value of the stage or discharge attained by a flood or storm event; also referred to as flood peak or peak discharge.*

PERLND. A pervious land segment in HSPF. It is used to model a particular landuse segment within a subwatershed (e.g. pasture, urban land, or crop land).

Permit. *An authorization, license, or equivalent control document issued by EPA or an approved federal, state, or local agency to implement the requirements of an environmental regulation; e.g., a permit to operate a wastewater treatment plant or to operate a facility that may generate harmful emissions.*

Permit Compliance System (PCS). *Computerized management information system that contains data on NPDES permit-holding facilities. PCS keeps extensive records on more than 65,000 active water-discharge permits on sites located throughout the nation. PCS tracks permit, compliance, and enforcement status of NPDES facilities.*

Phased/staged approach. *Under the phased approach to TMDL development, load allocations and wasteload allocations are calculated using the best available data and information recognizing the need for additional monitoring data to accurately characterize sources and loadings. The phased approach is typically employed when nonpoint sources dominate. It provides for the implementation of load reduction strategies while collecting additional data.*

Phosphorus. An essential nutrient to the growth of organisms. Excessive amounts of phosphorus in water can contribute to abnormally high growth of algae, reducing light and oxygen in aquatic ecosystems.

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.*

Pollutant. *Dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural waste discharged into water. (CWA section 502(6)).*

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.*

Postaudit. *A subsequent examination and verification of a model's predictive performance following implementation of an environmental control program.*

Privately owned treatment works. *Any device or system that is (a) used to treat wastes from any facility whose operator is not the operator of the treatment works and (b) not a publicly owned treatment works.*

Public comment period. *The time allowed for the public to express its views and concerns regarding action by EPA or states (e.g., a Federal Register notice of a proposed rule-making, a public notice of a draft permit, or a Notice of Intent to Deny).*

Publicly owned treatment works (POTW). *Any device or system used in the treatment (including recycling and reclamation) of municipal sewage or industrial wastes of a liquid nature that is owned by a state or municipality. This definition includes sewers, pipes, or other conveyances only if they convey wastewater to a POTW providing treatment.*

Quartile. The 25^{th}, 50^{th}, and 75^{th} percentiles of a data set. A percentile (p) of a data set ordered by magnitude is the value that has at most p% of the measurements in the data set below it, and (100-p)% above it. The 50^{th} quartile is also known as the median. The 25^{th} and 75^{th} quartiles are referred to as the lower and upper quartiles, respectively.

Raw sewage. *Untreated municipal sewage.*

Rapid Bioassessment Protocol (RBP). A suite of measurements based on a quantitative assessment of benthic macroinvertebrates and a qualitative assessment of their habitat. RBP scores are compared to a reference condition or conditions to determine to what degree a water body may be biologically impaired.

Reach. Segment of a stream or river.

Receiving waters. *Creeks, streams, rivers, lakes, estuaries, ground-water formations, or other bodies of water into which surface water and/or treated or untreated waste are discharged, either naturally or in man-made systems.*

Reference Conditions. The chemical, physical, or biological quality or condition exhibited at either a single site or an aggregation of sites that are representative of non-impaired conditions for a watershed of a certain size, landuse distribution, and other related characteristics. Reference conditions are used to describe reference sites.

Reserve capacity. *Pollutant loading rate set aside in determining stream waste load allocation, accounting for uncertainty and future growth.*

Residence time. *Length of time that a pollutant remains within a section of a stream or river. The residence time is determined by the streamflow and the volume of the river reach or the average stream velocity and the length of the river reach.*

Restoration. *Return of an ecosystem to a close approximation of its presumed condition prior to disturbance.*

Riparian areas. *Areas bordering streams, lakes, rivers, and other watercourses. These areas have high water tables and support plants that require saturated soils during all or part of the year. Riparian areas include both wetland and upland zones.*

Riparian zone. *The border or banks of a stream. Although this term is sometimes used interchangeably with floodplain, the riparian zone is generally regarded as relatively narrow compared to a floodplain. The duration of flooding is generally much shorter, and the timing less predictable, in a riparian zone than in a river floodplain.*

Roughness coefficient. *A factor in velocity and discharge formulas representing the effects of channel roughness on energy losses in flowing water. Manning's "n" is a commonly used roughness coefficient.*

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

Seasonal Kendall test. A statistical tool used to test for trends in data, which is unaffected by seasonal cycles.

Sediment. In the context of water quality, soil particles, sand, and minerals dislodged from the land and deposited into aquatic systems as a result of erosion.

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

Sewer. *A channel or conduit that carries wastewater and storm water runoff from the source to a treatment plant or receiving stream. Sanitary sewers carry household, industrial, and commercial waste. Storm sewers carry runoff from rain or snow. Combined sewers handle both.*

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.*

Slope. *The degree of inclination to the horizontal. Usually expressed as a ratio, such as 1:25 or 1 on 25, indicating one unit vertical rise in 25 units of horizontal distance, or in a decimal fraction (0.04), degrees (2 degrees 18 minutes), or percent (4 percent).*

Source. An origination point, area, or entity that releases or emits a stressor. A source can alter the normal intensity, frequency, or duration of a natural attribute, whereby the attribute then becomes a stressor. (2)

Spatial segmentation. *A numerical discretization of the spatial component of a system into one or more dimensions; forms the basis for application of numerical simulation models.*

Staged Implementation. A process that allows for the evaluation of the adequacy of the TMDL in achieving the water quality standard. As stream monitoring continues to occur, staged or phased implementation allows for water quality improvements to be recorded as they are being achieved. It also provides a measure of quality control, and it helps to ensure that the most cost-effective practices are implemented first.

Stakeholder. Any person with a vested interest in the TMDL development.

Standard. In reference to water quality (e.g. 200 cfu/100 ml geometric mean limit).

Standard deviation. A measure of the variability of a data set. The positive square root of the variance of a set of measurements.

Standard error. The standard deviation of a distribution of a sample statistic, esp. when the mean is used as the statistic.

Statistical significance. An indication that the differences being observed are not due to random error. The p-value indicates the probability that the differences are due to random error (i.e. a low p-value indicates statistical significance).

Steady-state model. *Mathematical model of fate and transport that uses constant values of input variables to predict constant values of receiving water quality concentrations. Model variables are treated as not changing with respect to time.*

Stepwise regression. All possible one-variable models of the form $E(y) = B_0 + B_1 x_1$ are fit and the "best" x_1 is selected based on the *t*-test for B_1. Next, two-variable models of the form $E(y) = B_0 + B_1 x_1 + B_2 x_i$ are fit (where x_i is the variable selected in the first step): the "second best" x_i is selected based on the test for B_2. The process continues in this fashion until no more "important" *x*'s can be added to the model. (3)

Storm runoff. *Storm water runoff, snowmelt runoff, and surface runoff and drainage; rainfall that does not evaporate or infiltrate the ground because of impervious land surfaces or a soil infiltration rate lower than rainfall intensity, but instead flows onto adjacent land or into waterbodies or is routed into a drain or sewer system.*

Streamflow. *Discharge that occurs in a natural channel. Although the term "discharge" can be applied to the flow of a canal, the word "streamflow" uniquely describes the discharge in a surface stream course. The term "streamflow" is more general than "runoff" since streamflow may be applied to discharge whether or not it is affected by diversion or regulation.*

Stream Reach. A straight portion of a stream.

Stream restoration. *Various techniques used to replicate the hydrological, morphological, and ecological features that have been lost in a stream because of urbanization, farming, or other disturbance.*

Stressor. Any physical, chemical, or biological entity that can induce an adverse response. (2)

Surface area. *The area of the surface of a waterbody; best measured by planimetry or the use of a geographic information system.*

Surface runoff. *Precipitation, snowmelt, or irrigation water in excess of what can infiltrate the soil surface and be stored in small surface depressions; a major transporter of nonpoint source pollutants.*

Surface water. *All water naturally open to the atmosphere (rivers, lakes, reservoirs, ponds, streams, impoundments, seas, estuaries, etc.) and all springs, wells, or other collectors directly influenced by surface water.*

Suspended Solids. Usually fine sediments and organic matter. Suspended solids limit sunlight penetration into the water, inhibit oxygen uptake by fish, and alter aquatic habitat.

Technology-based standards. *Effluent limitations applicable to direct and indirect sources that are developed on a category-by-category basis using statutory factors, not including water quality effects.*

Timestep. An increment of time in modeling terms. The smallest unit of time used in a mathematical simulation model (e.g. 15-minutes, 1-hour, 1-day).

Topography. *The physical features of a geographic surface area including relative elevations and the positions of natural and man-made features.*

Total Dissolved Solids (TDS). A measure of the concentration of dissolved inorganic chemicals in water.

Total Maximum Daily Load (TMDL). *The sum of the individual wasteload allocations (WLAs) for point sources, load allocations (LAs) 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.*

TMDL Implementation Plan. A document required by Virginia statute detailing the suite of pollution control measures needed to remediate an impaired stream segment. The plans are also required to include a schedule of actions, costs, and monitoring. Once implemented, the plan should result in the previously impaired water meeting water quality standards and achieving a "fully supporting" use support status.

Transport of pollutants (in water). *Transport of pollutants in water involves two main processes: (1) advection, resulting from the flow of water, and (2) dispersion, or transport due to turbulence in the water.*

TRC. Total Residual Chlorine. A measure of the effectiveness of chlorinating treated waste water effluent.

Tributary. *A lower order-stream compared to a receiving waterbody. "Tributary to" indicates the largest stream into which the reported stream or tributary flows.*

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 processes under investigation. A validated model will have also been tested to ascertain whether it accurately and correctly solves the equations being used to define the system simulation.*

Variance. A measure of the variability of a data set. The sum of the squared deviations (observation – mean) divided by (number of observations) – 1.

VADACS. Virginia Department of Agriculture and Consumer Services.

VADCR. Virginia Department of Conservation and Recreation.

VADEQ. Virginia Department of Environmental Quality.

VDH. Virginia Department of Health.

Wasteload allocation (WLA). *The portion of a receiving waters' 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 (40 CFR 130.2(h)).*

Wastewater. *Usually refers to effluent from a sewage treatment plant. See also* ***Domestic wastewater****.*

Wastewater treatment. *Chemical, biological, and mechanical procedures applied to an industrial or municipal discharge or to any other sources of contaminated water to remove, reduce, or neutralize contaminants.*

Water quality. *The biological, chemical, and physical conditions of a waterbody. It is a measure of a waterbody's ability to support beneficial uses.*

Water quality-based effluent limitations (WQBEL). *Effluent limitations applied to dischargers when technology-based limitations alone would cause violations of water quality standards. Usually WQBELs are applied to discharges into small streams.*

Water quality-based permit. *A permit with an effluent limit more stringent than one based on technology performance. Such limits might be necessary to protect the designated use of receiving waters (e.g., recreation, irrigation, industry, or water supply).*

Water quality criteria. *Levels of water quality expected to render a body of water suitable for its designated use, composed of numeric and narrative criteria. Numeric criteria are scientifically derived ambient concentrations developed by EPA or states for various pollutants of concern to protect human health and aquatic life. Narrative criteria are statements that describe the desired water quality goal. Criteria are based on specific levels of pollutants that would make the water harmful if used for drinking, swimming, farming, fish production, or industrial processes.*

Water quality standard. *Law or regulation that consists of the beneficial designated use or uses of a waterbody, the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular waterbody, and an antidegradation 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.*

WQIA. Water Quality Improvement Act.

APPENDIX A

FREQUENCY ANALYSIS OF WATER QUALITY SAMPLING DATA

Figure A.1 Frequency analysis of fecal coliform concentrations at station 1BBAK001.74 in the Middle River impairment for period August 2001 to June 2002.

*Red indicates a value which violates the listing standard of 1,000 cfu/100 ml.

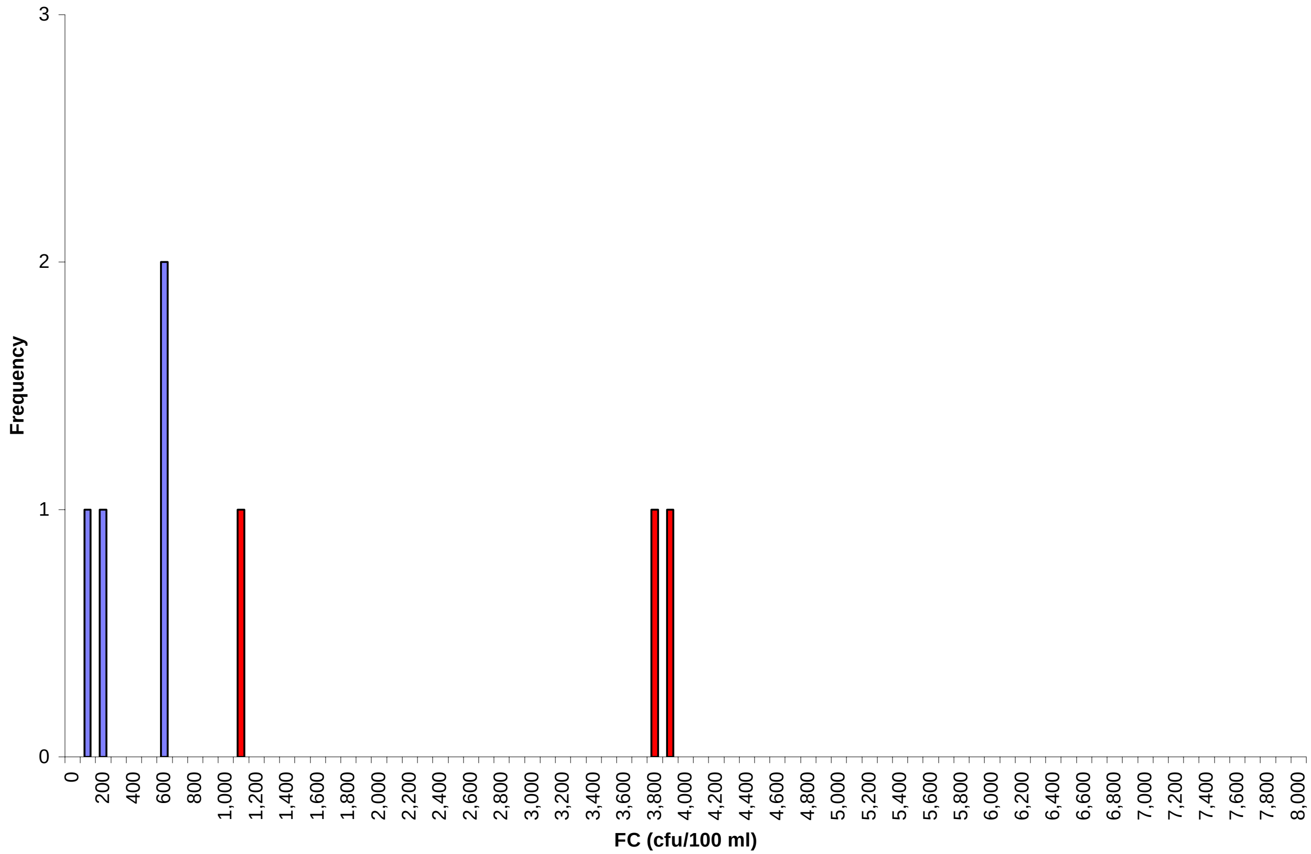

Figure A.2 Frequency analysis of fecal coliform concentrations at station 1BEDN003.67 in the Middle River impairment for period August 2001 to August 2002.

*Red indicates a value which violates the listing standard of 1,000 cfu/100 ml.

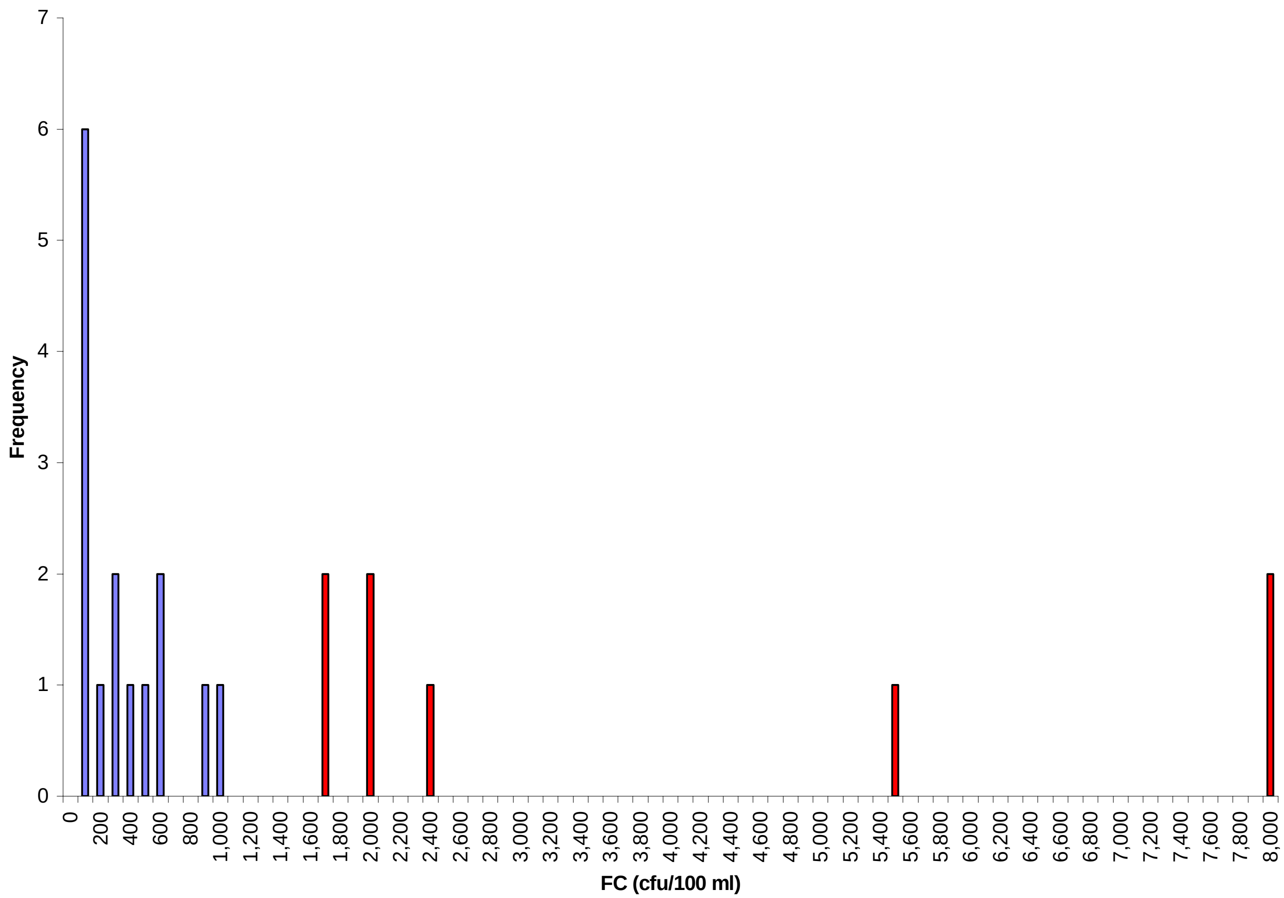

Figure A.3 Frequency analysis of fecal coliform concentrations at station 1BMDL060.48 in the Middle River impairment for period April 1999 to August 2002.

*Red indicates a value which violates the listing standard of 1,000 cfu/100 ml.

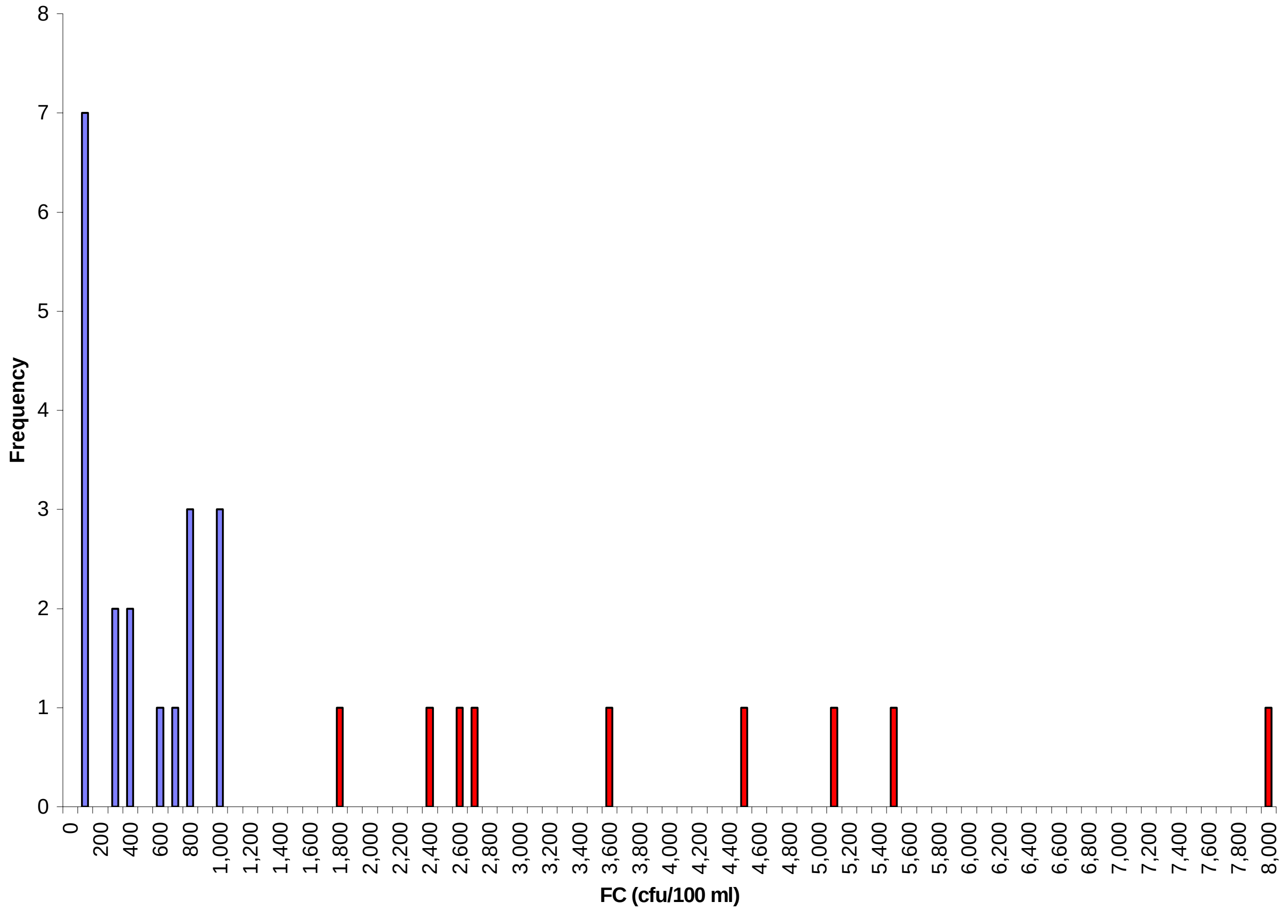

Figure A.4 Frequency analysis of fecal coliform concentrations at station 1BMDL061.07 in the Middle River impairment for period February 1992 to February 1999.

*Red indicates a value which violates the listing standard of 1,000 cfu/100 ml.

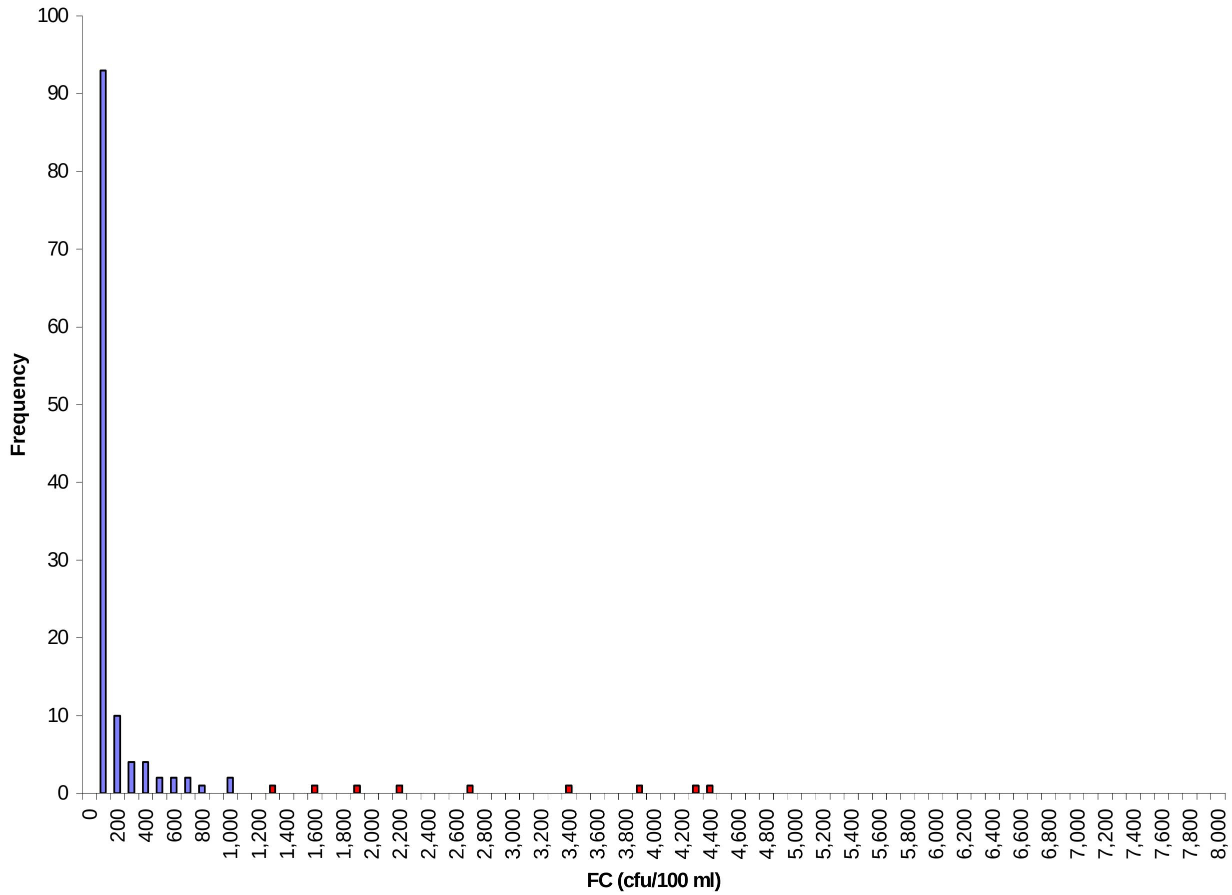

Figure A.5 Frequency analysis of fecal coliform concentrations at station 1BMDL036.08 in the Middle River impairment for period January 1990 to July 2002.

*Red indicates a value which violates the listing standard of 1,000 cfu/100 ml.

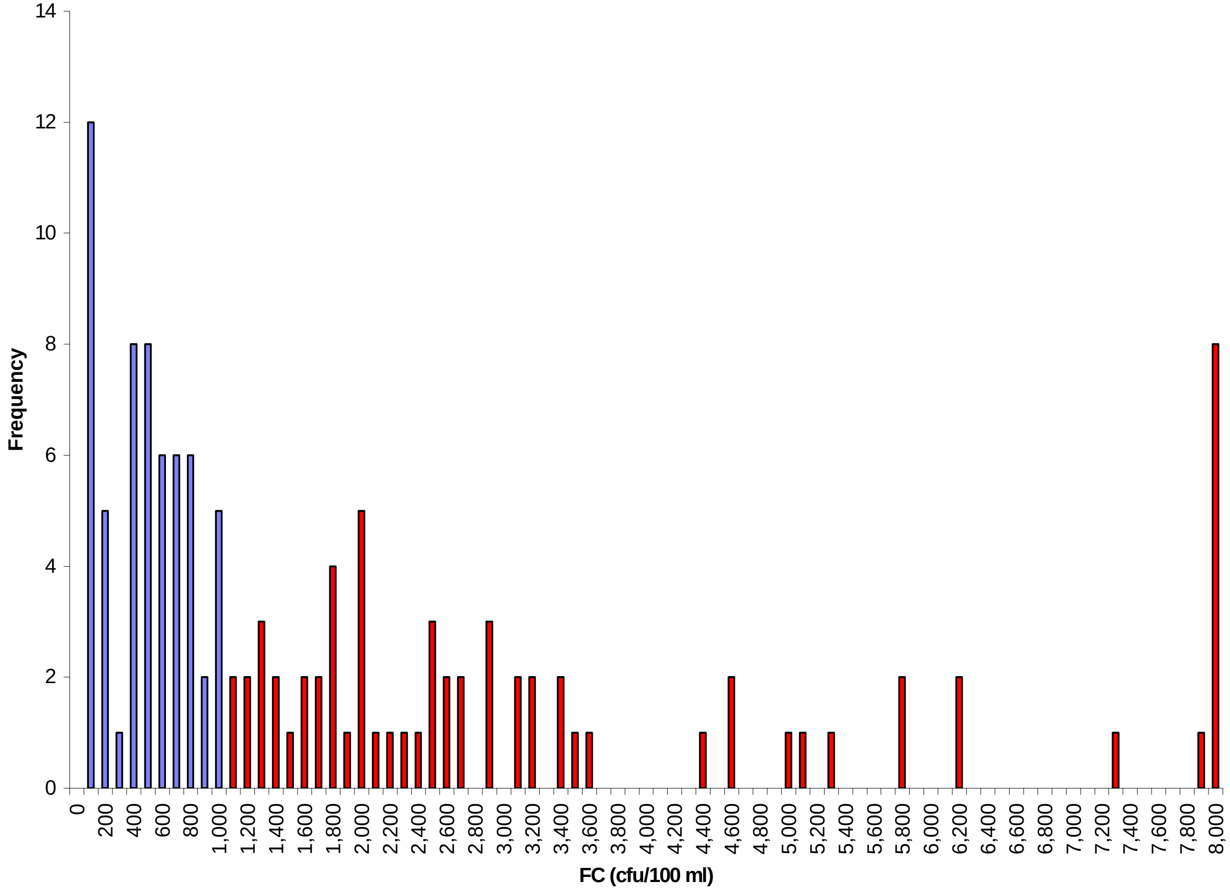

Figure A.6 Frequency analysis of fecal coliform concentrations at station 1BLEW002.91 in the Middle River impairment for period September 1991 to July 2002.

*Red indicates a value which violates the listing standard of 1,000 cfu/100 ml.

Figure A.7 Frequency analysis of fecal coliform concentrations at station 1BEKR000.25 in the Middle River impairment for period August 2001 to July 2002.

*Red indicates a value which violates the listing standard of 1,000 cfu/100 ml.

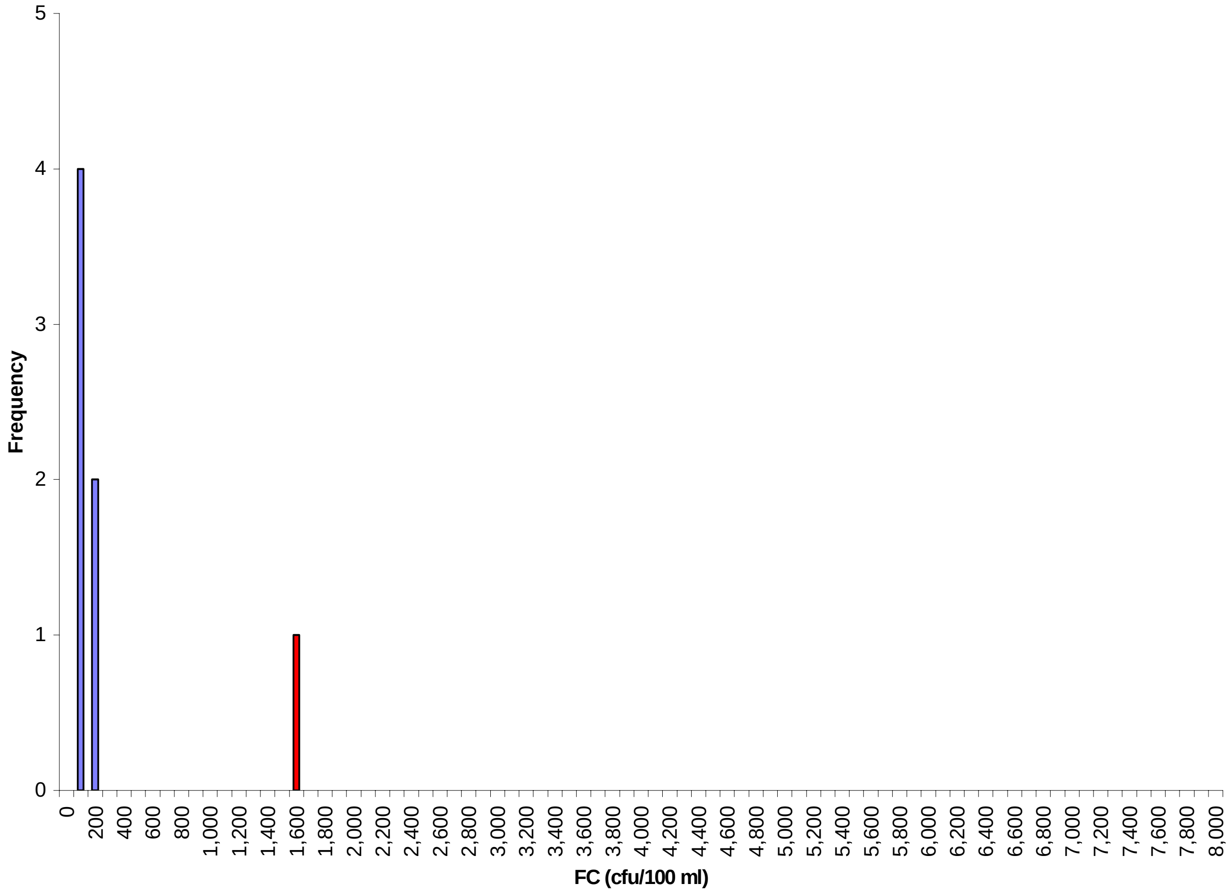

Figure A.8 Frequency analysis of fecal coliform concentrations at station 1BMFT001.43 in the Middle River impairment for the period August 2001 to July 2002.

*Red indicates a value which violates the listing standard of 1,000 cfu/100 ml.

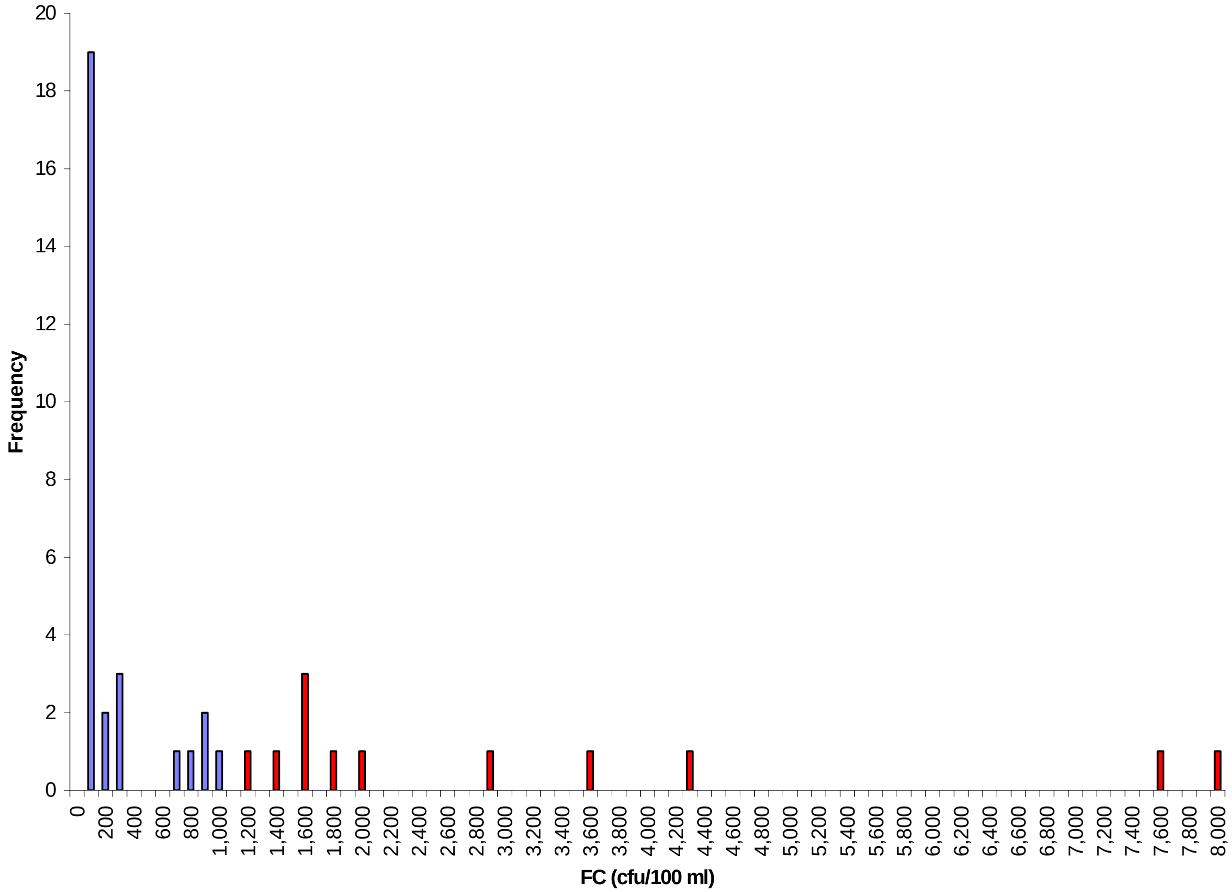

Figure A.9 Frequency analysis of fecal coliform concentrations at station 1BMFT006.20 in the Middle River impairment for the period February 1992 to June 2001.

*Red indicates a value which violates the listing standard of 1,000 cfu/100 ml.

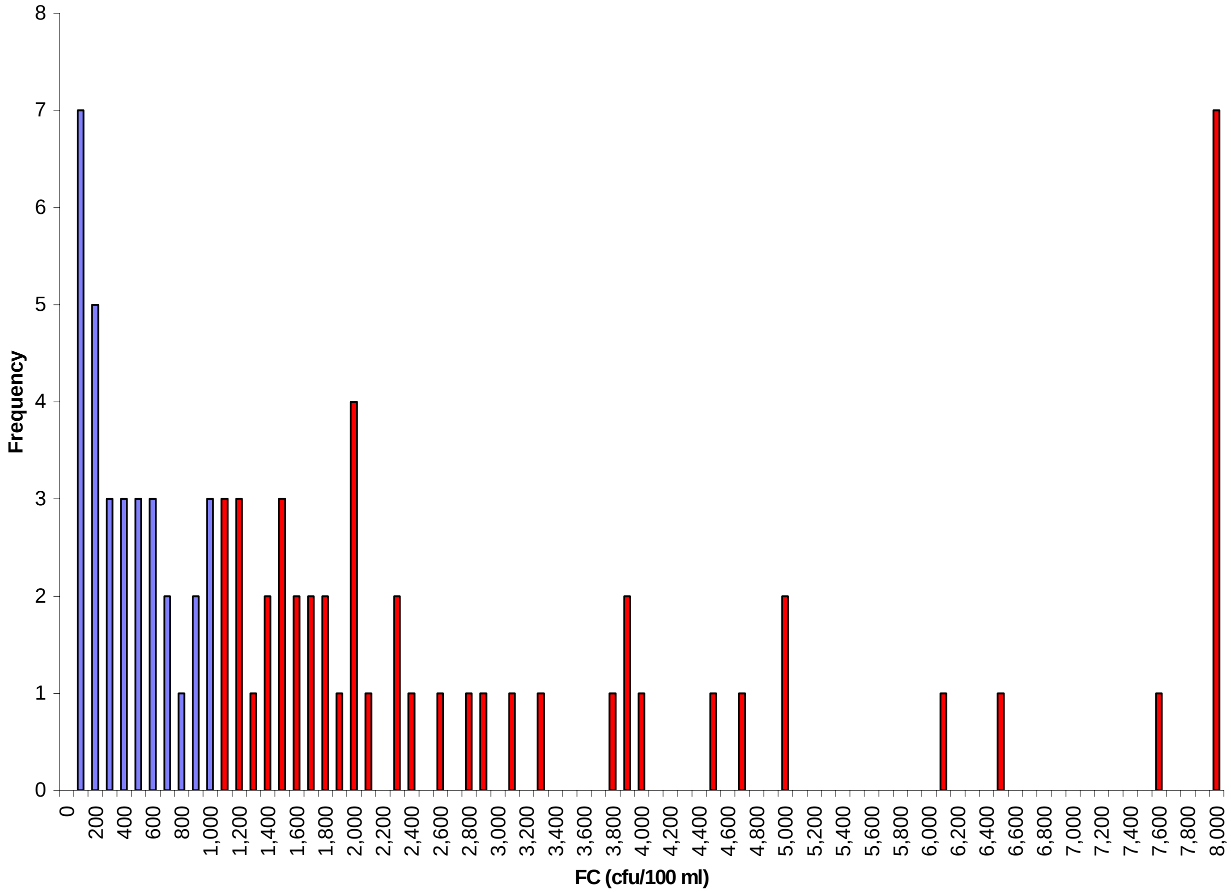

Figure A.10 Frequency analysis of fecal coliform concentrations at station 1BPCD001.03 in the Middle River impairment for period June 1993 to October 2000.

*Red indicates a value which violates the listing standard of 1,000 cfu/100 ml.

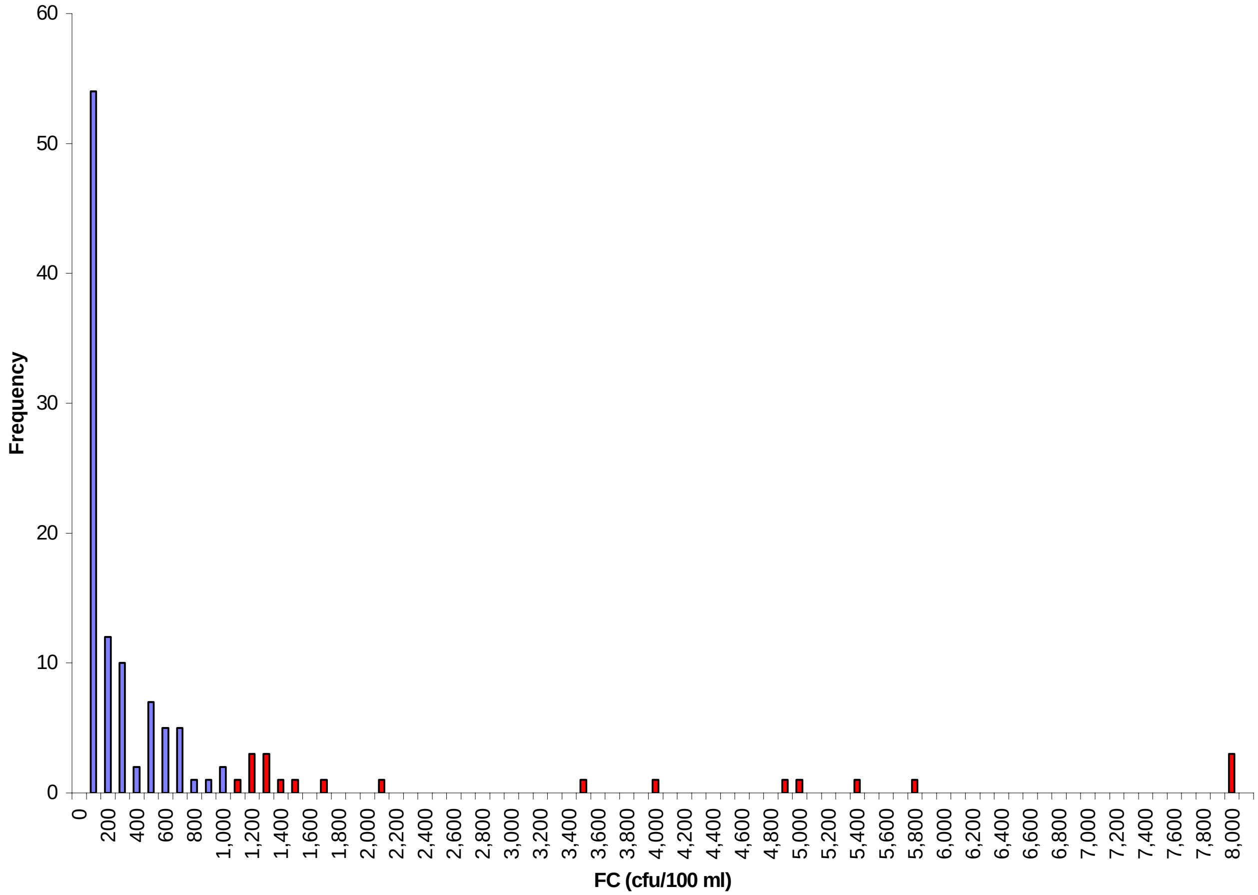

Figure A.11 Frequency analysis of fecal coliform concentrations at station 1BMDL001.83 in the Middle River impairment for period January 1990 to July 2002.

*Red indicates a value which violates the listing standard of 1,000 cfu/100 ml.

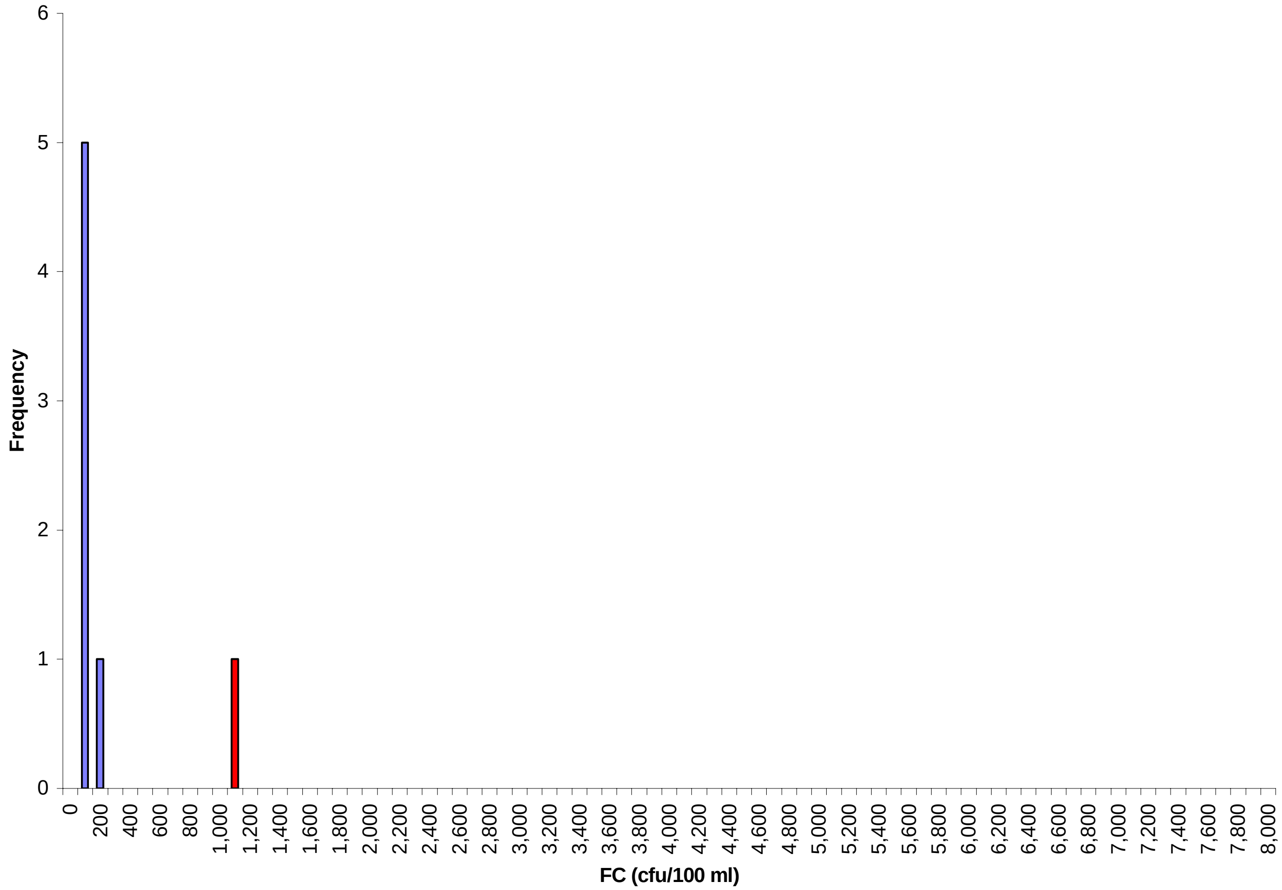

Figure A.12 Frequency analysis of fecal coliform concentrations at station 1BPNE000.04 in the Middle River impairment for period August 2001 to July 2002.

*Red indicates a value which violates the listing standard of 1,000 cfu/100 ml.

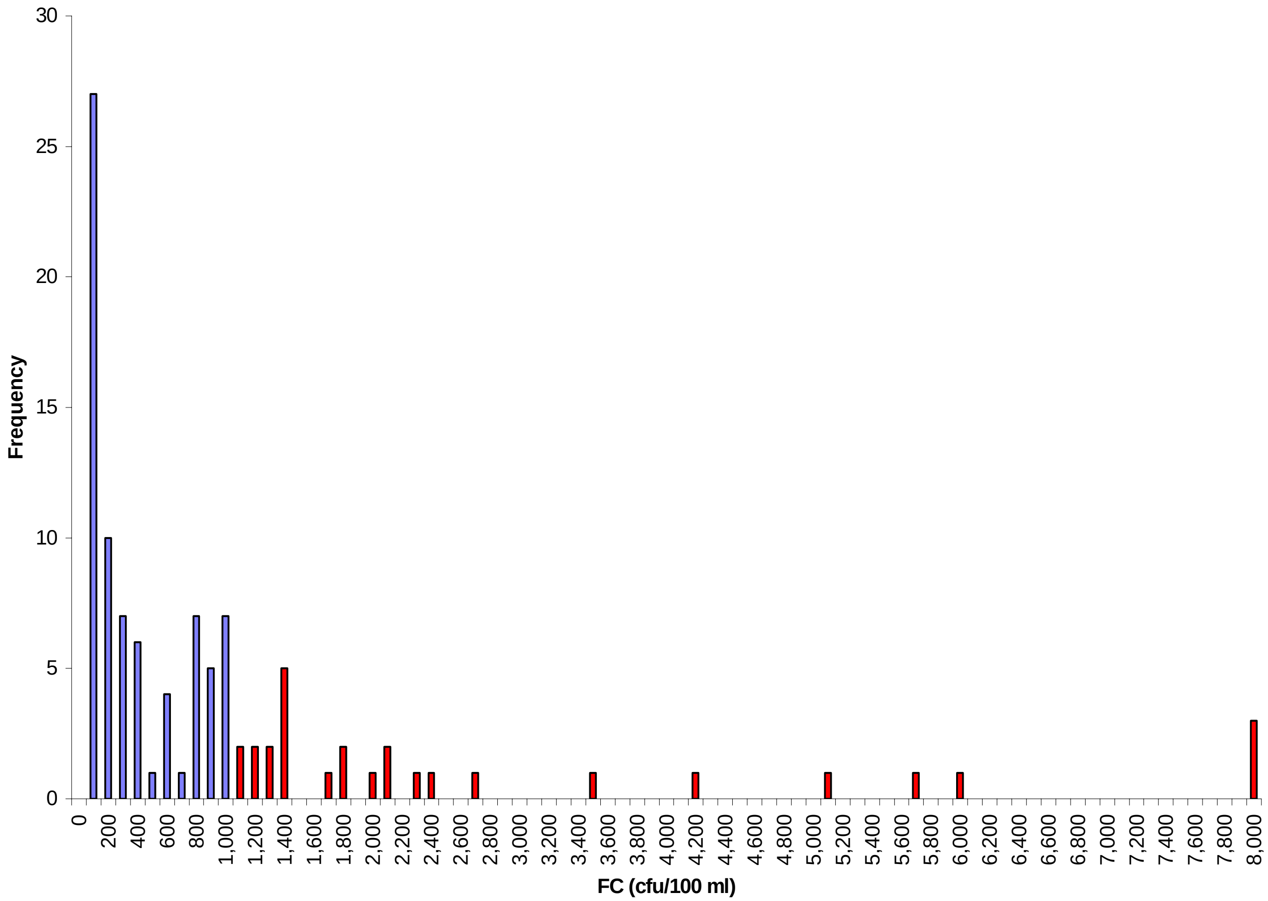

Figure A.13 Frequency analysis of fecal coliform concentrations at station 1BSTH041.68 in the Middle River impairment for period July 1991 to July 2002.

*Red indicates a value which violates the listing standard of 1,000 cfu/100 ml.

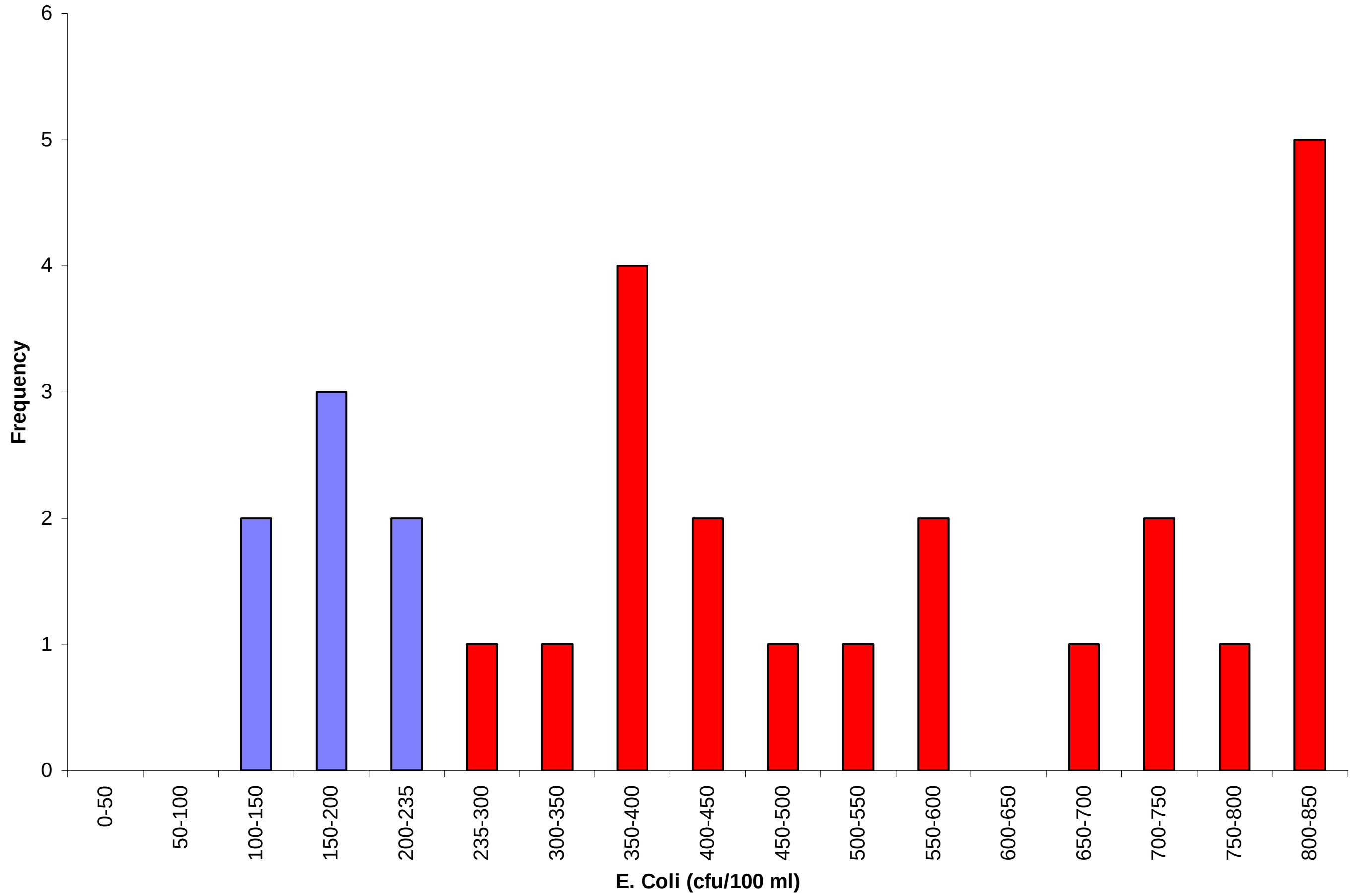

Figure A.14 Frequency analysis of *E. Coli* concentrations at station 1BLEW002.91 in the Middle River impairment for period January 2000 to July 2002.

*Red indicates a value which violates the listing standard of 1,000 cfu/100 ml.

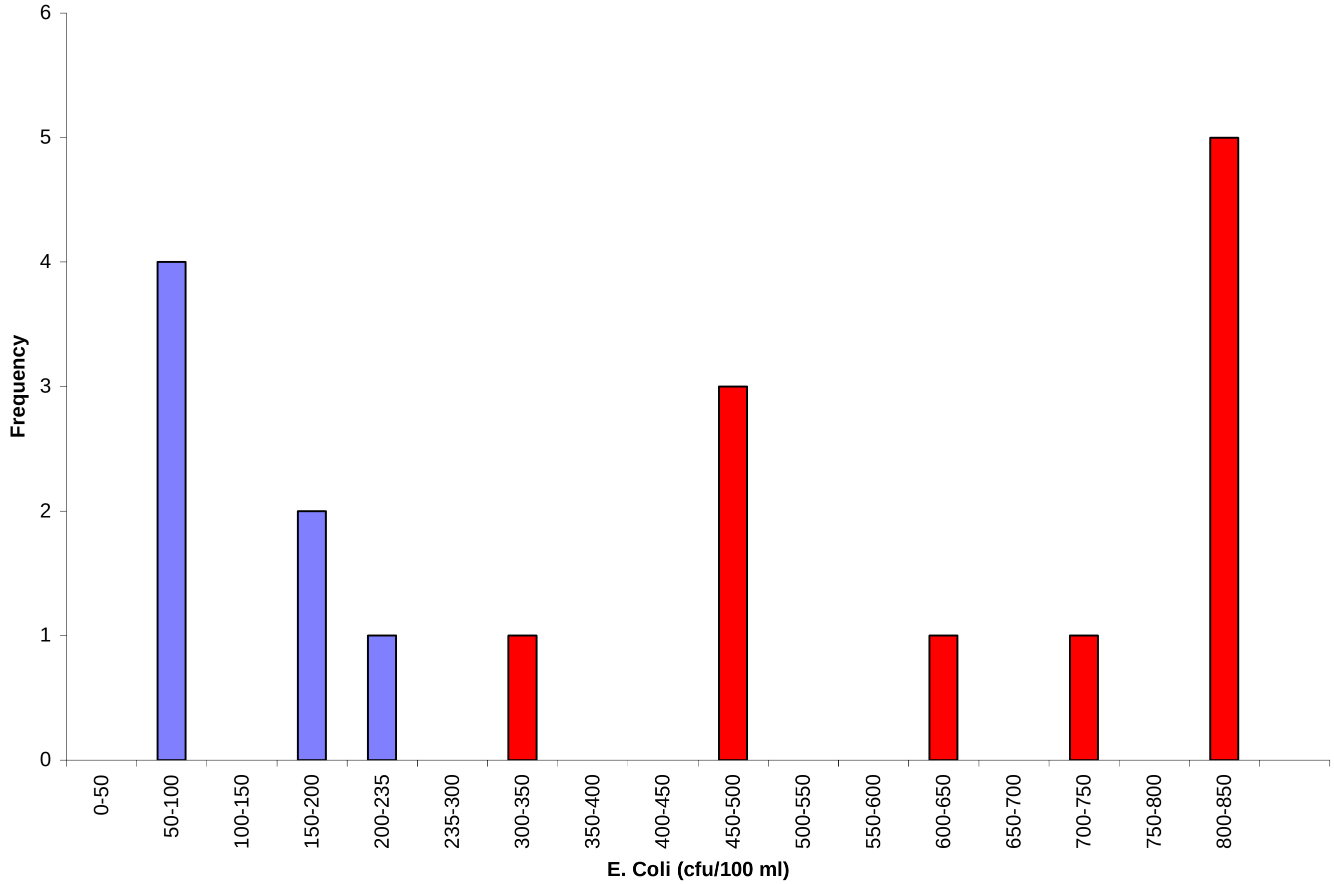

Figure A.15 Frequency analysis of *E. coli* concentrations at station 1BMDL060.48 in the Middle River impairment for period January 2000 to August 2002.

*Red indicates a value which violates the listing standard of 1,000 cfu/100 ml.

APPENDIX B

FECAL COLIFORM LOADS IN EXISTING CONDITIONS

Table B.1 Current conditions (2003) of land applied fecal coliform load for the Upper Middle River impairment (Subsheds 1-10).

	Commercial (cfu/ac*day)	Cropland (cfu/ac*day)	Farmstead (cfu/ac*day)	Improved Pasture (cfu/ac*day)	Livestock Access (cfu/ac*day)
January	1.74E+08	4.31E+10	3.18E+09	1.26E+10	1.13E+10
February	1.74E+08	5.05E+10	3.11E+09	1.43E+10	1.17E+10
March	1.74E+08	4.78E+11	2.97E+09	1.64E+10	1.46E+10
April	1.74E+08	4.78E+11	2.90E+09	1.71E+10	1.79E+10
May	1.74E+08	4.77E+11	2.83E+09	1.63E+10	1.79E+10
June	1.74E+08	1.58E+09	2.76E+09	2.80E+10	2.09E+10
July	1.74E+08	1.57E+09	2.63E+09	2.84E+10	2.09E+10
August	1.74E+08	1.57E+09	2.63E+09	2.84E+10	2.09E+10
September	1.74E+08	1.42E+11	2.63E+09	1.75E+10	1.79E+10
October	1.74E+08	4.77E+11	2.56E+09	1.73E+10	1.46E+10
November	1.74E+08	4.77E+11	2.63E+09	1.56E+10	1.40E+10
December	1.74E+08	4.31E+10	2.90E+09	1.39E+10	1.13E+10

Table B.1 Current conditions (2003) of land applied fecal coliform load for the Upper Middle River impairment (Subsheds 1-10) (Continued).

	Livestock Operation (cfu/ac*day)	Residential (cfu/ac*day)	Unimproved Pasture (cfu/ac*day)	Water (cfu/ac*day)	Woodland (cfu/ac*day)
January	4.63E+09	2.72E+10	1.29E+10	6.95E+03	1.25E+09
February	4.63E+09	2.66E+10	1.46E+10	6.95E+03	1.25E+09
March	4.63E+09	2.55E+10	1.67E+10	6.95E+03	1.25E+09
April	4.63E+09	2.49E+10	1.73E+10	6.95E+03	1.25E+09
May	4.63E+09	2.43E+10	1.65E+10	6.95E+03	1.25E+09
June	4.63E+09	2.37E+10	1.66E+10	6.95E+03	1.25E+09
July	4.63E+09	2.26E+10	1.70E+10	6.95E+03	1.25E+09
August	4.63E+09	2.26E+10	1.70E+10	6.95E+03	1.25E+09
September	4.63E+09	2.26E+10	1.77E+10	6.95E+03	1.25E+09
October	4.63E+09	2.20E+10	1.76E+10	6.95E+03	1.25E+09
November	4.63E+09	2.26E+10	1.58E+10	6.95E+03	1.25E+09
December	4.63E+09	2.49E+10	1.42E+10	6.95E+03	1.25E+09

Table B.2 Current conditions (2003) of land applied fecal coliform load for the Jennings Branch watershed (non-impaired) (Subsheds 11-12).

	Commercial (cfu/ac*day)	Cropland (cfu/ac*day)	Farmstead (cfu/ac*day)	Improved Pasture (cfu/ac*day)	Livestock Access (cfu/ac*day)
January	8.09E+07	2.56E+08	7.72E+08	1.31E+09	1.58E+09
February	8.09E+07	6.22E+08	7.56E+08	1.82E+09	1.62E+09
March	8.09E+07	1.97E+09	7.23E+08	3.15E+09	1.74E+09
April	8.09E+07	1.67E+09	7.06E+08	2.84E+09	1.90E+09
May	8.09E+07	5.99E+08	6.90E+08	1.77E+09	1.90E+09
June	8.09E+07	6.10E+08	6.74E+08	1.77E+09	2.01E+09
July	8.09E+07	5.99E+08	6.41E+08	1.75E+09	2.01E+09
August	8.09E+07	5.99E+08	6.41E+08	1.75E+09	2.01E+09
September	8.09E+07	9.64E+08	6.41E+08	2.13E+09	1.90E+09
October	8.09E+07	9.42E+08	6.24E+08	2.13E+09	1.74E+09
November	8.09E+07	9.64E+08	6.41E+08	2.00E+09	1.68E+09
December	8.09E+07	2.56E+08	7.06E+08	1.31E+09	1.58E+09

Table B.2 Current conditions (2003) of land applied fecal coliform load for the Jennings Branch watershed (non-impaired) (Subsheds 11-12) (Continued).

	Livestock Operation (cfu/ac*day)	Residential (cfu/ac*day)	Unimproved Pasture (cfu/ac*day)	Water (cfu/ac*day)	Woodland (cfu/ac*day)
January	5.45E+07	2.62E+09	1.32E+09	9.72E+02	2.58E+08
February	5.45E+07	2.57E+09	1.83E+09	9.72E+02	2.58E+08
March	5.45E+07	2.48E+09	3.17E+09	9.72E+02	2.58E+08
April	5.45E+07	2.43E+09	2.85E+09	9.72E+02	2.58E+08
May	5.45E+07	2.38E+09	1.78E+09	9.72E+02	2.58E+08
June	5.45E+07	2.33E+09	1.78E+09	9.72E+02	2.58E+08
July	5.45E+07	2.23E+09	1.77E+09	9.72E+02	2.58E+08
August	5.45E+07	2.23E+09	1.77E+09	9.72E+02	2.58E+08
September	5.45E+07	2.23E+09	2.15E+09	9.72E+02	2.58E+08
October	5.45E+07	2.19E+09	2.14E+09	9.72E+02	2.58E+08
November	5.45E+07	2.23E+09	2.02E+09	9.72E+02	2.58E+08
December	5.45E+07	2.43E+09	1.32E+09	9.72E+02	2.58E+08

Table B.3 Current conditions (2003) of land applied fecal coliform load for the Moffett Creek impairment (Subsheds 13-17).

	Commercial (cfu/ac*day)	Cropland (cfu/ac*day)	Farmstead (cfu/ac*day)	Improved Pasture (cfu/ac*day)	Livestock Access (cfu/ac*day)
January	9.54E+06	2.74E+10	2.38E+09	4.78E+09	3.30E+09
February	9.54E+06	3.29E+10	2.32E+09	6.00E+09	3.34E+09
March	9.54E+06	3.10E+11	2.20E+09	9.99E+09	4.37E+09
April	9.54E+06	3.09E+11	2.14E+09	9.32E+09	5.43E+09
May	9.54E+06	3.06E+11	2.08E+09	6.33E+09	5.43E+09
June	9.54E+06	1.58E+09	2.02E+09	1.01E+10	6.46E+09
July	9.54E+06	1.54E+09	1.91E+09	1.01E+10	6.46E+09
August	9.54E+06	1.54E+09	1.91E+09	1.01E+10	6.46E+09
September	9.54E+06	9.21E+10	1.91E+09	7.60E+09	5.43E+09
October	9.54E+06	3.07E+11	1.85E+09	7.59E+09	4.37E+09
November	9.54E+06	3.07E+11	1.91E+09	7.36E+09	4.31E+09
December	9.54E+06	2.74E+10	2.14E+09	5.12E+09	3.30E+09

Table B.3 Current conditions (2003) of land applied fecal coliform load for the Moffett Creek impairment (Subsheds 13-17) (Continued).

	Livestock Operation (cfu/ac*day)	Residential (cfu/ac*day)	Unimproved Pasture (cfu/ac*day)	Water (cfu/ac*day)	Woodland (cfu/ac*day)
January	8.54E+07	1.05E+10	4.83E+09	6.57E+02	4.92E+08
February	8.54E+07	1.03E+10	6.06E+09	6.57E+02	4.92E+08
March	8.54E+07	9.85E+09	1.00E+10	6.57E+02	4.92E+08
April	8.54E+07	9.62E+09	9.37E+09	6.57E+02	4.92E+08
May	8.54E+07	9.39E+09	6.39E+09	6.57E+02	4.92E+08
June	8.54E+07	9.16E+09	6.41E+09	6.57E+02	4.92E+08
July	8.54E+07	8.71E+09	6.48E+09	6.57E+02	4.92E+08
August	8.54E+07	8.71E+09	6.48E+09	6.57E+02	4.92E+08
September	8.54E+07	8.71E+09	7.65E+09	6.57E+02	4.92E+08
October	8.54E+07	8.48E+09	7.64E+09	6.57E+02	4.92E+08
November	8.54E+07	8.71E+09	7.41E+09	6.57E+02	4.92E+08
December	8.54E+07	9.62E+09	5.18E+09	6.57E+02	4.92E+08

Table B.4 Current conditions (2003) of land applied fecal coliform load for the Lewis Creek impairment (Subsheds 18-25).

	Commercial (cfu/ac*day)	Cropland (cfu/ac*day)	Farmstead (cfu/ac*day)	Improved Pasture (cfu/ac*day)	Livestock Access (cfu/ac*day)
January	2.13E+08	2.35E+11	1.39E+09	5.35E+09	6.54E+09
February	2.13E+08	2.75E+11	1.37E+09	5.69E+09	6.56E+09
March	2.13E+08	2.66E+12	1.35E+09	6.84E+09	7.75E+09
April	2.13E+08	2.66E+12	1.34E+09	6.87E+09	8.93E+09
May	2.13E+08	2.66E+12	1.33E+09	6.21E+09	8.93E+09
June	2.13E+08	1.09E+09	1.32E+09	1.01E+10	1.01E+10
July	2.13E+08	1.08E+09	1.29E+09	1.02E+10	1.01E+10
August	2.13E+08	1.08E+09	1.29E+09	1.02E+10	1.01E+10
September	2.13E+08	7.83E+11	1.29E+09	6.74E+09	8.93E+09
October	2.13E+08	2.66E+12	1.28E+09	6.76E+09	7.75E+09
November	2.13E+08	2.66E+12	1.29E+09	6.55E+09	7.73E+09
December	2.13E+08	2.35E+11	1.34E+09	5.77E+09	6.54E+09

Table B.4 Current conditions (2003) of land applied fecal coliform load for the Lewis Creek impairment (Subsheds 18-25) (Continued).

	Livestock Operation (cfu/ac*day)	Residential (cfu/ac*day)	Unimproved Pasture (cfu/ac*day)	Water (cfu/ac*day)	Woodland (cfu/ac*day)
January	5.33E+06	8.84E+09	2.11E+09	6.50E+02	8.93E+08
February	5.33E+06	8.74E+09	2.13E+09	6.50E+02	8.93E+08
March	5.33E+06	8.54E+09	2.19E+09	6.50E+02	8.93E+08
April	5.33E+06	8.44E+09	2.33E+09	6.50E+02	8.93E+08
May	5.33E+06	8.34E+09	2.42E+09	6.50E+02	8.93E+08
June	5.33E+06	8.24E+09	2.43E+09	6.50E+02	8.93E+08
July	5.33E+06	8.04E+09	2.49E+09	6.50E+02	8.93E+08
August	5.33E+06	8.04E+09	2.49E+09	6.50E+02	8.93E+08
September	5.33E+06	8.04E+09	2.55E+09	6.50E+02	8.93E+08
October	5.33E+06	7.94E+09	2.57E+09	6.50E+02	8.93E+08
November	5.33E+06	8.04E+09	2.45E+09	6.50E+02	8.93E+08
December	5.33E+06	8.44E+09	2.33E+09	6.50E+02	8.93E+08

Table B.5 Current conditions (2003) of land applied fecal coliform load for the Middle River watershed (non-impaired) (Subsheds 26-32).

	Commercial (cfu/ac*day)	Cropland (cfu/ac*day)	Farmstead (cfu/ac*day)	Improved Pasture (cfu/ac*day)	Livestock Access (cfu/ac*day)
January	2.03E+07	2.45E+10	1.39E+09	5.95E+09	6.51E+09
February	2.03E+07	2.94E+10	1.37E+09	7.30E+09	6.63E+09
March	2.03E+07	2.71E+11	1.31E+09	1.11E+10	7.86E+09
April	2.03E+07	2.70E+11	1.29E+09	1.04E+10	9.19E+09
May	2.03E+07	2.67E+11	1.26E+09	7.54E+09	9.19E+09
June	2.03E+07	2.09E+09	1.23E+09	1.03E+10	1.04E+10
July	2.03E+07	2.06E+09	1.18E+09	1.03E+10	1.04E+10
August	2.03E+07	2.06E+09	1.18E+09	1.03E+10	1.04E+10
September	2.03E+07	8.10E+10	1.18E+09	8.73E+09	9.19E+09
October	2.03E+07	2.68E+11	1.15E+09	8.74E+09	7.86E+09
November	2.03E+07	2.68E+11	1.18E+09	8.37E+09	7.69E+09
December	2.03E+07	2.45E+10	1.29E+09	6.25E+09	6.51E+09

Table B.5 Current conditions (2003) of land applied fecal coliform load for the Middle River watershed (non-impaired) (Subsheds 26-32) (Continued).

	Livestock Operation (cfu/ac*day)	Residential (cfu/ac*day)	Unimproved Pasture (cfu/ac*day)	Water (cfu/ac*day)	Woodland (cfu/ac*day)
January	5.33E+08	1.77E+10	4.13E+09	1.08E+03	1.25E+09
February	5.33E+08	1.73E+10	5.35E+09	1.08E+03	1.25E+09
March	5.33E+08	1.65E+10	8.73E+09	1.08E+03	1.25E+09
April	5.33E+08	1.61E+10	8.05E+09	1.08E+03	1.25E+09
May	5.33E+08	1.57E+10	5.43E+09	1.08E+03	1.25E+09
June	5.33E+08	1.53E+10	5.43E+09	1.08E+03	1.25E+09
July	5.33E+08	1.45E+10	5.45E+09	1.08E+03	1.25E+09
August	5.33E+08	1.45E+10	5.45E+09	1.08E+03	1.25E+09
September	5.33E+08	1.45E+10	6.43E+09	1.08E+03	1.25E+09
October	5.33E+08	1.41E+10	6.43E+09	1.08E+03	1.25E+09
November	5.33E+08	1.45E+10	6.12E+09	1.08E+03	1.25E+09
December	5.33E+08	1.61E+10	4.28E+09	1.08E+03	1.25E+09

Table B.6 Current conditions (2003) of land applied fecal coliform load for the Polecat Draft impairment (Subshed 33).

	Cropland (cfu/ac*day)	Farmstead (cfu/ac*day)	Improved Pasture (cfu/ac*day)	Livestock Access (cfu/ac*day)	Livestock Operation (cfu/ac*day)
January	4.69E+09	4.15E+08	1.52E+09	1.80E+09	1.44E+07
February	5.88E+09	4.05E+08	2.09E+09	1.86E+09	1.44E+07
March	5.33E+10	3.84E+08	3.71E+09	2.39E+09	1.44E+07
April	5.30E+10	3.74E+08	3.41E+09	2.94E+09	1.44E+07
May	5.17E+10	3.64E+08	2.18E+09	2.94E+09	1.44E+07
June	5.99E+08	3.54E+08	3.10E+09	3.46E+09	1.44E+07
July	5.85E+08	3.33E+08	3.12E+09	3.46E+09	1.44E+07
August	5.85E+08	3.33E+08	3.12E+09	3.46E+09	1.44E+07
September	1.61E+10	3.33E+08	2.67E+09	2.94E+09	1.44E+07
October	5.21E+10	3.23E+08	2.66E+09	2.39E+09	1.44E+07
November	5.21E+10	3.33E+08	2.51E+09	2.30E+09	1.44E+07
December	4.69E+09	3.74E+08	1.62E+09	1.80E+09	1.44E+07

Table B.6 Current conditions (2003) of land applied fecal coliform load for the Polecat Draft impairment (Subshed 33) (Continued).

	Residential (cfu/ac*day)	Unimproved Pasture (cfu/ac*day)	Water (cfu/ac*day)	Woodland (cfu/ac*day)
January	2.97E+10	1.38E+09	0.00E+00	9.08E+07
February	2.90E+10	1.95E+09	0.00E+00	9.08E+07
March	2.75E+10	3.56E+09	0.00E+00	9.08E+07
April	2.68E+10	3.26E+09	0.00E+00	9.08E+07
May	2.60E+10	2.03E+09	0.00E+00	9.08E+07
June	2.53E+10	2.04E+09	0.00E+00	9.08E+07
July	2.38E+10	2.06E+09	0.00E+00	9.08E+07
August	2.38E+10	2.06E+09	0.00E+00	9.08E+07
September	2.38E+10	2.52E+09	0.00E+00	9.08E+07
October	2.31E+10	2.51E+09	0.00E+00	9.08E+07
November	2.38E+10	2.36E+09	0.00E+00	9.08E+07
December	2.68E+10	1.48E+09	0.00E+00	9.08E+07

Table B.7 Current conditions (2003) of land applied fecal coliform load for the Lower Middle River impairment (Subsheds 34-38).

	Commercial (cfu/ac*day)	Cropland (cfu/ac*day)	Farmstead (cfu/ac*day)	Improved Pasture (cfu/ac*day)	Livestock Access (cfu/ac*day)
January	7.76E+07	2.52E+10	8.94E+08	1.32E+10	7.74E+09
February	7.76E+07	3.02E+10	8.75E+08	1.47E+10	7.95E+09
March	7.76E+07	2.84E+11	8.38E+08	1.82E+10	1.15E+10
April	7.76E+07	2.84E+11	8.19E+08	1.81E+10	1.51E+10
May	7.76E+07	2.81E+11	8.00E+08	1.61E+10	1.51E+10
June	7.76E+07	1.37E+09	7.81E+08	2.66E+10	1.87E+10
July	7.76E+07	1.34E+09	7.43E+08	2.69E+10	1.87E+10
August	7.76E+07	1.34E+09	7.43E+08	2.69E+10	1.87E+10
September	7.76E+07	8.45E+10	7.43E+08	1.76E+10	1.51E+10
October	7.76E+07	2.82E+11	7.24E+08	1.77E+10	1.15E+10
November	7.76E+07	2.82E+11	7.43E+08	1.66E+10	1.12E+10
December	7.76E+07	2.52E+10	8.19E+08	1.44E+10	7.74E+09

Table B.7 Current conditions (2003) of land applied fecal coliform load for the Lower Middle River impairment (Subsheds 34-38) (Continued).

	Livestock Operation (cfu/ac*day)	Residential (cfu/ac*day)	Unimproved Pasture (cfu/ac*day)	Water (cfu/ac*day)	Woodland (cfu/ac*day)
January	1.46E+07	4.17E+09	7.89E+09	1.23E+03	1.01E+09
February	1.46E+07	4.09E+09	9.30E+09	1.23E+03	1.01E+09
March	1.46E+07	3.94E+09	1.26E+10	1.23E+03	1.01E+09
April	1.46E+07	3.87E+09	1.22E+10	1.23E+03	1.01E+09
May	1.46E+07	3.79E+09	9.89E+09	1.23E+03	1.01E+09
June	1.46E+07	3.72E+09	9.89E+09	1.23E+03	1.01E+09
July	1.46E+07	3.57E+09	1.00E+10	1.23E+03	1.01E+09
August	1.46E+07	3.57E+09	1.00E+10	1.23E+03	1.01E+09
September	1.46E+07	3.57E+09	1.11E+10	1.23E+03	1.01E+09
October	1.46E+07	3.50E+09	1.11E+10	1.23E+03	1.01E+09
November	1.46E+07	3.57E+09	1.04E+10	1.23E+03	1.01E+09
December	1.46E+07	3.87E+09	8.46E+09	1.23E+03	1.01E+09

Table B.8 Current conditions (2003) of land applied fecal coliform load for the South River impairment (Subsheds 39-44).

	Commercial (cfu/ac*day)	Cropland (cfu/ac*day)	Farmstead (cfu/ac*day)	Improved Pasture (cfu/ac*day)	Livestock Access (cfu/ac*day)
January	3.70E+08	1.27E+10	1.49E+09	5.85E+09	5.39E+09
February	3.70E+08	1.52E+10	1.45E+09	6.89E+09	5.55E+09
March	3.70E+08	1.36E+11	1.39E+09	8.72E+09	6.46E+09
April	3.70E+08	1.36E+11	1.35E+09	8.41E+09	7.48E+09
May	3.70E+08	1.34E+11	1.32E+09	7.06E+09	7.48E+09
June	3.70E+08	1.47E+09	1.29E+09	9.27E+09	8.38E+09
July	3.70E+08	1.46E+09	1.22E+09	9.32E+09	8.38E+09
August	3.70E+08	1.46E+09	1.22E+09	9.32E+09	8.38E+09
September	3.70E+08	4.10E+10	1.22E+09	7.69E+09	7.48E+09
October	3.70E+08	1.35E+11	1.18E+09	7.74E+09	6.46E+09
November	3.70E+08	1.35E+11	1.22E+09	7.13E+09	6.22E+09
December	3.70E+08	1.27E+10	1.35E+09	6.08E+09	5.39E+09

Table B.8 Current conditions (2003) of land applied fecal coliform load for the South River impairment (Subsheds 39-44) (Continued).

	Livestock Operation (cfu/ac*day)	Residential (cfu/ac*day)	Unimproved Pasture (cfu/ac*day)	Water (cfu/ac*day)	Woodland (cfu/ac*day)
January	1.91E+08	5.28E+09	6.06E+09	3.09E+03	9.35E+08
February	1.91E+08	5.18E+09	7.10E+09	3.09E+03	9.35E+08
March	1.91E+08	4.99E+09	8.93E+09	3.09E+03	9.35E+08
April	1.91E+08	4.89E+09	8.62E+09	3.09E+03	9.35E+08
May	1.91E+08	4.79E+09	7.27E+09	3.09E+03	9.35E+08
June	1.91E+08	4.69E+09	7.24E+09	3.09E+03	9.35E+08
July	1.91E+08	4.49E+09	7.30E+09	3.09E+03	9.35E+08
August	1.91E+08	4.49E+09	7.30E+09	3.09E+03	9.35E+08
September	1.91E+08	4.49E+09	7.90E+09	3.09E+03	9.35E+08
October	1.91E+08	4.39E+09	7.95E+09	3.09E+03	9.35E+08
November	1.91E+08	4.49E+09	7.34E+09	3.09E+03	9.35E+08
December	1.91E+08	4.89E+09	6.29E+09	3.09E+03	9.35E+08

Table B.9 Monthly, directly deposited fecal coliform loads in each reach of the Upper Middle River impairment (subsheds 1-10).

Reach	Source	Jan (cfu/day)	Feb (cfu/day)	Mar (cfu/day)	Apr (cfu/day)	May (cfu/day)	Jun (cfu/day)
1	Human	1.18E+08	1.18E+08	1.18E+08	1.18E+08	1.18E+08	1.18E+08
	Livestock	1.19E+11	1.23E+11	2.08E+11	3.02E+11	3.02E+11	3.88E+11
	Wildlife	2.95E+10	2.95E+10	2.95E+10	2.95E+10	2.95E+10	2.95E+10
2	Human	2.07E+08	2.07E+08	2.07E+08	2.07E+08	2.07E+08	2.07E+08
	Livestock	1.50E+10	1.94E+10	2.77E+10	3.88E+10	3.88E+10	4.72E+10
	Wildlife	1.67E+10	1.67E+10	1.67E+10	1.67E+10	1.67E+10	1.67E+10
3	Human	3.01E+08	3.01E+08	3.01E+08	3.01E+08	3.01E+08	3.01E+08
	Livestock	2.48E+10	3.19E+10	4.56E+10	6.38E+10	6.38E+10	7.75E+10
	Wildlife	1.82E+10	1.82E+10	1.82E+10	1.82E+10	1.82E+10	1.82E+10
4	Human	2.72E+07	2.72E+07	2.72E+07	2.72E+07	2.72E+07	2.72E+07
	Livestock	4.12E+10	4.36E+10	7.28E+10	1.02E+11	1.02E+11	1.32E+11
	Wildlife	3.84E+09	3.84E+09	3.84E+09	3.84E+09	3.84E+09	3.84E+09
5	Human	3.52E+08	3.52E+08	3.52E+08	3.52E+08	3.52E+08	3.52E+08
	Livestock	1.14E+10	1.39E+10	1.99E+10	2.79E+10	2.79E+10	3.39E+10
	Wildlife	8.96E+09	8.96E+09	8.96E+09	8.96E+09	8.96E+09	8.96E+09
6	Human	1.22E+09	1.22E+09	1.22E+09	1.22E+09	1.22E+09	1.22E+09
	Livestock	1.79E+10	2.33E+10	3.33E+10	6.34E+10	6.34E+10	7.70E+10
	Wildlife	2.67E+10	2.67E+10	2.67E+10	2.67E+10	2.67E+10	2.67E+10
7	Human	7.71E+07	7.71E+07	7.71E+07	7.71E+07	7.71E+07	7.71E+07
	Livestock	1.42E+09	1.70E+09	2.97E+09	4.35E+09	4.35E+09	5.62E+09
	Wildlife	3.64E+09	3.64E+09	3.64E+09	3.64E+09	3.64E+09	3.64E+09
8	Human	2.98E+07	2.98E+07	2.98E+07	2.98E+07	2.98E+07	2.98E+07
	Livestock	0.00E+00	1.40E+08	2.00E+08	2.80E+08	2.80E+08	3.40E+08
	Wildlife	4.81E+09	4.81E+09	4.81E+09	4.81E+09	4.81E+09	4.81E+09
9	Human	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09
	Livestock	2.45E+09	3.18E+09	4.54E+09	7.39E+09	7.39E+09	8.97E+09
	Wildlife	4.60E+10	4.60E+10	4.60E+10	4.60E+10	4.60E+10	4.60E+10
10	Human	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Livestock	4.96E+09	5.70E+09	8.14E+09	1.14E+10	1.14E+10	1.38E+10
	Wildlife	9.03E+09	9.03E+09	9.03E+09	9.03E+09	9.03E+09	9.03E+09

Table B.9 Monthly, directly deposited fecal coliform loads in each reach of the Upper Middle River impairment (subsheds 1-10) cont.

Reach	Source	Jul (cfu/day)	Aug (cfu/day)	Sep (cfu/day)	Oct (cfu/day)	Nov (cfu/day)	Dec (cfu/day)
1	Human	1.18E+08	1.18E+08	1.18E+08	1.18E+08	1.18E+08	1.18E+08
	Livestock	3.88E+11	3.88E+11	3.02E+11	2.08E+11	2.03E+11	1.19E+11
	Wildlife	2.95E+10	2.95E+10	2.95E+10	2.95E+10	2.95E+10	2.95E+10
2	Human	2.07E+08	2.07E+08	2.07E+08	2.07E+08	2.07E+08	2.07E+08
	Livestock	4.72E+10	4.72E+10	3.88E+10	2.77E+10	2.14E+10	1.50E+10
	Wildlife	1.67E+10	1.67E+10	1.67E+10	1.67E+10	1.67E+10	1.67E+10
3	Human	3.01E+08	3.01E+08	3.01E+08	3.01E+08	3.01E+08	3.01E+08
	Livestock	7.75E+10	7.75E+10	6.38E+10	4.56E+10	3.55E+10	2.48E+10
	Wildlife	1.82E+10	1.82E+10	1.82E+10	1.82E+10	1.82E+10	2.00E+10
4	Human	2.72E+07	2.72E+07	2.72E+07	2.72E+07	2.72E+07	2.72E+07
	Livestock	1.32E+11	1.32E+11	1.02E+11	7.28E+10	6.94E+10	4.12E+10
	Wildlife	3.84E+09	3.84E+09	3.84E+09	3.84E+09	3.84E+09	3.84E+09
5	Human	3.52E+08	3.52E+08	3.52E+08	3.52E+08	3.52E+08	3.52E+08
	Livestock	3.39E+10	3.39E+10	2.79E+10	1.99E+10	1.63E+10	1.14E+10
	Wildlife	8.96E+09	8.96E+09	8.96E+09	8.96E+09	8.96E+09	8.96E+09
6	Human	1.22E+09	1.22E+09	1.22E+09	1.22E+09	1.22E+09	1.22E+09
	Livestock	7.70E+10	7.70E+10	6.34E+10	3.33E+10	2.56E+10	1.79E+10
	Wildlife	2.67E+10	2.67E+10	2.67E+10	2.67E+10	2.67E+10	2.67E+10
7	Human	7.71E+07	7.71E+07	7.71E+07	7.71E+07	7.71E+07	7.71E+07
	Livestock	5.62E+09	5.62E+09	4.35E+09	2.97E+09	2.57E+09	1.42E+09
	Wildlife	3.64E+09	3.64E+09	3.64E+09	3.64E+09	3.64E+09	3.64E+09
8	Human	2.98E+07	2.98E+07	2.98E+07	2.98E+07	2.98E+07	2.98E+07
	Livestock	3.40E+08	3.40E+08	2.80E+08	2.00E+08	0.00E+00	0.00E+00
	Wildlife	4.81E+09	4.81E+09	4.81E+09	4.81E+09	4.81E+09	4.81E+09
9	Human	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09	1.30E+09
	Livestock	8.97E+09	8.97E+09	7.39E+09	4.54E+09	3.50E+09	2.45E+09
	Wildlife	4.60E+10	4.60E+10	4.60E+10	4.60E+10	4.60E+10	4.60E+10
10	Human	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Livestock	1.38E+10	1.38E+10	1.14E+10	8.14E+09	7.09E+09	4.96E+09
	Wildlife	9.03E+09	9.03E+09	9.03E+09	9.03E+09	9.03E+09	9.03E+09

Table B.10 Monthly, directly deposited fecal coliform loads in each reach of the Jennings Branch watershed (non-impaired) (subsheds 11-12).

Reach	Source	Jan (cfu/day)	Feb (cfu/day)	Mar (cfu/day)	Apr (cfu/day)	May (cfu/day)	Jun (cfu/day)
11	Human	1.60E+09	1.60E+09	1.60E+09	1.60E+09	1.60E+09	1.60E+09
	Livestock	1.23E+10	1.48E+10	2.11E+10	2.96E+10	2.96E+10	3.59E+10
	Wildlife	5.23E+10	5.23E+10	5.23E+10	5.23E+10	5.23E+10	5.23E+10
12	Human	4.49E+08	4.49E+08	4.49E+08	4.49E+08	4.49E+08	4.49E+08
	Livestock	3.84E+09	4.16E+09	5.94E+09	8.32E+09	8.32E+09	1.01E+10
	Wildlife	1.96E+10	1.96E+10	1.96E+10	1.96E+10	1.96E+10	1.96E+10
Reach	**Source**	**Jul (cfu/day)**	**Aug (cfu/day)**	**Sep (cfu/day)**	**Oct (cfu/day)**	**Nov (cfu/day)**	**Dec (cfu/day)**
11	Human	1.60E+09	1.60E+09	1.60E+09	1.60E+09	1.60E+09	1.60E+09
	Livestock	3.59E+10	3.59E+10	2.96E+10	2.11E+10	1.76E+10	1.23E+10
	Wildlife	5.23E+10	5.23E+10	5.23E+10	5.23E+10	5.23E+10	5.23E+10
12	Human	4.49E+08	4.49E+08	4.49E+08	4.49E+08	4.49E+08	4.49E+08
	Livestock	1.01E+10	1.01E+10	8.32E+09	5.94E+09	5.49E+09	3.84E+09
	Wildlife	1.96E+10	1.96E+10	1.96E+10	1.96E+10	1.96E+10	1.96E+10

Table B.11 Monthly, directly deposited fecal coliform loads in each reach of the Moffett Creek impairment (subsheds 13-17).

Reach	Source	Jan (cfu/day)	Feb (cfu/day)	Mar (cfu/day)	Apr (cfu/day)	May (cfu/day)	Jun (cfu/day)
13	Human	3.64E+07	3.64E+07	3.64E+07	3.64E+07	3.64E+07	3.64E+07
	Livestock	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Wildlife	1.03E+10	1.03E+10	1.03E+10	1.03E+10	1.03E+10	1.03E+10
14	Human	1.05E+08	1.05E+08	1.05E+08	1.05E+08	1.05E+08	1.05E+08
	Livestock	1.86E+10	1.86E+10	3.40E+10	4.95E+10	4.95E+10	6.49E+10
	Wildlife	7.11E+09	7.11E+09	7.11E+09	7.11E+09	7.11E+09	7.11E+09
15	Human	2.66E+08	2.66E+08	2.66E+08	2.66E+08	2.66E+08	2.66E+08
	Livestock	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Wildlife	8.65E+09	8.65E+09	8.65E+09	8.65E+09	8.65E+09	8.65E+09
16	Human	2.54E+08	2.54E+08	2.54E+08	2.54E+08	2.54E+08	2.54E+08
	Livestock	4.36E+10	4.45E+10	8.00E+10	1.16E+11	1.16E+11	1.52E+11
	Wildlife	1.20E+10	1.20E+10	1.20E+10	1.20E+10	1.20E+10	1.20E+10
17	Human	1.77E+08	1.77E+08	1.77E+08	1.77E+08	1.77E+08	1.77E+08
	Livestock	1.84E+10	2.01E+10	3.47E+10	5.03E+10	5.03E+10	6.50E+10
	Wildlife	1.23E+10	1.23E+10	1.23E+10	1.23E+10	1.23E+10	1.23E+10

Reach	Source	Jul (cfu/day)	Aug (cfu/day)	Sep (cfu/day)	Oct (cfu/day)	Nov (cfu/day)	Dec (cfu/day)
13	Human	3.64E+07	3.64E+07	3.64E+07	3.64E+07	3.64E+07	3.64E+07
	Livestock	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Wildlife	1.03E+10	1.03E+10	1.03E+10	1.03E+10	1.03E+10	1.03E+10
14	Human	1.05E+08	1.05E+08	1.05E+08	1.05E+08	1.05E+08	1.05E+08
	Livestock	6.49E+10	6.49E+10	4.95E+10	3.40E+10	3.40E+10	1.86E+10
	Wildlife	7.11E+09	7.11E+09	7.11E+09	7.11E+09	7.11E+09	7.11E+09
15	Human	2.66E+08	2.66E+08	2.66E+08	2.66E+08	2.66E+08	2.66E+08
	Livestock	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Wildlife	8.65E+09	8.65E+09	8.65E+09	8.65E+09	8.65E+09	8.65E+09
16	Human	2.54E+08	2.54E+08	2.54E+08	2.54E+08	2.54E+08	2.54E+08
	Livestock	1.52E+11	1.52E+11	1.16E+11	8.00E+10	7.88E+10	4.36E+10
	Wildlife	1.20E+10	1.20E+10	1.20E+10	1.20E+10	1.20E+10	1.20E+10
17	Human	1.77E+08	1.77E+08	1.77E+08	1.77E+08	1.77E+08	1.77E+08
	Livestock	6.50E+10	6.50E+10	5.03E+10	3.47E+10	3.23E+10	1.84E+10
	Wildlife	1.23E+10	1.23E+10	1.23E+10	1.23E+10	1.23E+10	1.23E+10

Table B.12 Monthly, directly deposited fecal coliform loads in each reach of the Lewis Creek impairment (subsheds 18-25).

Reach	Source	Jan (cfu/day)	Feb (cfu/day)	Mar (cfu/day)	Apr (cfu/day)	May (cfu/day)	Jun (cfu/day)
18	Human	4.71E+08	4.71E+08	4.71E+08	4.71E+08	4.71E+08	4.71E+08
	Livestock	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Wildlife	7.80E+09	7.80E+09	7.80E+09	7.80E+09	7.80E+09	7.80E+09
19	Human	3.16E+08	3.16E+08	3.16E+08	3.16E+08	3.16E+08	3.16E+08
	Livestock	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Wildlife	5.29E+09	5.29E+09	5.29E+09	5.29E+09	5.29E+09	5.29E+09
20	Human	1.34E+08	1.34E+08	1.34E+08	1.34E+08	1.34E+08	1.34E+08
	Livestock	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Wildlife	4.04E+09	4.04E+09	4.04E+09	4.04E+09	4.04E+09	4.04E+09
21	Human	8.10E+07	8.10E+07	8.10E+07	8.10E+07	8.10E+07	8.10E+07
	Livestock	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Wildlife	1.15E+10	1.15E+10	1.15E+10	1.15E+10	1.15E+10	1.15E+10
22	Human	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Livestock	8.55E+09	8.55E+09	1.61E+10	2.34E+10	2.34E+10	3.09E+10
	Wildlife	4.60E+09	4.60E+09	4.60E+09	4.60E+09	4.60E+09	4.60E+09
23	Human	2.91E+07	2.91E+07	2.91E+07	2.91E+07	2.91E+07	2.91E+07
	Livestock	1.06E+10	1.08E+10	1.99E+10	2.89E+10	2.89E+10	3.79E+10
	Wildlife	6.19E+09	6.19E+09	6.19E+09	6.19E+09	6.19E+09	6.19E+09
24	Human	3.48E+07	3.48E+07	3.48E+07	3.48E+07	3.48E+07	3.48E+07
	Livestock	2.20E+10	2.20E+10	4.13E+10	6.03E+10	6.03E+10	7.96E+10
	Wildlife	8.00E+09	8.00E+09	8.00E+09	8.00E+09	8.00E+09	8.00E+09
25	Human	1.33E+08	1.33E+08	1.33E+08	1.33E+08	1.33E+08	1.33E+08
	Livestock	8.19E+09	8.54E+09	1.48E+10	2.14E+10	2.14E+10	2.77E+10
	Wildlife	6.44E+09	6.44E+09	6.44E+09	6.44E+09	6.44E+09	6.44E+09

Table B.12 Monthly, directly deposited fecal coliform loads in each reach of the Lewis Creek impairment (subsheds 18-25) cont.

Reach	Source	Jul (cfu/day)	Aug (cfu/day)	Sep (cfu/day)	Oct (cfu/day)	Nov (cfu/day)	Dec (cfu/day)
18	Human	4.71E+08	4.71E+08	4.71E+08	4.71E+08	4.71E+08	4.71E+08
	Livestock	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Wildlife	7.80E+09	7.80E+09	7.80E+09	7.80E+09	7.80E+09	7.80E+09
19	Human	3.16E+08	3.16E+08	3.16E+08	3.16E+08	3.16E+08	3.16E+08
	Livestock	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Wildlife	5.29E+09	5.29E+09	5.29E+09	5.29E+09	5.29E+09	5.29E+09
20	Human	1.34E+08	1.34E+08	1.34E+08	1.34E+08	1.34E+08	1.34E+08
	Livestock	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Wildlife	4.04E+09	4.04E+09	4.04E+09	4.04E+09	4.04E+09	4.04E+09
21	Human	8.10E+07	8.10E+07	8.10E+07	8.10E+07	8.10E+07	8.10E+07
	Livestock	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Wildlife	1.15E+10	1.15E+10	1.15E+10	1.15E+10	1.15E+10	1.15E+10
22	Human	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Livestock	3.09E+10	3.09E+10	2.34E+10	1.61E+10	1.61E+10	8.55E+09
	Wildlife	4.60E+09	4.60E+09	4.60E+09	4.60E+09	4.60E+09	4.60E+09
23	Human	2.91E+07	2.91E+07	2.91E+07	2.91E+07	2.91E+07	2.91E+07
	Livestock	3.79E+10	3.79E+10	2.89E+10	1.99E+10	1.95E+10	1.06E+10
	Wildlife	6.19E+09	6.19E+09	6.19E+09	6.19E+09	6.19E+09	6.19E+09
24	Human	3.48E+07	3.48E+07	3.48E+07	3.48E+07	3.48E+07	3.48E+07
	Livestock	7.96E+10	7.96E+10	6.03E+10	4.13E+10	4.13E+10	2.20E+10
	Wildlife	8.00E+09	8.00E+09	8.00E+09	8.00E+09	8.00E+09	8.00E+09
25	Human	1.33E+08	1.33E+08	1.33E+08	1.33E+08	1.33E+08	1.33E+08
	Livestock	2.77E+10	2.77E+10	2.14E+10	1.48E+10	1.43E+10	8.19E+09
	Wildlife	6.44E+09	6.44E+09	6.44E+09	6.44E+09	6.44E+09	6.44E+09

Table B.13 Monthly, directly deposited fecal coliform loads in each reach of the Middle River watershed (non-impaired) (subsheds 26-32)

Reach	Source	Jan (cfu/day)	Feb (cfu/day)	Mar (cfu/day)	Apr (cfu/day)	May (cfu/day)	Jun (cfu/day)
26	Human	1.07E+09	1.07E+09	1.07E+09	1.07E+09	1.07E+09	1.07E+09
	Livestock	1.65E+10	1.80E+10	2.58E+10	3.61E+10	3.61E+10	4.38E+10
	Wildlife	2.82E+10	2.82E+10	2.82E+10	2.82E+10	2.82E+10	2.82E+10
27	Human	2.93E+08	2.93E+08	2.93E+08	2.93E+08	2.93E+08	2.93E+08
	Livestock	2.50E+10	2.65E+10	4.64E+10	6.73E+10	6.73E+10	8.72E+10
	Wildlife	1.64E+10	1.64E+10	1.64E+10	1.64E+10	1.64E+10	1.64E+10
28	Human	2.25E+08	2.25E+08	2.25E+08	2.25E+08	2.25E+08	2.25E+08
	Livestock	1.31E+10	1.54E+10	2.27E+10	3.20E+10	3.20E+10	3.92E+10
	Wildlife	1.68E+10	1.68E+10	1.68E+10	1.68E+10	1.68E+10	1.68E+10
29	Human	2.53E+08	2.53E+08	2.53E+08	2.53E+08	2.53E+08	2.53E+08
	Livestock	2.06E+10	2.30E+10	3.73E+10	5.33E+10	5.33E+10	6.76E+10
	Wildlife	1.54E+10	1.54E+10	1.54E+10	1.54E+10	1.54E+10	1.54E+10
30	Human	2.07E+06	2.07E+06	2.07E+06	2.07E+06	2.07E+06	2.07E+06
	Livestock	7.91E+09	8.08E+09	1.48E+10	2.16E+10	2.16E+10	2.84E+10
	Wildlife	1.09E+10	1.09E+10	1.09E+10	1.09E+10	1.09E+10	1.09E+10
31	Human	8.38E+07	8.38E+07	8.38E+07	8.38E+07	8.38E+07	8.38E+07
	Livestock	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Wildlife	9.96E+09	9.96E+09	9.96E+09	9.96E+09	9.96E+09	9.96E+09
32	Human	1.21E+08	1.21E+08	1.21E+08	1.21E+08	1.21E+08	1.21E+08
	Livestock	2.48E+10	2.49E+10	4.52E+10	6.57E+10	6.57E+10	8.61E+10
	Wildlife	1.09E+10	1.09E+10	1.09E+10	1.09E+10	1.09E+10	1.09E+10

Table B.13 Monthly, directly deposited fecal coliform loads in each reach of the Middle River watershed (non-impaired) (subsheds 26-32) cont.

Reach	Source	Jul (cfu/day)	Aug (cfu/day)	Sep (cfu/day)	Oct (cfu/day)	Nov (cfu/day)	Dec (cfu/day)
26	Human	1.07E+09	1.07E+09	1.07E+09	1.07E+09	1.07E+09	1.07E+09
	Livestock	4.38E+10	4.38E+10	3.61E+10	2.58E+10	2.36E+10	1.65E+10
	Wildlife	2.82E+10	2.82E+10	2.82E+10	2.82E+10	2.82E+10	2.82E+10
27	Human	2.93E+08	2.93E+08	2.93E+08	2.93E+08	2.93E+08	2.93E+08
	Livestock	8.72E+10	8.72E+10	6.73E+10	4.64E+10	4.42E+10	2.50E+10
	Wildlife	1.64E+10	1.64E+10	1.64E+10	1.64E+10	1.64E+10	1.64E+10
28	Human	2.25E+08	2.25E+08	2.25E+08	2.25E+08	2.25E+08	2.25E+08
	Livestock	3.92E+10	3.92E+10	3.20E+10	2.27E+10	1.94E+10	1.31E+10
	Wildlife	1.68E+10	1.68E+10	1.68E+10	1.68E+10	1.68E+10	1.68E+10
29	Human	2.53E+08	2.53E+08	2.53E+08	2.53E+08	2.53E+08	2.53E+08
	Livestock	6.76E+10	6.76E+10	5.33E+10	3.73E+10	3.39E+10	2.06E+10
	Wildlife	1.54E+10	1.54E+10	1.54E+10	1.54E+10	1.54E+10	1.54E+10
30	Human	2.07E+06	2.07E+06	2.07E+06	2.07E+06	2.07E+06	2.07E+06
	Livestock	2.84E+10	2.84E+10	2.16E+10	1.48E+10	1.46E+10	7.91E+09
	Wildlife	1.09E+10	1.09E+10	1.09E+10	1.09E+10	1.09E+10	1.09E+10
31	Human	8.38E+07	8.38E+07	8.38E+07	8.38E+07	8.38E+07	8.38E+07
	Livestock	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Wildlife	9.96E+09	9.96E+09	9.96E+09	9.96E+09	9.96E+09	9.96E+09
32	Human	1.21E+08	1.21E+08	1.21E+08	1.21E+08	1.21E+08	1.21E+08
	Livestock	8.61E+10	8.61E+10	6.57E+10	4.52E+10	4.50E+10	2.48E+10
	Wildlife	1.09E+10	1.09E+10	1.09E+10	1.09E+10	1.09E+10	1.09E+10

Table B.14 Monthly, directly deposited fecal coliform loads in each reach of the Polecat Draft impairment (subshed 33).

Reach	Source	Jan (cfu/day)	Feb (cfu/day)	Mar (cfu/day)	Apr (cfu/day)	May (cfu/day)	Jun (cfu/day)
33	Human	1.68E+08	1.68E+08	1.68E+08	1.68E+08	1.68E+08	1.68E+08
	Livestock	2.63E+10	2.88E+10	4.93E+10	7.10E+10	7.10E+10	9.15E+10
	Wildlife	1.59E+10	1.59E+10	1.59E+10	1.59E+10	1.59E+10	1.59E+10

Reach	Source	Jul (cfu/day)	Aug (cfu/day)	Sep (cfu/day)	Oct (cfu/day)	Nov (cfu/day)	Dec (cfu/day)
33	Human	1.68E+08	1.68E+08	1.68E+08	1.68E+08	1.68E+08	1.68E+08
	Livestock	9.15E+10	9.15E+10	7.10E+10	4.93E+10	4.57E+10	2.63E+10
	Wildlife	1.59E+10	1.59E+10	1.59E+10	1.59E+10	1.59E+10	1.59E+10

Table B.15 Monthly, directly deposited fecal coliform loads in each reach of the Lower Middle River impairment (subsheds 34-38).

Reach	Source	Jan (cfu/day)	Feb (cfu/day)	Mar (cfu/day)	Apr (cfu/day)	May (cfu/day)	Jun (cfu/day)
34	Human	2.38E+08	2.38E+08	2.38E+08	2.38E+08	2.38E+08	2.38E+08
	Livestock	7.05E+10	7.55E+10	1.32E+11	1.91E+11	1.91E+11	2.48E+11
	Wildlife	2.67E+10	2.67E+10	2.67E+10	2.67E+10	2.67E+10	2.67E+10
35	Human	1.94E+08	1.94E+08	1.94E+08	1.94E+08	1.94E+08	1.94E+08
	Livestock	4.81E+10	5.17E+10	9.01E+10	1.30E+11	1.30E+11	1.68E+11
	Wildlife	1.78E+10	1.78E+10	1.78E+10	1.78E+10	1.78E+10	1.78E+10
36	Human	2.99E+07	2.99E+07	2.99E+07	2.99E+07	2.99E+07	2.99E+07
	Livestock	6.48E+09	8.42E+09	1.20E+10	1.68E+10	1.68E+10	2.05E+10
	Wildlife	1.27E+10	1.27E+10	1.27E+10	1.27E+10	1.27E+10	1.27E+10
37	Human	5.12E+07	5.12E+07	5.12E+07	5.12E+07	5.12E+07	5.12E+07
	Livestock	9.77E+10	1.01E+11	1.85E+11	2.70E+11	2.70E+11	3.54E+11
	Wildlife	1.60E+10	1.60E+10	1.60E+10	1.60E+10	1.60E+10	1.60E+10
38	Human	1.31E+07	1.31E+07	1.31E+07	1.31E+07	1.31E+07	1.31E+07
	Livestock	1.92E+10	1.96E+10	3.61E+10	5.26E+10	5.26E+10	6.91E+10
	Wildlife	2.01E+13	1.82E+13	2.01E+13	1.95E+13	2.01E+13	1.95E+13

Reach	Source	Jul (cfu/day)	Aug (cfu/day)	Sep (cfu/day)	Oct (cfu/day)	Nov (cfu/day)	Dec (cfu/day)
34	Human	2.38E+08	2.38E+08	2.38E+08	2.38E+08	2.38E+08	2.38E+08
	Livestock	2.48E+11	2.48E+11	1.91E+11	1.32E+11	1.25E+11	7.05E+10
	Wildlife	2.67E+10	2.67E+10	2.67E+10	2.67E+10	2.67E+10	2.67E+10
35	Human	1.94E+08	1.94E+08	1.94E+08	1.94E+08	1.94E+08	1.94E+08
	Livestock	1.68E+11	1.68E+11	1.30E+11	9.01E+10	8.48E+10	4.81E+10
	Wildlife	1.78E+10	1.78E+10	1.78E+10	1.78E+10	1.78E+10	1.78E+10
36	Human	2.99E+07	2.99E+07	2.99E+07	2.99E+07	2.99E+07	2.99E+07
	Livestock	2.05E+10	2.05E+10	1.68E+10	1.20E+10	9.25E+09	6.48E+09
	Wildlife	1.27E+10	1.27E+10	1.27E+10	1.27E+10	1.27E+10	1.27E+10
37	Human	5.12E+07	5.12E+07	5.12E+07	5.12E+07	5.12E+07	5.12E+07
	Livestock	3.54E+11	3.54E+11	2.70E+11	1.85E+11	1.80E+11	9.77E+10
	Wildlife	1.60E+10	1.60E+10	1.60E+10	1.60E+10	1.60E+10	1.60E+10
38	Human	1.31E+07	1.31E+07	1.31E+07	1.31E+07	1.31E+07	1.31E+07
	Livestock	6.91E+10	6.91E+10	5.26E+10	3.61E+10	3.56E+10	1.92E+10
	Wildlife	2.01E+13	2.01E+13	1.95E+13	2.01E+13	1.95E+13	2.01E+13

Table B.16 Monthly, directly deposited fecal coliform loads in each reach of the South River impairment (subsheds 39-44).

Reach	Source	Jan (cfu/day)	Feb (cfu/day)	Mar (cfu/day)	Apr (cfu/day)	May (cfu/day)	Jun (cfu/day)
39	Human	3.59E+08	3.59E+08	3.59E+08	3.59E+08	3.59E+08	3.59E+08
	Livestock	2.81E+10	3.36E+10	5.20E+10	7.43E+10	7.43E+10	9.28E+10
	Wildlife	1.82E+10	1.82E+10	1.82E+10	1.82E+10	1.82E+10	1.82E+10
40	Human	4.57E+08	4.57E+08	4.57E+08	4.57E+08	4.57E+08	4.57E+08
	Livestock	1.40E+10	1.63E+10	2.33E+10	3.26E+10	3.26E+10	3.96E+10
	Wildlife	2.01E+13	1.82E+13	2.01E+13	1.95E+13	2.01E+13	1.95E+13
41	Human	1.53E+09	1.53E+09	1.53E+09	1.53E+09	1.53E+09	1.53E+09
	Livestock	1.75E+09	2.27E+09	3.25E+09	4.54E+09	4.54E+09	5.52E+09
	Wildlife	3.10E+10	3.10E+10	3.10E+10	3.10E+10	3.10E+10	3.10E+10
42	Human	4.72E+07	4.72E+07	4.72E+07	4.72E+07	4.72E+07	4.72E+07
	Livestock	5.97E+09	7.05E+09	1.08E+10	1.53E+10	1.53E+10	1.90E+10
	Wildlife	1.12E+10	1.12E+10	1.12E+10	1.12E+10	1.12E+10	1.12E+10
43	Human	9.91E+07	9.91E+07	9.91E+07	9.91E+07	9.91E+07	9.91E+07
	Livestock	1.66E+10	1.72E+10	3.12E+10	4.53E+10	4.53E+10	5.93E+10
	Wildlife	1.25E+10	1.25E+10	1.25E+10	1.25E+10	1.25E+10	1.25E+10
44	Human	8.64E+07	8.64E+07	8.64E+07	8.64E+07	8.64E+07	8.64E+07
	Livestock	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Wildlife	1.14E+10	1.14E+10	1.14E+10	1.14E+10	1.14E+10	1.14E+10

Reach	Source	Jul (cfu/day)	Aug (cfu/day)	Sep (cfu/day)	Oct (cfu/day)	Nov (cfu/day)	Dec (cfu/day)
39	Human	3.59E+08	3.59E+08	3.59E+08	3.59E+08	3.59E+08	3.59E+08
	Livestock	9.28E+10	9.28E+10	7.43E+10	5.20E+10	4.42E+10	2.81E+10
	Wildlife	1.82E+10	1.82E+10	1.82E+10	1.82E+10	1.82E+10	1.82E+10
40	Human	4.57E+08	4.57E+08	4.57E+08	4.57E+08	4.57E+08	4.57E+08
	Livestock	3.96E+10	3.96E+10	3.26E+10	2.33E+10	2.00E+10	1.40E+10
	Wildlife	2.01E+13	2.01E+13	1.95E+13	2.01E+13	1.95E+13	2.01E+13
41	Human	1.53E+09	1.53E+09	1.53E+09	1.53E+09	1.53E+09	1.53E+09
	Livestock	5.52E+09	5.52E+09	4.54E+09	3.25E+09	2.50E+09	1.75E+09
	Wildlife	3.10E+10	3.10E+10	3.10E+10	3.10E+10	3.10E+10	3.10E+10
42	Human	4.72E+07	4.72E+07	4.72E+07	4.72E+07	4.72E+07	4.72E+07
	Livestock	1.90E+10	1.90E+10	1.53E+10	1.08E+10	9.21E+09	5.97E+09
	Wildlife	1.12E+10	1.12E+10	1.12E+10	1.12E+10	1.12E+10	1.12E+10
43	Human	9.91E+07	9.91E+07	9.91E+07	9.91E+07	9.91E+07	9.91E+07
	Livestock	5.93E+10	5.93E+10	4.53E+10	3.12E+10	3.04E+10	1.66E+10
	Wildlife	1.25E+10	1.25E+10	1.25E+10	1.25E+10	1.25E+10	1.25E+10
44	Human	8.64E+07	8.64E+07	8.64E+07	8.64E+07	8.64E+07	8.64E+07
	Livestock	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Wildlife	1.14E+10	1.14E+10	1.14E+10	1.14E+10	1.14E+10	1.14E+10

Table B.17 Existing annual loads from land-based sources for the Upper Middle River impairment (Subsheds 1-10).

Source	Commercial Services (cfu/yr)	Cropland (cfu/yr)	Farmstead (cfu/yr)	Improved Pasture (cfu/yr)	Livestock Access (cfu/yr)	Livestock Operation (cfu/yr)	Residential (cfu/yr)	Unimproved Pasture (cfu/yr)	Water (cfu/yr)	Woodlands (cfu/yr)
<u>Pets</u>										
Dogs	0.00E+00	0.00E+00	6.94E+12	0.00E+00	0.00E+00	0.00E+00	6.03E+13	0.00E+00	0.00E+00	0.00E+00
Cats	0.00E+00	0.00E+00	5.38E+06	0.00E+00	0.00E+00	0.00E+00	4.67E+07	0.00E+00	0.00E+00	0.00E+00
Total	0.00E+00	0.00E+00	6.94E+12	0.00E+00	0.00E+00	0.00E+00	6.03E+13	0.00E+00	0.00E+00	0.00E+00
<u>Human</u>										
Failed Septic	0.00E+00	0.00E+00	9.24E+12	0.00E+00	0.00E+00	0.00E+00	6.54E+13	0.00E+00	0.00E+00	0.00E+00
<u>Livestock</u>										
Dairy	0.00E+00	1.20E+16	0.00E+00	3.31E+15	1.95E+14	0.00E+00	0.00E+00	1.64E+13	0.00E+00	0.00E+00
Beef	0.00E+00	0.00E+00	0.00E+00	4.45E+15	2.45E+14	0.00E+00	0.00E+00	9.59E+13	0.00E+00	0.00E+00
Horse	0.00E+00	0.00E+00	0.00E+00	3.27E+14	0.00E+00	0.00E+00	0.00E+00	1.23E+13	0.00E+00	0.00E+00
Swine	0.00E+00	8.39E+13	0.00E+00	4.67E+12	0.00E+00	6.31E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sheep	0.00E+00	0.00E+00	0.00E+00	5.64E+12	0.00E+00	0.00E+00	0.00E+00	4.68E+11	0.00E+00	0.00E+00
Goat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Poultry	0.00E+00	7.91E+13	0.00E+00	7.58E+14	0.00E+00	0.00E+00	0.00E+00	3.02E+13	0.00E+00	0.00E+00
Total	0.00E+00	1.22E+16	0.00E+00	8.86E+15	4.40E+14	6.31E+12	0.00E+00	1.55E+14	0.00E+00	0.00E+00
<u>Wildlife</u>										
Raccoon	3.49E+11	5.51E+13	1.31E+12	6.25E+14	5.76E+13	2.29E+11	8.79E+12	2.95E+13	0.00E+00	5.56E+14
Muskrat	1.45E+11	2.56E+13	9.28E+11	4.25E+14	2.36E+14	2.61E+11	5.77E+12	2.97E+13	0.00E+00	3.68E+14
Deer	5.36E+10	9.15E+12	1.88E+11	9.52E+13	5.43E+12	3.47E+10	5.15E+11	3.55E+12	0.00E+00	9.55E+13
Turkey	2.55E+07	1.49E+08	2.57E+07	1.41E+10	1.02E+09	5.30E+06	6.92E+07	5.61E+08	0.00E+00	5.28E+10
Goose	1.05E+08	6.71E+09	8.06E+08	1.11E+11	6.17E+10	1.81E+08	1.50E+09	7.75E+09	0.00E+00	9.56E+10
Duck	3.88E+06	2.46E+08	2.96E+07	4.06E+09	2.27E+09	6.65E+06	5.51E+07	2.85E+08	0.00E+00	3.51E+09
Unquantifiable	5.48E+10	8.99E+12	2.42E+11	1.14E+14	3.00E+13	5.25E+10	1.51E+12	6.28E+12	0.00E+00	1.02E+14
Total	6.02E+11	9.89E+13	2.66E+12	1.26E+15	3.30E+14	5.77E+11	1.66E+13	6.90E+13	0.00E+00	1.12E+15

Table B.18 Existing annual loads from land-based sources for Jennings Branch watershed (non-impaired) (Subsheds 11-12).

Source	Commercial Services (cfu/yr)	Cropland (cfu/yr)	Farmstead (cfu/yr)	Improved Pasture (cfu/yr)	Livestock Access (cfu/yr)	Livestock Operation (cfu/yr)	Residential (cfu/yr)	Unimproved Pasture (cfu/yr)	Water (cfu/yr)	Woodlands (cfu/yr)
Pets										
Dogs	0.00E+00	0.00E+00	2.26E+12	0.00E+00	0.00E+00	0.00E+00	2.89E+13	0.00E+00	0.00E+00	0.00E+00
Cats	0.00E+00	0.00E+00	1.75E+06	0.00E+00	0.00E+00	0.00E+00	2.24E+07	0.00E+00	0.00E+00	0.00E+00
Total	0.00E+00	0.00E+00	2.26E+12	0.00E+00	0.00E+00	0.00E+00	2.89E+13	0.00E+00	0.00E+00	0.00E+00
Human										
Failed Septic	0.00E+00	0.00E+00	2.94E+12	0.00E+00	0.00E+00	0.00E+00	3.15E+13	0.00E+00	0.00E+00	0.00E+00
Livestock										
Dairy	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Beef	0.00E+00	0.00E+00	0.00E+00	4.87E+14	2.70E+13	0.00E+00	0.00E+00	1.88E+13	0.00E+00	0.00E+00
Horse	0.00E+00	0.00E+00	0.00E+00	8.22E+13	0.00E+00	0.00E+00	0.00E+00	2.63E+12	0.00E+00	0.00E+00
Swine	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sheep	0.00E+00	0.00E+00	0.00E+00	2.34E+11	0.00E+00	0.00E+00	0.00E+00	5.42E+09	0.00E+00	0.00E+00
Goat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Poultry	0.00E+00	3.77E+13	0.00E+00	3.06E+14	0.00E+00	0.00E+00	0.00E+00	1.17E+13	0.00E+00	0.00E+00
Total	0.00E+00	3.77E+13	0.00E+00	8.76E+14	2.70E+13	0.00E+00	0.00E+00	3.31E+13	0.00E+00	0.00E+00
Wildlife										
Raccoon	1.74E+11	1.43E+13	5.78E+11	1.25E+14	1.45E+13	1.55E+10	8.48E+12	4.28E+12	0.00E+00	3.81E+14
Muskrat	2.61E+11	6.90E+12	6.38E+11	1.00E+14	6.10E+13	1.45E+11	1.70E+13	3.89E+12	0.00E+00	2.86E+14
Deer	2.08E+10	1.94E+12	5.46E+10	1.63E+13	1.22E+12	3.97E+09	3.27E+11	5.15E+11	0.00E+00	6.09E+13
Turkey	9.63E+06	2.04E+07	8.23E+06	2.49E+09	2.82E+08	9.77E+05	6.00E+07	8.37E+07	0.00E+00	3.40E+10
Goose	1.58E+08	1.79E+09	5.50E+08	2.61E+10	1.59E+10	3.77E+07	4.41E+09	1.01E+09	0.00E+00	7.44E+10
Duck	5.82E+06	6.59E+07	2.02E+07	9.58E+08	5.85E+08	1.38E+06	1.62E+08	3.71E+07	0.00E+00	2.73E+09
Unquantifiable	4.56E+10	2.31E+12	1.27E+11	2.41E+13	7.67E+12	1.64E+10	2.58E+12	8.68E+11	0.00E+00	7.28E+13
Total	5.02E+11	2.54E+13	1.40E+12	2.65E+14	8.44E+13	1.81E+11	2.84E+13	9.55E+12	0.00E+00	8.00E+14

Table B.19 Existing annual loads from land-based sources for the Moffett Creek impairment (Subsheds 13-17).

Source	Commercial Services (cfu/yr)	Cropland (cfu/yr)	Farmstead (cfu/yr)	Improved Pasture (cfu/yr)	Livestock Access (cfu/yr)	Livestock Operation (cfu/yr)	Residential (cfu/yr)	Unimproved Pasture (cfu/yr)	Water (cfu/yr)	Woodlands (cfu/yr)
Pets										
Dogs	0.00E+00	0.00E+00	4.60E+12	0.00E+00	0.00E+00	0.00E+00	1.36E+13	0.00E+00	0.00E+00	0.00E+00
Cats	0.00E+00	0.00E+00	3.57E+06	0.00E+00	0.00E+00	0.00E+00	1.05E+07	0.00E+00	0.00E+00	0.00E+00
Total	0.00E+00	0.00E+00	4.60E+12	0.00E+00	0.00E+00	0.00E+00	1.36E+13	0.00E+00	0.00E+00	0.00E+00
Human										
Failed Septic	0.00E+00	0.00E+00	6.23E+12	0.00E+00	0.00E+00	0.00E+00	1.29E+13	0.00E+00	0.00E+00	0.00E+00
Livestock										
Dairy	0.00E+00	7.29E+15	0.00E+00	1.95E+15	1.30E+14	0.00E+00	0.00E+00	2.07E+14	0.00E+00	0.00E+00
Beef	0.00E+00	0.00E+00	0.00E+00	4.23E+14	2.53E+13	0.00E+00	0.00E+00	5.11E+13	0.00E+00	0.00E+00
Horse	0.00E+00	0.00E+00	0.00E+00	8.54E+13	0.00E+00	0.00E+00	0.00E+00	1.06E+13	0.00E+00	0.00E+00
Swine	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sheep	0.00E+00	0.00E+00	0.00E+00	9.67E+11	0.00E+00	0.00E+00	0.00E+00	2.89E+11	0.00E+00	0.00E+00
Goat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Poultry	0.00E+00	1.21E+14	0.00E+00	8.43E+14	0.00E+00	0.00E+00	0.00E+00	9.41E+13	0.00E+00	0.00E+00
Total	0.00E+00	7.41E+15	0.00E+00	3.31E+15	1.55E+14	0.00E+00	0.00E+00	3.63E+14	0.00E+00	0.00E+00
Wildlife										
Raccoon	1.94E+10	1.79E+13	5.47E+11	1.46E+14	2.00E+13	1.32E+11	1.01E+12	1.81E+13	0.00E+00	1.90E+14
Muskrat	0.00E+00	9.66E+12	2.90E+11	1.04E+14	7.12E+13	2.32E+11	8.41E+11	1.40E+13	0.00E+00	1.32E+14
Deer	4.96E+09	2.82E+12	8.33E+10	2.27E+13	2.01E+12	2.78E+10	1.04E+11	2.85E+12	0.00E+00	3.02E+13
Turkey	2.79E+06	7.12E+07	1.58E+07	3.54E+09	4.76E+08	5.58E+06	3.34E+07	5.54E+08	0.00E+00	1.66E+10
Goose	0.00E+00	2.51E+09	2.34E+08	2.71E+10	1.86E+10	6.03E+07	2.19E+08	3.66E+09	0.00E+00	3.44E+10
Duck	0.00E+00	9.22E+07	8.59E+06	9.97E+08	6.82E+08	2.22E+06	8.03E+06	1.34E+08	0.00E+00	1.27E+09
Unquantifiable	2.43E+09	3.04E+12	9.20E+10	2.73E+13	9.32E+12	3.92E+10	1.96E+11	3.50E+12	0.00E+00	3.53E+13
Total	2.68E+10	3.35E+13	1.01E+12	3.00E+14	1.03E+14	4.31E+11	2.15E+12	3.85E+13	0.00E+00	3.88E+14

Table B.20 Existing annual loads from land-based sources for the Lewis Creek impairment (subsheds 18-25).

Source	Commercial Services (cfu/yr)	Cropland (cfu/yr)	Farmstead (cfu/yr)	Improved Pasture (cfu/yr)	Livestock Access (cfu/yr)	Livestock Operation (cfu/yr)	Residential (cfu/yr)	Unimproved Pasture (cfu/yr)	Water (cfu/yr)	Woodlands (cfu/yr)
Pets										
Dogs	0.00E+00	0.00E+00	1.79E+12	0.00E+00	0.00E+00	0.00E+00	4.70E+14	0.00E+00	0.00E+00	0.00E+00
Cats	0.00E+00	0.00E+00	1.39E+06	0.00E+00	0.00E+00	0.00E+00	3.64E+08	0.00E+00	0.00E+00	0.00E+00
Total	0.00E+00	0.00E+00	1.79E+12	0.00E+00	0.00E+00	0.00E+00	4.70E+14	0.00E+00	0.00E+00	0.00E+00
Human										
Failed Septic	0.00E+00	0.00E+00	4.92E+11	0.00E+00	0.00E+00	0.00E+00	3.79E+13	0.00E+00	0.00E+00	0.00E+00
Livestock										
Dairy	0.00E+00	5.51E+15	0.00E+00	1.53E+15	9.10E+13	0.00E+00	0.00E+00	1.38E+13	0.00E+00	0.00E+00
Beef	0.00E+00	0.00E+00	0.00E+00	9.84E+13	5.32E+12	0.00E+00	0.00E+00	1.06E+12	0.00E+00	0.00E+00
Horse	0.00E+00	0.00E+00	0.00E+00	1.11E+14	0.00E+00	0.00E+00	0.00E+00	6.50E+11	0.00E+00	0.00E+00
Swine	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sheep	0.00E+00	0.00E+00	0.00E+00	3.59E+12	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Goat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Poultry	0.00E+00	9.93E+12	0.00E+00	8.02E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total	0.00E+00	5.52E+15	0.00E+00	1.83E+15	9.64E+13	0.00E+00	0.00E+00	1.55E+13	0.00E+00	0.00E+00
Wildlife										
Raccoon	2.18E+12	8.05E+12	3.95E+11	2.23E+14	2.20E+13	3.88E+09	6.27E+13	7.83E+11	0.00E+00	9.28E+13
Muskrat	2.99E+12	4.15E+12	5.51E+11	1.68E+14	9.08E+13	0.00E+00	4.13E+13	0.00E+00	0.00E+00	4.60E+13
Deer	1.97E+11	1.29E+12	5.03E+10	3.14E+13	2.00E+12	9.92E+08	2.91E+12	1.99E+11	0.00E+00	1.55E+13
Turkey	4.83E+07	2.87E+07	8.93E+06	4.73E+09	3.87E+08	0.00E+00	1.86E+08	3.08E+07	0.00E+00	8.33E+09
Goose	6.22E+09	1.09E+09	6.25E+08	4.39E+10	2.45E+10	0.00E+00	1.09E+10	0.00E+00	0.00E+00	1.21E+10
Duck	2.29E+08	3.99E+07	2.30E+07	1.61E+09	9.02E+08	0.00E+00	4.02E+08	0.00E+00	0.00E+00	4.43E+08
Unquantifiable	5.37E+11	1.35E+12	9.97E+10	4.22E+13	1.15E+13	4.87E+08	1.07E+13	9.82E+10	0.00E+00	1.54E+13
Total	5.91E+12	1.48E+13	1.10E+12	4.64E+14	1.26E+14	5.35E+09	1.18E+14	1.08E+12	0.00E+00	1.70E+14

Table B.21 Existing annual loads from land-based sources for the Middle River watershed (non-impaired) (Subsheds 26-32).

Source	Commercial Services (cfu/yr)	Cropland (cfu/yr)	Farmstead (cfu/yr)	Improved Pasture (cfu/yr)	Livestock Access (cfu/yr)	Livestock Operation (cfu/yr)	Residential (cfu/yr)	Unimproved Pasture (cfu/yr)	Water (cfu/yr)	Woodlands (cfu/yr)
<u>Pets</u>										
Dogs	0.00E+00	0.00E+00	3.58E+12	0.00E+00	0.00E+00	0.00E+00	1.19E+14	0.00E+00	0.00E+00	0.00E+00
Cats	0.00E+00	0.00E+00	2.77E+06	0.00E+00	0.00E+00	0.00E+00	9.20E+07	0.00E+00	0.00E+00	0.00E+00
Total	0.00E+00	0.00E+00	3.58E+12	0.00E+00	0.00E+00	0.00E+00	1.19E+14	0.00E+00	0.00E+00	0.00E+00
<u>Human</u>										
Failed Septic	0.00E+00	0.00E+00	3.45E+12	0.00E+00	0.00E+00	0.00E+00	7.40E+13	0.00E+00	0.00E+00	0.00E+00
<u>Livestock</u>										
Dairy	0.00E+00	6.28E+15	0.00E+00	1.89E+15	1.15E+14	0.00E+00	0.00E+00	6.06E+12	0.00E+00	0.00E+00
Beef	0.00E+00	0.00E+00	0.00E+00	1.55E+15	8.31E+13	0.00E+00	0.00E+00	9.34E+12	0.00E+00	0.00E+00
Horse	0.00E+00	0.00E+00	0.00E+00	2.48E+14	0.00E+00	0.00E+00	0.00E+00	1.08E+12	0.00E+00	0.00E+00
Swine	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sheep	0.00E+00	0.00E+00	0.00E+00	5.23E+12	0.00E+00	0.00E+00	0.00E+00	4.01E+10	0.00E+00	0.00E+00
Goat	0.00E+00	0.00E+00	0.00E+00	2.25E+11	0.00E+00	0.00E+00	0.00E+00	1.24E+09	0.00E+00	0.00E+00
Poultry	0.00E+00	1.18E+14	0.00E+00	9.93E+14	0.00E+00	0.00E+00	0.00E+00	9.94E+12	0.00E+00	0.00E+00
Total	0.00E+00	6.40E+15	0.00E+00	4.69E+15	1.98E+14	0.00E+00	0.00E+00	2.65E+13	0.00E+00	0.00E+00
<u>Wildlife</u>										
Raccoon	7.98E+11	4.92E+13	7.60E+11	4.15E+14	4.14E+13	1.59E+11	1.10E+13	2.48E+12	0.00E+00	2.46E+14
Muskrat	1.74E+11	3.09E+13	3.77E+11	3.02E+14	1.75E+14	1.45E+11	4.29E+12	1.30E+12	0.00E+00	2.07E+14
Deer	1.53E+11	5.93E+12	1.17E+11	6.10E+13	3.69E+12	2.18E+10	6.98E+11	2.97E+11	0.00E+00	3.64E+13
Turkey	3.99E+07	9.78E+07	1.77E+07	9.31E+09	9.01E+08	4.74E+06	5.86E+07	5.43E+07	0.00E+00	1.95E+10
Goose	1.88E+08	8.04E+09	3.24E+08	7.86E+10	4.56E+10	3.77E+07	1.12E+09	3.39E+08	0.00E+00	5.39E+10
Duck	6.92E+06	2.95E+08	1.19E+07	2.89E+09	1.67E+09	1.38E+06	4.10E+07	1.25E+07	0.00E+00	1.98E+09
Unquantifiable	1.13E+11	8.60E+12	1.25E+11	7.78E+13	2.20E+13	3.26E+10	1.60E+12	4.09E+11	0.00E+00	4.90E+13
Total	1.24E+12	9.47E+13	1.38E+12	8.56E+14	2.42E+14	3.58E+11	1.76E+13	4.49E+12	0.00E+00	5.39E+14

Table B.22 Existing annual loads from land-based sources for the Polecat Draft impairment (subshed 33).

Source	Commercial Services (cfu/yr)	Cropland (cfu/yr)	Farmstead (cfu/yr)	Improved Pasture (cfu/yr)	Livestock Access (cfu/yr)	Livestock Operation (cfu/yr)	Residential (cfu/yr)	Unimproved Pasture (cfu/yr)	Water (cfu/yr)	Woodlands (cfu/yr)
Pets										
Dogs	0.00E+00	0.00E+00	9.37E+11	0.00E+00	0.00E+00	0.00E+00	7.26E+12	0.00E+00	0.00E+00	0.00E+00
Cats	0.00E+00	0.00E+00	7.27E+05	0.00E+00	0.00E+00	0.00E+00	5.63E+06	0.00E+00	0.00E+00	0.00E+00
Total	0.00E+00	0.00E+00	9.37E+11	0.00E+00	0.00E+00	0.00E+00	7.26E+12	0.00E+00	0.00E+00	0.00E+00
Human										
Failed Septic	0.00E+00	0.00E+00	1.39E+12	0.00E+00	0.00E+00	0.00E+00	8.23E+12	0.00E+00	0.00E+00	0.00E+00
Livestock										
Dairy	0.00E+00	2.14E+15	0.00E+00	6.02E+14	3.55E+13	0.00E+00	0.00E+00	1.96E+11	0.00E+00	0.00E+00
Beef	0.00E+00	0.00E+00	0.00E+00	2.83E+14	1.52E+13	0.00E+00	0.00E+00	1.15E+11	0.00E+00	0.00E+00
Horse	0.00E+00	0.00E+00	0.00E+00	2.23E+13	0.00E+00	0.00E+00	0.00E+00	9.04E+09	0.00E+00	0.00E+00
Swine	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sheep	0.00E+00	0.00E+00	0.00E+00	9.57E+11	0.00E+00	0.00E+00	0.00E+00	3.88E+08	0.00E+00	0.00E+00
Goat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Poultry	0.00E+00	6.19E+13	0.00E+00	3.56E+14	0.00E+00	0.00E+00	0.00E+00	1.44E+11	0.00E+00	0.00E+00
Total	0.00E+00	2.21E+15	0.00E+00	1.26E+15	5.07E+13	0.00E+00	0.00E+00	4.64E+11	0.00E+00	0.00E+00
Wildlife										
Raccoon	0.00E+00	1.15E+13	2.05E+11	6.36E+13	5.15E+12	6.20E+10	2.33E+10	1.16E+10	0.00E+00	2.13E+13
Muskrat	0.00E+00	8.18E+12	5.80E+10	6.26E+13	2.88E+13	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.55E+12
Deer	0.00E+00	1.26E+12	1.79E+10	7.25E+12	3.27E+11	9.92E+09	2.98E+09	2.98E+09	0.00E+00	3.77E+12
Turkey	0.00E+00	2.72E+07	3.07E+06	1.07E+09	4.74E+07	2.51E+06	1.12E+06	1.26E+06	0.00E+00	2.02E+09
Goose	0.00E+00	2.13E+09	1.36E+08	1.64E+10	7.51E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.70E+09
Duck	0.00E+00	7.81E+07	4.98E+06	6.02E+08	2.76E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.26E+07
Unquantifiable	0.00E+00	2.10E+12	2.81E+10	1.33E+13	3.42E+12	7.19E+09	2.62E+09	1.46E+09	0.00E+00	3.16E+12
Total	0.00E+00	2.31E+13	3.10E+11	1.47E+14	3.77E+13	7.91E+10	2.89E+10	1.61E+10	0.00E+00	3.47E+13

Table B.23 Existing annual loads from land-based sources for the Lower Middle River impairment (subsheds 34-38).

Source	Commercial Services (cfu/yr)	Cropland (cfu/yr)	Farmstead (cfu/yr)	Improved Pasture (cfu/yr)	Livestock Access (cfu/yr)	Livestock Operation (cfu/yr)	Residential (cfu/yr)	Unimproved Pasture (cfu/yr)	Water (cfu/yr)	Woodlands (cfu/yr)
Pets										
Dogs	0.00E+00	0.00E+00	4.56E+12	0.00E+00	0.00E+00	0.00E+00	3.59E+13	0.00E+00	0.00E+00	0.00E+00
Cats	0.00E+00	0.00E+00	3.53E+06	0.00E+00	0.00E+00	0.00E+00	2.78E+07	0.00E+00	0.00E+00	0.00E+00
Total	0.00E+00	0.00E+00	4.56E+12	0.00E+00	0.00E+00	0.00E+00	3.59E+13	0.00E+00	0.00E+00	0.00E+00
Human										
Failed Septic	0.00E+00	0.00E+00	4.46E+12	0.00E+00	0.00E+00	0.00E+00	2.67E+13	0.00E+00	0.00E+00	0.00E+00
Livestock										
Dairy	0.00E+00	2.14E+16	0.00E+00	6.30E+15	3.84E+14	0.00E+00	0.00E+00	8.21E+13	0.00E+00	0.00E+00
Beef	0.00E+00	0.00E+00	0.00E+00	1.61E+15	8.86E+13	0.00E+00	0.00E+00	2.92E+13	0.00E+00	0.00E+00
Horse	0.00E+00	0.00E+00	0.00E+00	1.40E+14	0.00E+00	0.00E+00	0.00E+00	2.43E+12	0.00E+00	0.00E+00
Swine	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sheep	0.00E+00	0.00E+00	0.00E+00	5.46E+12	0.00E+00	0.00E+00	0.00E+00	9.87E+10	0.00E+00	0.00E+00
Goat	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Poultry	0.00E+00	2.00E+14	0.00E+00	8.05E+14	0.00E+00	0.00E+00	0.00E+00	3.50E+12	0.00E+00	0.00E+00
Total	0.00E+00	2.16E+16	0.00E+00	8.87E+15	4.73E+14	0.00E+00	0.00E+00	1.17E+14	0.00E+00	0.00E+00
Wildlife										
Raccoon	2.40E+11	7.14E+13	9.26E+11	3.05E+14	3.08E+13	6.20E+10	6.68E+12	4.79E+12	0.00E+00	8.85E+13
Muskrat	1.04E+12	2.52E+13	3.48E+11	2.44E+14	1.23E+14	0.00E+00	2.87E+12	1.94E+12	0.00E+00	1.13E+14
Deer	3.47E+10	1.06E+13	1.48E+11	4.13E+13	2.75E+12	1.59E+10	4.11E+11	7.37E+11	0.00E+00	1.12E+13
Turkey	5.86E+06	1.33E+08	1.86E+07	6.04E+09	5.73E+08	3.07E+06	2.87E+07	1.12E+08	0.00E+00	5.98E+09
Goose	7.16E+08	6.56E+09	6.48E+08	6.35E+10	3.21E+10	0.00E+00	7.46E+08	5.05E+08	0.00E+00	2.94E+10
Duck	2.63E+07	2.41E+08	2.38E+07	2.33E+09	1.18E+09	0.00E+00	2.74E+07	1.86E+07	0.00E+00	1.08E+09
Unquantifiable	1.32E+11	1.07E+13	1.42E+11	5.90E+13	1.56E+13	7.79E+09	9.96E+11	7.47E+11	0.00E+00	2.13E+13
Total	1.45E+12	1.18E+14	1.57E+12	6.49E+14	1.72E+14	8.57E+10	1.10E+13	8.22E+12	0.00E+00	2.34E+14

Table B.24 Existing annual loads from land-based sources for the South River impairment (subsheds 39-44).

Source	Commercial Services (cfu/yr)	Cropland (cfu/yr)	Farmstead (cfu/yr)	Improved Pasture (cfu/yr)	Livestock Access (cfu/yr)	Livestock Operation (cfu/yr)	Residential (cfu/yr)	Unimproved Pasture (cfu/yr)	Water (cfu/yr)	Woodlands (cfu/yr)
Pets										
Dogs	0.00E+00	0.00E+00	4.22E+12	0.00E+00	0.00E+00	0.00E+00	6.36E+13	0.00E+00	0.00E+00	0.00E+00
Cats	0.00E+00	0.00E+00	3.27E+06	0.00E+00	0.00E+00	0.00E+00	4.93E+07	0.00E+00	0.00E+00	0.00E+00
Total	0.00E+00	0.00E+00	4.22E+12	0.00E+00	0.00E+00	0.00E+00	6.36E+13	0.00E+00	0.00E+00	0.00E+00
Human										
Failed Septic	0.00E+00	0.00E+00	5.88E+12	0.00E+00	0.00E+00	0.00E+00	6.85E+13	0.00E+00	0.00E+00	0.00E+00
Livestock										
Dairy	0.00E+00	1.75E+15	0.00E+00	6.89E+14	4.67E+13	0.00E+00	0.00E+00	2.13E+13	0.00E+00	0.00E+00
Beef	0.00E+00	0.00E+00	0.00E+00	1.38E+15	7.57E+13	0.00E+00	0.00E+00	2.84E+13	0.00E+00	0.00E+00
Horse	0.00E+00	0.00E+00	0.00E+00	1.19E+14	0.00E+00	0.00E+00	0.00E+00	2.73E+12	0.00E+00	0.00E+00
Swine	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sheep	0.00E+00	0.00E+00	0.00E+00	5.18E+12	0.00E+00	0.00E+00	0.00E+00	7.08E+10	0.00E+00	0.00E+00
Goat	0.00E+00	0.00E+00	0.00E+00	3.02E+11	0.00E+00	0.00E+00	0.00E+00	6.77E+09	0.00E+00	0.00E+00
Poultry	0.00E+00	4.03E+13	0.00E+00	3.33E+14	0.00E+00	0.00E+00	0.00E+00	4.30E+12	0.00E+00	0.00E+00
Total	0.00E+00	1.79E+15	0.00E+00	2.53E+15	1.22E+14	0.00E+00	0.00E+00	5.68E+13	0.00E+00	0.00E+00
Wildlife										
Raccoon	2.01E+12	2.90E+13	1.05E+12	2.45E+14	2.55E+13	1.12E+11	1.54E+13	6.20E+12	0.00E+00	3.46E+14
Muskrat	7.92E+12	1.70E+13	7.83E+11	1.87E+14	1.16E+14	1.74E+11	7.83E+12	5.77E+12	0.00E+00	3.13E+14
Deer	2.46E+11	4.26E+12	1.37E+11	3.33E+13	2.15E+12	1.39E+10	1.32E+12	8.20E+11	0.00E+00	4.96E+13
Turkey	1.00E+08	1.04E+08	3.06E+07	5.00E+09	4.47E+08	2.37E+06	4.25E+08	1.34E+08	0.00E+00	2.74E+10
Goose	4.50E+09	4.42E+09	8.36E+08	4.88E+10	3.09E+10	1.36E+08	2.03E+09	1.54E+09	0.00E+00	8.17E+10
Duck	1.65E+08	1.62E+08	3.07E+07	1.79E+09	1.13E+09	4.98E+06	7.48E+07	5.65E+07	0.00E+00	3.00E+09
Unquantifiable	1.02E+12	5.03E+12	1.97E+11	4.65E+13	1.43E+13	3.00E+10	2.46E+12	1.28E+12	0.00E+00	7.09E+13
Total	1.12E+13	5.53E+13	2.16E+12	5.12E+14	1.58E+14	3.30E+11	2.70E+13	1.41E+13	0.00E+00	7.80E+14

Table B.25 Existing annual loads from direct-deposition sources for the Upper Middle River impairment (subwatersheds 1-10).

Source	Fecal Coliform Load (cfu/yr)
<u>Human</u>	
Straight Pipes	1.32E+12
Total	1.32E+12
<u>Livestock</u>	
Dairy	6.66E+15
Beef	2.05E+15
Swine	4.07E+13
Goats	0.00E+00
Sheep	2.62E+12
Horse	1.45E+14
Poultry	1.22E+13
Total	8.91E+15
<u>Wildlife</u>	
Raccoon	3.35E+12
Muskrat	5.21E+13
Beaver	1.09E+10
Deer	1.05E+11
Turkey	3.44E+07
Goose	7.40E+09
Duck	4.13E+08
Total	5.56E+13

Table B.26 Existing annual loads from direct-deposition sources for the Jennings Branch watershed (non-impaired) (subwatersheds 11-12).

Source	Fecal Coliform Load (cfu/yr)
Human	
Straight Pipes	7.46E+11
Total	7.46E+11
Livestock	
Dairy	0.00E+00
Beef	2.29E+14
Swine	0.00E+00
Goats	0.00E+00
Sheep	1.03E+11
Horse	3.64E+13
Poultry	5.02E+12
Total	2.71E+14
Wildlife	
Raccoon	1.37E+12
Muskrat	2.24E+13
Beaver	4.25E+09
Deer	4.06E+10
Turkey	1.85E+07
Goose	3.19E+09
Duck	1.78E+08
Total	2.38E+13

Table B.27 Existing annual loads from direct-deposition sources for the Moffett Creek impairment (subwatersheds 13-17).

Source	Fecal Coliform Load (cfu/yr)
Human	
Straight Pipes	3.06E+11
Total	3.06E+11
Livestock	
Dairy	4.11E+15
Beef	2.14E+14
Swine	0.00E+00
Goats	0.00E+00
Sheep	5.39E+11
Horse	4.11E+13
Poultry	1.49E+13
Total	4.38E+15
Wildlife	
Raccoon	9.87E+11
Muskrat	1.57E+13
Beaver	2.89E+09
Deer	3.04E+10
Turkey	1.06E+07
Goose	2.23E+09
Duck	1.24E+08
Total	1.67E+13

Table B.28 Existing annual loads from direct-deposition sources for the Lewis Creek impairment (subwatersheds 18-25).

Source	Fecal Coliform Load (cfu/yr)
Human	
Straight Pipes	4.37E+11
Total	4.37E+11
Livestock	
Dairy	3.06E+15
Beef	4.49E+13
Swine	0.00E+00
Goats	0.00E+00
Sheep	1.54E+12
Horse	4.77E+13
Poultry	1.27E+12
Total	3.16E+15
Wildlife	
Raccoon	1.03E+12
Muskrat	1.68E+13
Beaver	2.13E+09
Deer	2.68E+10
Turkey	6.88E+06
Goose	2.57E+09
Duck	1.43E+08
Total	1.79E+13

Table B.29 Existing annual loads from direct-deposition sources for the Middle River watershed (non-impaired) (subwatersheds 26-32).

Source	Fecal Coliform Load (cfu/yr)
Human	
Straight Pipes	7.49E+11
Total	7.49E+11
Livestock	
Dairy	3.56E+15
Beef	7.03E+14
Swine	0.00E+00
Goats	9.71E+10
Sheep	2.26E+12
Horse	1.07E+14
Poultry	1.58E+13
Total	4.39E+15
Wildlife	
Raccoon	1.92E+12
Muskrat	3.40E+13
Beaver	5.17E+09
Deer	5.41E+10
Turkey	1.50E+07
Goose	4.83E+09
Duck	2.70E+08
Total	3.60E+13

Table B.30 Existing annual loads from direct-deposition sources for the Polecat Draft impairment (subwatershed 33).

Source	Fecal Coliform Load (cfu/yr)
Human	
Straight Pipes	2.17E+13
Total	2.17E+13
Livestock	
Dairy	1.19E+15
Beef	1.28E+14
Swine	0.00E+00
Goats	0.00E+00
Sheep	4.10E+11
Horse	9.57E+12
Poultry	5.89E+12
Total	1.33E+15
Wildlife	
Raccoon	2.55E+11
Muskrat	5.01E+12
Beaver	5.13E+06
Deer	6.33E+09
Turkey	1.59E+06
Goose	7.15E+08
Duck	3.99E+07
Total	5.27E+12

Table B.31 Existing annual loads from direct-deposition sources for the Lower Middle River impairment (subwatersheds 34-38).

Source	Fecal Coliform Load (cfu/yr)
<u>Human</u>	
Straight Pipes	1.92E+11
Total	1.92E+11
<u>Livestock</u>	
Dairy	1.21E+16
Beef	7.43E+14
Swine	0.00E+00
Goats	0.00E+00
Sheep	2.38E+12
Horse	6.10E+13
Poultry	1.42E+13
Total	1.29E+16
<u>Wildlife</u>	
Raccoon	1.27E+12
Muskrat	2.41E+13
Beaver	4.06E+09
Deer	3.36E+10
Turkey	6.45E+06
Goose	3.44E+09
Duck	1.92E+08
Total	2.54E+13

Table B.32 Existing annual loads from direct-deposition sources for the South River impairment (subwatersheds 39-44).

Source	Fecal Coliform Load (cfu/yr)
Human	
Straight Pipes	9.41E+11
Total	9.41E+11
Livestock	
Dairy	1.07E+15
Beef	6.37E+14
Swine	0.00E+00
Goats	1.32E+11
Sheep	2.25E+12
Horse	5.21E+13
Poultry	5.33E+12
Total	1.77E+15
Wildlife	
Raccoon	1.69E+12
Muskrat	3.20E+13
Beaver	8.41E+09
Deer	4.60E+10
Turkey	1.69E+07
Goose	4.65E+09
Duck	2.59E+08
Total	3.37E+13

APPENDIX C

Use of Antibiotic Resistance Analysis (ARA) to Identify Nonpoint Sources of Fecal Contamination in Several Augusta County Watersheds

Final Report

presented to

The Virginia Department of Conservation and Recreation

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September 30, 2003

Abstract

The antibiotic resistance analysis (ARA) method of determining the sources of fecal contamination in natural waterways was applied to several watersheds in Augusta County. ARA involves isolation of indicator bacteria (enterococci) from different known fecal samples, as well as from unknown water samples. Source identification is accomplished by using the statistical method of discriminant analysis to classify each isolate extracted from water by comparing its antibiotic resistance patterns with the resistance patterns of isolates taken from known fecal samples. The potential sources of fecal contamination that were tested were human septic systems, domesticated animals such as cattle, dogs, poultry, and horses, and wild animals such as geese and deer. Twenty-four stations on Mossy Creek, Moffett Creek, Lewis Creek, Polecat Draft, Upper Middle River, Lower Middle River, and Upper South River were sampled monthly from September 2002 through August 2003. The samples were processed using ARA, and fecal coliform and *E. coli* counts were measured to evaluate the quantity of fecal material in the water. The results indicate that livestock sources are the major contributor to the fecal pollution in these watersheds, although human and wild sources were present at lower levels.

Introduction

Fecal contamination in natural waterways can lead to several problems, including an increased incidence of pathogens (3). Additionally, the increased levels of phosphorous and nitrogen in natural waterways due to fecal pollution can lead to algal blooms that, when degraded, result in deoxygenation of waterways (1). This situation is currently leading to a deterioration of the aquatic environment in the Chesapeake Bay. Fecal contamination in waterways has consistently been demonstrated by the presence of indicator organisms such as fecal coliforms or enterococci (3). However, differentiation of the sources of fecal contamination in waters receiving mixed agricultural and human waste is more difficult. Knowledge of the source of fecal contamination is important because humans are more susceptible to infections by pathogens found in human feces (3). Once the source is identified, steps can be taken to control the influx of fecal pollution.

Antibiotic resistant bacteria can develop in animals and humans as a result of treatment with antibiotics. Our laboratory has developed antibiotic resistance analysis (ARA), which uses enterococci as an indicator organism in identification of sources of fecal contamination (4). Enterococci are a group of gram-positive, catalase-negative cocci that hydrolyze esculin, and are capable of growing at 6.5% NaCl and at 45°C. Enterococci are used because they survive well in natural waters and can be isolated from all potential sources of fecal pollution (4, 5). In this approach, enterococci are isolated from known fecal sources, and grown on plates containing various concentrations of 11 different antibiotics. The resulting antibiotic resistance patterns of each isolate are then analyzed using discriminant analysis, a multivariate statistical method. The results are pooled to form a "known library" of antibiotic resistance patterns from different fecal sources. Resistance patterns of isolates from natural waterways are then compared with this known library to determine the source(s) of fecal pollution in that waterway (4, 5, 7).

In this report, ARA, fecal coliform counts, and *E. coli* counts were used to draw conclusions about the source(s) of fecal contamination in several watersheds in Augusta County, Virginia. Mossy Creek is a tributary of the North River. Moffett Creek, Lewis Creek, Polecat Draft are tributaries of the Middle River. The North River, the Middle River, and the South River join together to form the South Fork of the Shenandoah River, which eventually flows into the Chesapeake Bay. The possible sources of fecal contamination in these watersheds have been identified as failing human septic systems, domesticated animals (including cattle, poultry, horses, and dogs) and wild animals (such as geese and deer). Twelve monthly sets of 24 samples were analyzed during the course of the project.

Materials and Methods

Sample Collection

Stream samples were collected in sterile 500-ml bottles by laboratory personnel and transported on wet ice to the laboratory. All stream samples were filtered within 6 hours of collection. Twenty-four sites (Table 1) were sampled each month (Table 2). A total of 288 stream samples were attempted to be collected. However, 15 samples could not be collected because the stream was dry, 7 samples could not be collected because the stream was frozen, 3 samples could not be collected because of mechanical problems with our field vehicle, and 1 sample was lost when the bottle was dropped.

Known fecal samples were collected by laboratory personnel, and were collected in sterile whirl-pack bags and transported in coolers to the lab. The numbers and sources of the known samples that were collected during the sampling period are shown in Table 3.

Isolation of enterococci

Varying amounts of fecal samples (0.1 – 0.5 g) were suspended in 50 ml of saline buffer. The sample was mixed vigorously before filtering through 0.45-µm pore-size filters. Varying volumes of stream samples were filtered using the same kind of filters. The filters were placed in 50-mm petri dishes containing 5 ml of m-Enterococcus agar. The petri dishes were incubated at 37°C for 48 hours. After incubation, isolated colonies were selected (23 for unknown samples, and 12 for known samples) and transferred to 96-microwell plates containing 0.2 ml of Enterococcosel broth. The microwell plates were incubated at 37°C for 48 hours. Esculin-negative isolates were not analyzed. The goal was to test 23 isolates from each sample, resulting in a precision of approximately 4%. Because of low counts, fewer isolates were analyzed for some samples.

Counting of Fecal Indicator Organisms

Fecal coliform (FC) counts were performed by filtering various volumes of all unknown stream samples, and of the suspended fecal samples (as described above). The filters were then placed in 50 mm petri-dishes containing 5 ml of m-FC agar. The petri dishes were incubated in an incubator at 35°C for 2 hours, and then transferred to a water bath at 44.5°C for 18 – 24 hours. After incubation, the number of blue colonies were enumerated and recorded.

Counts of *E. coli* were performed by filtering various volumes of all unknown stream samples, and of the suspended fecal samples (as described above). The filters were then placed in 50 mm petri-dishes containing 5 ml of modified mTEC agar (8). The petri dishes were incubated in an incubator at 35°C for 2 hours, and then transferred to a water bath at 44.5°C for 18 – 24 hours. After incubation, the number of red or magenta colonies were enumerated and recorded.

Enteroccocci counts were performed by filtering various volumes of all unknown stream samples, and of the suspended fecal samples (as described above). The filters were then placed in 50 mm petri-dishes containing 5 ml of mEnterococcus agar. The petri dishes were incubated at 37°C for 48 hours. After incubation, the number of red colonies were enumerated and recorded.

Antibiotics

Isolates from the 96-microwell plate were transferred to antibiotic-containing Trypticase Soy agar (TSA) plates using a sterile 48-prong replica-plater. Various concentrations of 11 antibiotics were used (37 concentrations total) (6). The isolates were also replica-plated to two TSA plates that did not contain antibiotics as a control. All TSA plates were incubated at 37°C for 24-48 hours. After incubation, the growth of each isolate on each concentration of each antibiotic was determined, and the resulting antibiotic resistance patterns were combined to form a library of known sources. For known samples, isolates with identical resistance patterns were discarded. Only unique isolates were used in the known library (Table 2).

Additional Libraries

In addition to the known isolates collected for this project, isolates from six other Virginia watersheds were used to create a larger, merged library. The watersheds used were: Blacks Run, Holmans Creek, Goose Creek, Long Glade Creek, Moores Creek, and Thumb Run.

Statistical Analysis

The results from resistance testing were entered into the SAS statistical program where they were analyzed using the DISCRIM procedure, which produces a classification table. The average rate of correct classification (ARCC) is the average rate that known isolates are correctly classified, and was used to measure the reliability of the known library. To cross-validate the known library, jackknife analyses were performed by removing all of the isolates from each sample, and classifying them using the resulting library. This simulates how well the library can classify "new" isolates, and is an estimation of the representativeness of the library. If a library is representative of a watershed, then isolates from new samples should be classified as well (on average) as the isolates of that type that are in the library.

The Minimum Detectable Percentage (MDP) was determined by averaging the expected frequency of misclassification (the percentages of other source types that were misclassified as that type) for each source type, and then adding three standard deviations to this average. The MDP estimates the average minimum percentage that can be detected in a stream sample (7).

Secondary discriminant analysis was also performed. For these analyses, a sub-library comprised of isolates from either Domestic or Wild sources was used to classify the unknown isolates that were classified into the “Domestic” and “Wild” categories, respectively.

Results

Library Construction

A library of the isolates obtained from eight types of known sources was constructed. As shown in Table 3, this Augusta County library consisted of 1,145 unique isolates. Unfortunately, because of the avian influenza outbreak, it was not possible for us to collect any poultry samples. Three-way discriminant analysis was performed on this library, with beef, dairy, sheep, horse, and dog isolates were pooled together as domestic, and duck and goose isolates were pooled together as wild. The ARCC for this library was 59% (Table 4). Jackknife analysis of this library resulted in an ARCC of 50% (not shown). This decrease suggests that the Augusta County library is not entirely representative of the watersheds it was collected from, and the absence of poultry isolates clearly underscores this. To resolve this lack, the isolates from the Augusta County library were combined with a much larger library comprised of 7,447 unique isolates collected in six other watersheds in

Virginia. Although larger libraries generally have slightly lower ARCCs, they are much more representative, and thus the confidence in the results is higher. When a three-way analysis was performed on this merged Virginia library, the ARCC was 55% (Table 5). The jackknife ARCC of this combined library was 53% (not shown), demonstrating that this library is very good at classifying new patterns. Because the merged library showed lower reductions in ARCC when cross-validated with jackknife analysis, this library was used to classify the unknown isolates.

Based on the merged library, the Minimum Detectable Percentage (MDP) was calculated. The expected frequency of misclassification was 20%, 24.5%, and 22.5% for human, domestic, and wild isolates, respectively. The mean of these is 22.3%, and the standard deviation is ± 2.25%. Adding 3 standard deviations to the means yields a MDP value of 29%. This means that if the percentage of, for example, domestic isolates in a sample exceeds 29%, we can be confident that these are actually domestic isolates, and not human or wild isolates that have been misclassified.

<u>Levels of Indicator Organisms</u>

A summary of the results for each sub-watershed is shown in Table 6, and the complete data are shown in Tables 7-13. Fifty-nine of the 266 samples for which counts were obtained had FC levels above the standard of 1000 FC/100 ml. The geometric mean of the FC counts over the 12 months exceeded 200 FC/100 ml at 13 of the 24 stations. The highest average counts were observed at Station 12 on Lewis Creek and at Station 28 on Back Creek. Fecal coliform counts were very similar to *E. coli* counts in the water samples. The correlation between the logs of the FC and *E. coli* counts was 86% (Figure 1). A paired t-test between the two sets of counts showed no significant difference ($p = 0.19$).

Fecal coliform, *E. coli*, and enterococci counts were also measured in the known fecal samples. The levels of FC and E. coli were approximately equal in all sources (Table 3). Generally, enterococci were found at lower levels than the coliforms, with the exception of geese and ducks, where they were approximately the same. The log of FC counts ranged from 3.91 cells/ml (humans) to 7.08 cells/g (dogs). Human septic samples had the lowest total counts, but this was because the fecal material was diluted in water.

<u>Three-way Classification of Unknown Isolates: Human vs. Domestic vs. Wild</u>

Using the merged library, the stream samples were classified. A summary of the results for each watershed is shown in Table 14, and the complete data are shown in Tables 15-21.

Mossy Creek. Pollution from domestic sources was the major contributor to all 4 stations on Mossy Creek. Every sample but one had levels of domestic sources above the MDP. Wild sources were present at levels above the MDP during the summer months at Stations 1, 2, and 4. Human pollution was detected at levels above the MDP occasionally, with the most occurring during the winter months at Station 1.

Moffett Creek. Pollution from domestic sources was the major contributor to all 4 stations on Moffett Creek. Every sample but one had levels of domestic sources above the MDP. Wild sources were present at levels above the MDP during the summer months at Stations 6 and, to a lesser extent, at Station 10. Human pollution was only occasionally detected at levels above the MDP, with the most occurring at Station 10.

Upper Middle River. Pollution from domestic sources was the major contributor to all 6 stations on Upper Middle River. Fifty-eight out of sixty-six samples had levels of domestic sources above the MDP. Wild sources were present at high levels at Stations 26 and 27. Human pollution was detected at levels above the MDP in 4 of 8 samples at Station 28. High levels of Human sources were present in January and February.

Middle Middle River. Pollution from domestic sources was the major contributor to both stations on Middle Middle River. Only two samples had levels of domestic sources below the MDP. Wild sources were present at high levels at Station 9. Human pollution was detected at levels above the MDP only occasionally, with the most occurring at Station 15.

Lewis Creek. Pollution from domestic sources was a major contributor to the stations on Lewis Creek. Twenty-five out of thirty-two samples had levels of domestic sources above the MDP. Wild sources were present at levels above the MDP in ten samples. Human pollution was a significant source at Station 12, with 8 of 12 samples with levels above the MDP.

Lower Middle River. Pollution from domestic sources was the major contributor to all 3 stations on Lower Middle River. Twenty-three out of thirty samples had levels of domestic sources above the MDP. Wild sources were present at high levels at Stations 17 and 23. Human pollution was detected at levels above the MDP only occasionally.

Upper South River. Pollution from domestic sources was the major contributor to both stations on Upper South River. Only two samples had levels of domestic sources below the MDP. Wild sources were present at high levels in 10 of 24 samples. Human pollution was detected in just 2 of 24 samples.

Secondary Classification of Unknown Isolates

To determine which of the domestic and wild sources were present in the samples, secondary discriminant analyses were performed.

Domestic sources. For this analysis, a sub-library comprised of known isolates from Domestic sources (grouped into Livestock, Poultry, and Dog) was used to classify the unknown isolates that were classified into the "Domestic" category. Of the 2,252 unknown isolates that were initially classified as Domestic, 2,122 of them (94%) were classified into the Livestock group.

Wild sources. For this analysis, a sub-library comprised of known isolates from Wild sources (grouped into Bird and Mammal) was used to classify the unknown isolates that were classified into the "Wild" category. Of the 1,194 unknown isolates that were initially classified as Wild, 657 of them (55%) were classified into the Bird group, and 537 were classified as Mammal (45%). All Stations had approximately equal proportions of each source.

Conclusions

These results show that domestic sources, primarily livestock, are the major source of pollution in these Augusta County watersheds. Every station showed levels of domestic animal fecal pollution at percentages above the MDP, and of this, 94% was classified as coming from livestock. Human fecal pollution was detected at several stations, but only two stations had average levels above the MDP. Fecal pollution from wild sources was more common than human, with seven stations showing average levels above the MDP. Wild sources were evenly split between birds and mammals.

More than half of the stations had fecal coliform counts that were above the Virginia standard of a geometric mean of 200 FC/100 ml. All but three stations had one or more monthly samples that exceeded the single-sample limit of 1000 FC/100 ml. Fecal coliform counts and *E. coli* counts correlated well (86%) and were not significantly different from one another.

Limitations of this study. The water samples analyzed in this study were collected over a twelve-month period. There may be year-to-year variation in the numbers and proportions of sources that were not included in the time frame of this study. Additionally, keep in mind that all BST methods, including ARA, are still being developed, and there are no "standard methods" yet for any method. There are many variables that determine the sources of fecal bacteria in water, and many of them are poorly understood.

Acknowledgments

This work was supported by a grant from the Virginia Department of Conservation and Recreation. Special thanks to Bill Keeling for coordinating the project, and to Philip Cash, Scott Dart, Shellie Davis, David Garrison, Jacquie McCarthy, Peter Rosanelli, and Amy Varner for technical assistance and laboratory analysis.

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Table 1. Location and description of sampling sites. Sites are listed from upstream to downstream.

Site #	Description	Latitude	Longitude
	Mossy Creek (HU B19)		
4	@ Route 731	38°20.499'	79°05.001'
3	@ Route 613	38°21.113'	79°02.923'
2	@ Route 747	38°21.448'	79°01.851'
1	@ Route 727	38°23.137'	79°00.904'
	Moffett Creek (HU B13)		
5	@ Route 42	38°17.613'	79°07.525'
6	Elk Run @ Route 835	38°15.740'	79°06.356'
7	@ Route 733	38°15.708'	79°06.072'
10	@ Route 732	38°14.661'	79°05.072'
	Upper Middle River (HU B10)		
31	@ Route 602	38°04.929'	79°14.812'
27	@ Route 705	38°08.509'	79°13.114'
30	Back Creek @ Route 841	38°06.430'	79°12.838'
28	Back Creek @ Route 707	38°08.601'	79°11.468'
26	@ Route 720	38°11.472'	79°09.856'
24	Buffalo Branch @ Route 703	38°11.127'	79°13.802'
	Middle Middle River (HU B12)		
9	@ Route 732	38°14.404'	79°06.381'
15	@ Route 11	38°12.471'	79°00.161'
	Lewis Creek (HU B12)		
34	@ Route 252	38°08.151'	79°05.252'
12	@ Route 254	38°09.102'	79°03.424'
14	@ Route 612	38°10.971'	78°58.536
	Lower Middle River (HU B15)		
22	@ Route 16	38°12.535'	78°55.613'
23	Polecat Draft @ Route 608	38°13.687'	78°58.019'
17	@ Route 769	38°15.717'	78°51.770'
	Upper South River (HU B30)		
38	@ Route 662	38°00.418'	79°09.666'
36	@ Route 652	38°01.356'	79°05.639'

Table 2. Dates of sampling of the sites in Augusta County. All samples were analyzed on the day they were collected. Set 1: sites # 9, 24, 26, 27, 28, 30, 31, and 34. Set 2: sites # 1, 2, 3, 4, 5, 6, 7, and 10. Set 3: sites # 12, 14, 15, 17, 22, 23, 36, and 38. Due to weather on some days, some stations were not sampled.

Month	Date Set 1 Collected	Date Set 2 Collected	Date Set 3 Collected
September 2002	9/3	9/13	9/25
October 2002	10/2	10/21	10/30
November 2002	11/4	11/14	11/25
December 2002	12/9	12/17	12/29
January 2003	1/7	1/15	1/24
February 2003	2/5	2/24	2/28
March 2003	3/12	3/18	3/27
April 2003	4/9	4/16	4/28
May 2003	5/7	5/15	5/28
June 2003	6/11	6/17	6/23
July 2003	7/9	7/16	7/24
August 2003	8/15	8/21	8/28

Table 3. Numbers of known fecal samples and isolates collected for this study, and geometric means and SD of the numbers of indicator organisms in each source.

Source	No. of Samples	Total No. of Isolates	No. of Unique Isolates	Log #FC	Log #*E. coli*	Log #ENT
Beef	21	226	173	4.83 ± 0.60	4.81 ± 0.61	3.71 ± 0.51
Dairy	24	221	150	4.78 ± 0.64	4.71 ± 0.71	3.90 ± 0.74
Horse	6	67	47	4.12 ± 0.59	4.03 ± 0.70	3.61 ± 1.18
Dog	8	90	59	7.08 ± 0.72	7.09 ± 0.79	6.23 ± 0.96
Sheep	7	81	47	5.15 ± 0.18	5.05 ± 0.16	4.30 ± 0.57
Goose	27	352	206	6.59 ± 1.61	6.50 ± 1.31	7.04 ± 1.47
Duck	3	24	16	6.25 ± 0.71	6.18 ± 0.67	6.23 ± 0.55
Human	54	594	447	3.91 ± 0.49	3.79 ± 0.50	3.32 ± 0.64
Totals	150	1,655	1,145	--	--	--

Table 4. Classification of 1,145 unique isolates of enterococci from known human, domestic, and wild sources in Augusta County, Virginia. Correctly-classified isolates are shown in bold. The ARCC for this analysis is 59%.

	Number (and Percent) of Isolates Classified As:		
SOURCE	HUMAN	DOMESTIC	WILD
HUMAN (n = 447)	**288 (64)**	88 (20)	71 (16)
DOMESTIC (n = 476)	84 (18)	**235 (49)**	157 (33)
WILD (n = 222)	27 (12)	57 (26)	**138 (62)**

Table 5. Classification of 8,592 unique isolates of enterococci from known human, domestic, and wild sources in Virginia. Correctly-classified isolates are shown in bold. The ARCC for this analysis is 55%.

	Number (and Percent) of Isolates Classified As:		
SOURCE	HUMAN	DOMESTIC	WILD
HUMAN (n = 2,573)	**1,570 (61)**	544 (21)	459 (18)
DOMESTIC (n = 4,512)	917 (20)	**2,390 (53)**	1,205 (27)
WILD (n = 1,507)	299 (20)	422 (28)	**786 (52)**

Table 6. Summary of indicator counts for fecal coliforms (FC), *E. coli*, and enterococci (ENT) at each sampling site. Values are the geometric means of the monthly levels. Fecal coliform (FC) values in bold are above 200 cells/100 ml. *E. coli* (EC) values in bold are above 126 cells/100 ml.Sites are listed from upstream to downstream.

Site #	Description	FC	*E. coli*	ENT
	Mossy Creek (HU B19)			
4	@ Route 731	97	78	178
3	@ Route 613	**315**	**329**	269
2	@ Route 747	198	**215**	236
1	@ Route 727	**413**	**302**	325
	Moffett Creek (HU B13)			
5	@ Route 42	145	**168**	129
6	Elk Run @ Route 835	186	**237**	209
7	@ Route 733	188	**148**	210
10	@ Route 732	**253**	**188**	249
	Upper Middle River (HU B10)			
31	@ Route 602	**670**	**709**	214
27	@ Route 705	**356**	**368**	166
30	Back Creek @ Route 841	**249**	**249**	155
28	Back Creek @ Route 707	**1,019**	**868**	600
26	@ Route 720	160	**150**	133
24	Buffalo Branch @ Route 703	13	9	22
	Middle Middle River (HU B12)			
9	@ Route 732	147	110	117
15	@ Route 11	56	53	89
	Lewis Creek (HU B12)			
34	@ Route 252	**204**	**139**	122
12	@ Route 254	**1,471**	**559**	649
14	@ Route 612	**325**	**219**	220
	Lower Middle River (HU B15)			
22	@ Route 16	103	**165**	204
23	Polecat Draft @ Route 608	**333**	**284**	338
17	@ Route 769	121	103	162
	Upper South River (HU B30)			
38	@ Route 662	**646**	**442**	480
36	@ Route 652	**315**	**269**	283

Table 14. Summary of three-way ARA classification into human, domestic, or wild sources at each sampling site. Values are the averages of the monthly percentages. Values in bold are above the MDP of 29%. Sites are listed from upstream to downstream.

Site #	**Description**	Human	Domestic	Wild
	Mossy Creek (HU B19)			
4	@ Route 731	12	**68**	20
3	@ Route 613	20	**63**	17
2	@ Route 747	16	**58**	25
1	@ Route 727	17	**55**	28
	Moffett Creek (HU B13)			
5	@ Route 42	15	**64**	21
6	Elk Run @ Route 835	13	**57**	**30**
7	@ Route 733	15	**66**	19
10	@ Route 732	21	**58**	20
	Upper Middle River (HU B10)			
31	@ Route 602	17	**55**	28
27	@ Route 705	19	**52**	**29**
30	Back Creek @ Route 841	19	**57**	24
28	Back Creek @ Route 707	**29**	**49**	22
26	@ Route 720	20	**45**	**35**
24	Buffalo Branch @ Route 703	26	**51**	24
	Middle Middle River (HU B12)			
9	@ Route 732	18	**50**	**32**
15	@ Route 11	23	**53**	24
	Lewis Creek (HU B12)			
34	@ Route 252	24	**48**	27
12	@ Route 254	**39**	**41**	19
14	@ Route 612	21	**48**	**31**
	Lower Middle River (HU B15)			
22	@ Route 16	17	**59**	24
23	Polecat Draft @ Route 608	20	**41**	**39**
17	@ Route 769	13	**54**	**33**
	Upper South River (HU B30)			
38	@ Route 662	19	**57**	24
36	@ Route 652	15	**57**	28

APPENDIX D

Finalized GWLF Transport Input for Simulating Existing Conditions

Table D.1 Moffett Creek and Reference Watershed Mill Creek GWLF Watershed Parameters for Existing Conditions

GWLF Watershed Parameter	Units	Moffett Creek	Mill Creek
Recession Coefficient	Day^{-1}	0.0384	0.0484
Seepage Coefficient	Day^{-1}	0.02	0.02
Sediment Delivery Ratio		0.13	0.114
Unsaturated Water Capacity	(cm)	13	13
Erosivity Coefficient (April-Sept.)		0.25	0.25
Erosivity Coefficient (Oct.-Mar)		0.06	0.06
% developed land	(%)	0.20	0.69
Livestock density	(AU/ac)	0.1711	0.1170
Area-weighted soil erodibility		0.297	0.312
Area weighted runoff curve number		68.44	70.19
Total Stream Length	(m)	24770.0	69541.0
Mean channel depth	(m)	0.95	1.07

Table D.2 Moffett Creek and Reference Watershed Mill Creek GWLF Monthly Evaporation Cover Coefficients for Existing Conditions

Watershed	Apr	May	Jun	Jul*	Aug	Sep	Oct	Nov	Dec	Jan*	Feb	Mar
Moffett Cr.	0.30	0.60	1.10	1.10	1.10	0.65	0.65	0.50	0.50	0.50	0.40	0.40
Mill Cr.	0.5	0.65	0.80	0.77	0.76	0.74	0.72	0.66	0.65	0.65	0.65	0.45

Table D.3 Moffett Creek and Reference Watershed Mill Creek GWLF Landuse Parameters for Existing Conditions.

Landuse	Moffett Creek		Mill Creek	
Category	CN	KLSCP	CN	KLSCP
LDR-PER	65.97	0.0014	71.35	0.0018
MDR-PER		0.0000		0.0000
HDR-PER		0.0000		0.0000
COM-PER	69.37	0.0014	64.28	0.0015
Transitional	85.49	0.0667	83.89	0.0750
Forest	64.35	0.0022	66.88	0.0009
Urban Grass		0.0000		0.0000
Pasture 1	82.28	0.2058	83.89	0.1009
Pasture 2	73.68	0.0974	75.99	0.0466
Pasture 3	67.08	0.0161	70.09	0.0087
High-tillage	80.34	0.2698	81.02	0.3063
Low-tillage	77.28	0.0737	78.23	0.0837
LDR-IMP	98.00	0.0000	98.00	0.0000
MDR-IMP		0.0000		0.0000
HDR-IMP		0.0000		0.0000
COM-IMP	98.00	0.0000	98.00	0.0000

Table D.4 Area Adjustment for Moffett Creek TMDL Reference Watershed (ha) Mill Creek.

Landuse Category	Impaired	Mill Creek TMDL Original	Reference (area-adjusted)
	Moffett Creek	Mill Creek	Mill Creek (x 0.6678)
LDR-PER	10.36	35.53	23.73
MDR-PER	0.00	0.00	0.00
HDR-PER	0.00	0.00	0.00
COM-PER	0.35	0.60	0.40
Transitional	0.44	19.26	12.86
Forest	3,253.09	6,136.72	4,098.10
Urban Grass	0.00	0.00	0.00
Pasture 1	502.71	778.78	520.07
Pasture 2	1,173.00	1,168.18	780.11
Pasture 3	1,675.72	1,946.96	1,300.18
High-tillage	50.83	112.49	75.12
Low-tillage	202.06	67.21	44.88
LDR-IMP	2.75	34.14	22.80
MDR-IMP	0.00	0.00	0.00
HDR-IMP	0.00	0.00	0.00
Com-IMP	0.09	0.57	0.38

Table D.5 GWLF Watershed Parameters for Upper Middle River and Reference Watershed Hays Creek Existing Conditions.

GWLF Watershed Parameter	Units	Upper Middle River	Hays
Recession Coefficient	Day^{-1}	0.0384	0.0369
Seepage Coefficient	Day^{-1}	0.02	0.02
Sediment Delivery Ratio		0.11	0.09
Unsaturated Water Capacity	(cm)	13	15
Erosivity Coefficient (April-Sept.)		0.25	0.25
Erosivity Coefficient (Oct.-Mar)		0.06	0.06
% developed land	(%)	0.2	0.13
Livestock density	(AU/ac)	0.1618	0.1373
Area weighted soil erodibility		0.308	0.289
Area weighted runoff curve number		69.25	61.80
Total Stream Length	(m)	26,324	96,087
Mean channel depth	(m)	1.12	1.30

Table D.6 GWLF Monthly Evaporation Cover Coefficients Upper Middle River and Reference Watershed for Existing Conditions

Watershed	Apr	May	Jun	Jul*	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Upper Middle River	0.30	0.60	1.10	1.10	1.10	0.65	0.65	0.50	0.50	0.50	0.40	0.40
Hays	0.60	0.60	0.90	0.90	0.90	0.80	0.75	0.70	0.70	0.70	0.70	0.60

Table D.7 Upper Middle River and Reference Watershed Hays Creek GWLF Landuse Parameters for Existing Conditions.

Landuse Category	Upper Middle River		Hays	
	CN	KLSCP	CN	KLSCP
LDR-PER	65.97	0.00158	62.859	0.00242
MDR-PER		0.00000		0
HDR-PER		0.00000		0.00157
COM-PER		0.00000		0
Transitional	85.49	0.19586	85.93	0.26909
Forest	64.35	0.00177	58.38	0.00289
Urban Grass		0.00000		0
Pasture 1	82.28	0.14143	84.69	0.26848
Pasture 2	73.68	0.06694	70.74	0.129499
Pasture 3	67.08	0.01226	63.26	0.021421
High-tillage	80.34	0.20766	81.00	0.34318
Low-tillage	77.28	0.05675	77.01	0.09378
LDR-IMP	98.00	0.00000	98.00	0.00000
MDR-IMP		0.00000		0.00000
HDR-IMP		0.00000		0.00000
COM-IMP		0.00000		0.00000

Table D.8 Area Adjustment for Upper Middle River TMDL Reference Watershed (ha) Hays Creek.

Landuse Category	Upper Middle River TMDL		
	Impaired Upper Middle River	Original Hays	Reference Hays (x 0.5973)
LDR-PER	20.55	18.27	10.91
MDR-PER	0.00	0.00	0.00
HDR-PER	0.00	1.29	0.77
COM-PER	0.00	0.00	0.00
Transitional	28.46	13.39	8.00
Forest	4,592.51	10,672.63	6,374.76
Urban Grass	0.00	0.00	0.00
Pasture 1	1,065.74	0.00	0.00
Pasture 2	2,486.73	2,389.57	1,427.29
Pasture 3	3,552.48	7,168.73	4,281.88
High-tillage	111.04	61.61	36.80
Low-tillage	433.29	264.36	157.90
LDR-IMP	5.46	7.10	4.24
MDR-IMP	0.00	0.00	0.00
HDR-IMP	0.00	0.50	0.30
Com-IMP	0.00	0.00	0.00

Table D.9 Christians Creek and Reference Watershed Opequon Creek GWLF Watershed Parameters for Existing Conditions

GWLF Watershed Parameter	Units	Christians Creek	Opequon Creek
Recession Coefficient	Day^{-1}	0.0384	0.0655
Seepage Coefficient	Day^{-1}	0.02	0.02
Sediment Delivery Ratio		0.08	0.104
Unsaturated Water Capacity	(cm)	13	13
Erosivity Coefficient (April-Sept.)		0.25	0.25
Erosivity Coefficient (Oct.-Mar)		0.06	0.06
% developed land	(%)	4.3	4.6
Livestock density	(AU/ac)	0.1617	0.0769
Area weighted soil erodibility		0.307	0.310
Area weighted runoff curve number		70.29	74.59
Total Stream Length (Watershed)	(m)	68,459	50,824
First Order Stream Length	(m)	44,824	32,491
Mean channel depth	(m)	1.55	1.15

Table D.10 Christians Creek and Reference Watershed Opequon GWLF Monthly Evaporation Cover Coefficients for Existing Conditions

Watershed	Apr	May	Jun	Jul*	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Christians Creek	0.30	0.60	01.10	1.10	1.10	0.65	0.65	0.50	0.50	0.50	0.40	0.40
Opequon Creek	0.82	0.83	0.85	0.85	0.85	0.77	0.76	0.75	0.75	0.75	0.77	0.8

Table D.11 Christians Creek and Reference Watershed Opequon Creek GWLF Landuse Parameters for Existing Conditions.

Landuse Category	Christians Creek		Opequon Creek	
	CN	KLSCP	CN	KLSCP
LDR-STR-COR-PER	61.00	0.002186	74.86	0.003349
MDR-STR-COR-PER		0.000000		0.000000
HDR-STR-COR-PER		0.000000	74.60	0.001916
COM-STR-COR-PER	63.60	0.001754	75.25	0.001916
Trans.- STR-COR		0.00000	86.00	0.023648
Forest - COR	58.45	0.001172	71.81	0.002319
Urban Grass - COR		0.000000	78.02	0.000748
Pasture 1- STR-COR	77.72	0.0429180	86.22	0.144381
Pasture 2- STR-COR	66.68	0.0203150	79.37	0.06834
Pasture 3 – STR-COR	58.45	0.003720	74.44	0.012513
High till- STR-COR	75.30	0.110575	83.52	0.314014
Low till – STR-COR	71.00	0.030216	81.52	0.08581
LDR- STR-COR-IMP	98.00	0.000364	98.00	0.000558
MDR - STR-COR-IMP		0.000000	98.00	0.00000
HDR- STR-COR-IMP		0.000000		0.000000
COM-STR-COR-IMP	98.00	0.000292	98.00	0.000319

Table D.12 Area Adjustment for Christians Creek TMDL Reference Watersheds Opequon Creek.

Landuse Category	Impaired Christians Creek	Christians Creek TMDL Original Opequon Creek	Reference Opequon Creek x 2.029
LDR-PER-COR	0.118	10.740	21.791
MDR-PER-COR	0.000	0.000	0.000
HDR-PER-COR		0.279	0.565
COM-PER-COR	0.261	1.813	3.679
Transitional-COR	0.000	0.111	0.224
Forest-COR	84.444	149.438	303.210
Urban Grass-COR	0.000	5.092	10.331
Pasture 1-COR	41.717	0.799	1.620
Pasture 2-COR	97.339	18.662	37.865
Pasture 3-COR	139.055	145.586	295.394
High-tillage-COR	2.222	6.328	12.839
Low-tillage-COR	6.667	4.852	9.845
LDR-IMP-COR	0.104	6.306	12.794
MDR-IMP-COR	0.000	0.000	0.000
HDR-IMP-COR	0.000	0.164	0.332
COM-IMP-COR	0.295	1.065	2.161

APPENDIX E

Table E.1 Best Management Practices Listed by Impairment

Impairment	Subshed #s	BMP	# of BMPs	Description	Type of Implementation	Extent of Implementation
Upper Middle	1-10	FR-1	1	Reforestation of Erodible Crop and Pastureland	ACRES	4.00
		FR-3	3	Woodland Buffer Filter Area	ACRES	10.40
		SL-1	1	Permanent Vegetative Cover on Cropland (State)	ACRES	55.80
		SL-11	1	Permanent Vegetative Cover on Critical Areas	ACRES	1.00
		SL-6	10	Grazing Land Protection	LINEAR FEET	14,035.00
		SL-8B	25	Small grain cover crop for Nutrient Management	ACRES	707.70
		SP-1	1	Nutrient Management Plan Writing	ACRES	297.00
		WP-2	2	Stream Protection	LINEAR FEET	4,385.00
		WP-4	8	Animal Waste Control Facility	SYSTEM	8.00
		WP-4C	3	Composter Facility	SYSTEM	3.00
Jennings Branch	11-12	FR-1	2	Reforestation of Erodible Crop and Pastureland	ACRES	39.00
		SL-6	1	Grazing Land Protection	ACRES	212.00
		SL-8B	3	Small grain cover crop for Nutrient Management	ACRES	41.40
		WP-4	3	Animal Waste Control Facility	SYSTEM	3.00
		WP-4C	1	Composter Facility	SYSTEM	1.00
Moffett Creek	13-17	FR-1	3	Reforestation of Erodible Crop and Pastureland	ACRES	53.00
		NM-3	5	Woodland Buffer Filter Area	ACRES	196.40
		SL-6	2	Grazing Land Protection	ACRES	109.70
		SL-8B	16	Small grain cover crop for Nutrient Management	ACRES	435.40
		WP-2	3	Stream Protection	LINEAR FEET	584.00
		WP-4	4	Animal Waste Control Facility	SYSTEM	4.00
		WP-4C	1	Composter Facility	SYSTEM	1.00

Table E.1 Best Management Practices Listed by Impairment (cont.)

Impairment	Subshed #s	BMP	# of BMPs	Description	Type of Implementation	Extent of Implementation
Lewis Creek	18-25	FR-1	2	Reforestation of Erodible Crop and Pastureland	ACRES	18.00
		SL-11	1	Permanent Vegetative Cover on Critical Areas	ACRES	1.00
		SL-6	3	Grazing Land Protection	ACRES	98.00
		WP-2	1	Stream Protection	LIN FT	240.00
Middle River	26-32	FR-1	3	Reforestation of Erodible Crop and Pastureland	ACRES	44.00
		FR-3	3	Woodland Buffer Filter Area	ACRES	9.90
		NM-1	2	Nutrient Management Plan Writing	ACRES	42.70
		SL-1	2	Permanent Vegetative Cover on Cropland (State)	ACRES	37.00
		SL-3	1	Woodland Buffer Filter Area	ACRES	18.50
		SL-6	10	Grazing Land Protection	LINEAR FEET	1,733.50
		SL-8B	17	Small grain cover crop for Nutrient Management	ACRES	302.90
		WP-2	2	Stream Protection	LINEAR FEET	7,040.00
		WP-2A	1	Streambank Stabilization	LINEAR FEET	160.00
		WP-3	1	Sod Waterway	ACRES	1.00
		WP-4	8	Animal Waste Control Facility	SYSTEM	8.00
		WP-4C	3	Composter Facility	SYSTEM	3.00
Polecat Draft	33	NM-3	2	Woodland Buffer Filter Area	ACRES	51.00
		NM-4	1	Late Winter Split Application of Nitrogen on Small Grain	ACRES	20.00
		SL-3	1	Woodland Buffer Filter Area	ACRES	129.00
		SL-6	1	Grazing Land Protection	ACRES	20.00
		SL-8B	4	Small grain cover crop for Nutrient Management	ACRES	83.00
		WP-4	1	Animal Waste Control Facility	SYSTEM	1.00
		WP-4C	1	Composter Facility	SYSTEM	1.00

Table E.1 Best Management Practices Listed by Impairment (cont.)

Impairment	Subshed #s	BMP	# of BMPs	Description	Type of Implementation	Extent of Implementation
Lower Middle	34-38	FR-1	1	Reforestation of Erodible Crop and Pastureland	ACRES	25.00
		NM-1	1	Nutrient Management Plan Writing	ACRES	109.00
		NM-3	2	Woodland Buffer Filter Area	ACRES	199.00
		NM-4	1	Late Winter Split Application of Nitrogen on Small Grain	ACRES	63.00
		SL-1	4	Permanent Vegetative Cover on Cropland (State)	ACRES	79.00
		SL-11	1	Permanent Vegetative Cover on Critical Areas	ACRES	1.00
		SL-3	3	Woodland Buffer Filter Area	ACRES	149.00
		SL-6	11	Grazing Land Protection	ACRES	7,496.90
		SL-8B	21	Small grain cover crop for Nutrient Management	ACRES	602.00
		WP-2	1	Stream Protection	LINEAR FEET	1,000.00
		WP-3	4	Sod Waterway	ACRES	8.86
		WP-4	15	Animal Waste Control Facility	SYSTEM	15.00
		WP-4B	3	Loafing Lot Management System	SYSTEM	202.00
		WP-4C	2	Composter Facility	SYSTEM	2.00

Table E.1 Best Management Practices Listed by Impairment (cont.)

Impairment	Subshed #s	BMP	# of BMPs	Description	Type of Implementation	Extent of Implementation
South River	39-44	FR-1	2	Reforestation of Erodible Crop and Pastureland	ACRES	26.00
		NM-1	7	Nutrient Management Plan Writing	ACRES	433.90
		NM-3B	1	Manure Application to Corn using Pre-Sidedress Nitrate Test to Determine Need for Sidedress Nitrogen	ACRES	45.00
		SL-11	1	Permanent Vegetative Cover on Critical Areas	ACRES	1.00
		SL-3	3	Woodland Buffer Filter Area	ACRES	87.00
		SL-6	7	Grazing Land Protection	LINEAR FEET	2,557.00
		SL-8B	9	Small grain cover crop for Nutrient Management	ACRES	277.10
		SP-1	1	Nutrient Management Plan Writing	ACRES	65.00
		SP-2	1	Soil Analysis for Nutrient Management Plan Writing	ACRES	65.00
		SP-3	1	Sidedress Application of N on Corn	ACRES	65.00
		WP-3	1	Sod Waterway	ACRES	1.00
		WP-4	3	Animal Waste Control Facility	SYSTEM	3.00
		WP-4C	2	Composter Facility	SYSTEM	2.00

APPENDIX F

EXCERPT FROM UCI FILE USED FOR MODELING

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PERLND
  ACTIVITY
*** <PLS >               Active Sections                               ***
*** x -  x ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC ***
   10  389    0    0    1    0    0    0    1    0    0    0    0    0
  END ACTIVITY

  PRINT-INFO
*** < PLS>                       Print-flags                           PIVL  PYR
*** x  - x ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC
   10  389    4    4    4    4    4    4    4    4    4    4    4    4    1    9
  END PRINT-INFO

  GEN-INFO
***             Name                  Unit-systems   Printer BinaryOut
*** <PLS >                                t-series Engl Metr Engl Metr
*** x -  x                                 in  out
   10     1_Livestock Access                1    1    0    0    0    0
   11     1_Commercial and Ser              1    1    0    0    0    0
   12     1_Cropland                        1    1    0    0    0    0
   13     1_Farmstead                       1    1    0    0    0    0
   14     1_Improved Pasture                1    1    0    0    0    0
   15     1_Livestock Operatio              1    1    0    0    0    0
   16     1_Residential                     1    1    0    0    0    0
   17     1_Unimproved Pasture              1    1    0    0    0    0
   18     1_Water                           1    1    0    0    0    0
   19     1_Woodland                        1    1    0    0    0    0
   20     2_Livestock Access                1    1    0    0    0    0
   22     2_Cropland                        1    1    0    0    0    0
   23     2_Farmstead                       1    1    0    0    0    0
   24     2_Improved Pasture                1    1    0    0    0    0
   26     2_Residential                     1    1    0    0    0    0
   27     2_Unimproved Pasture              1    1    0    0    0    0
   28     2_Water                           1    1    0    0    0    0
   29     2_Woodland                        1    1    0    0    0    0
   30     3_Livestock Access                1    1    0    0    0    0
   31     3_Commercial and Ser              1    1    0    0    0    0
   32     3_Cropland                        1    1    0    0    0    0
   33     3_Farmstead                       1    1    0    0    0    0
   34     3_Improved Pasture                1    1    0    0    0    0
   35     3_Livestock Operatio              1    1    0    0    0    0
   36     3_Residential                     1    1    0    0    0    0
   37     3_Unimproved Pasture              1    1    0    0    0    0
   38     3_Water                           1    1    0    0    0    0
   39     3_Woodland                        1    1    0    0    0    0
   40     4_Livestock Access                1    1    0    0    0    0
   42     4_Cropland                        1    1    0    0    0    0
   43     4_Farmstead                       1    1    0    0    0    0
   44     4_Improved Pasture                1    1    0    0    0    0
   46     4_Residential                     1    1    0    0    0    0
   47     4_Unimproved Pasture              1    1    0    0    0    0
   48     4_Water                           1    1    0    0    0    0
   49     4_Woodland                        1    1    0    0    0    0
   50     5_Livestock Access                1    1    0    0    0    0
   52     5_Cropland                        1    1    0    0    0    0
   53     5_Farmstead                       1    1    0    0    0    0
   54     5_Improved Pasture                1    1    0    0    0    0
   55     5_Livestock Operatio              1    1    0    0    0    0
   56     5_Residential                     1    1    0    0    0    0
   57     5_Unimproved Pasture              1    1    0    0    0    0
   58     5_Water                           1    1    0    0    0    0
   59     5_Woodland                        1    1    0    0    0    0
   60     6_Livestock Access                1    1    0    0    0    0
   61     6_Commercial and Ser              1    1    0    0    0    0
   62     6_Cropland                        1    1    0    0    0    0
   63     6_Farmstead                       1    1    0    0    0    0
   64     6_Improved Pasture                1    1    0    0    0    0
   65     6_Livestock Operatio              1    1    0    0    0    0
```

66	6_Residential	1	1	0	0	0	0
67	6_Unimproved Pasture	1	1	0	0	0	0
68	6_Water	1	1	0	0	0	0
69	6_Woodland	1	1	0	0	0	0
70	7_Livestock Access	1	1	0	0	0	0
71	7_Commercial and Ser	1	1	0	0	0	0
72	7_Cropland	1	1	0	0	0	0
73	7_Farmstead	1	1	0	0	0	0
74	7_Improved Pasture	1	1	0	0	0	0
76	7_Residential	1	1	0	0	0	0
77	7_Unimproved Pasture	1	1	0	0	0	0
79	7_Woodland	1	1	0	0	0	0
80	8_Livestock Access	1	1	0	0	0	0
83	8_Farmstead	1	1	0	0	0	0
84	8_Improved Pasture	1	1	0	0	0	0
86	8_Residential	1	1	0	0	0	0
87	8_Unimproved Pasture	1	1	0	0	0	0
89	8_Woodland	1	1	0	0	0	0
90	9_Livestock Access	1	1	0	0	0	0
91	9_Commercial and Ser	1	1	0	0	0	0
92	9_Cropland	1	1	0	0	0	0
93	9_Farmstead	1	1	0	0	0	0
94	9_Improved Pasture	1	1	0	0	0	0
95	9_Livestock Operatio	1	1	0	0	0	0
96	9_Residential	1	1	0	0	0	0
97	9_Unimproved Pasture	1	1	0	0	0	0
98	9_Water	1	1	0	0	0	0
99	9_Woodland	1	1	0	0	0	0
100	10_Livestock Access	1	1	0	0	0	0
102	10_Cropland	1	1	0	0	0	0
103	10_Farmstead	1	1	0	0	0	0
104	10_Improved Pasture	1	1	0	0	0	0
105	10_Livestock Operati	1	1	0	0	0	0
106	10_Residential	1	1	0	0	0	0
107	10_Unimproved Pastur	1	1	0	0	0	0
108	10_Water	1	1	0	0	0	0
109	10_Woodland	1	1	0	0	0	0
110	11_Livestock Access	1	1	0	0	0	0
111	11_Commercial and Se	1	1	0	0	0	0
112	11_Cropland	1	1	0	0	0	0
113	11_Farmstead	1	1	0	0	0	0
114	11_Improved Pasture	1	1	0	0	0	0
115	11_Livestock Operati	1	1	0	0	0	0
116	11_Residential	1	1	0	0	0	0
117	11_Unimproved Pastur	1	1	0	0	0	0
118	11_Water	1	1	0	0	0	0
119	11_Woodland	1	1	0	0	0	0
120	12_Livestock Access	1	1	0	0	0	0
121	12_Commercial and Se	1	1	0	0	0	0
122	12_Cropland	1	1	0	0	0	0
123	12_Farmstead	1	1	0	0	0	0
124	12_Improved Pasture	1	1	0	0	0	0
125	12_Livestock Operati	1	1	0	0	0	0
126	12_Residential	1	1	0	0	0	0
127	12_Unimproved Pastur	1	1	0	0	0	0
128	12_Water	1	1	0	0	0	0
129	12_Woodland	1	1	0	0	0	0
130	13_Livestock Access	1	1	0	0	0	0
131	13_Commercial and Se	1	1	0	0	0	0
134	13_Improved Pasture	1	1	0	0	0	0
136	13_Residential	1	1	0	0	0	0
137	13_Unimproved Pastur	1	1	0	0	0	0
139	13_Woodland	1	1	0	0	0	0
140	14_Livestock Access	1	1	0	0	0	0
142	14_Cropland	1	1	0	0	0	0
143	14_Farmstead	1	1	0	0	0	0
144	14_Improved Pasture	1	1	0	0	0	0
145	14_Livestock Operati	1	1	0	0	0	0
146	14_Residential	1	1	0	0	0	0
147	14_Unimproved Pastur	1	1	0	0	0	0
148	14_Water	1	1	0	0	0	0

149	14_Woodland	1	1	0	0	0	0
150	15_Livestock Access	1	1	0	0	0	0
152	15_Cropland	1	1	0	0	0	0
153	15_Farmstead	1	1	0	0	0	0
154	15_Improved Pasture	1	1	0	0	0	0
155	15_Livestock Operati	1	1	0	0	0	0
156	15_Residential	1	1	0	0	0	0
157	15_Unimproved Pastur	1	1	0	0	0	0
159	15_Woodland	1	1	0	0	0	0
160	16_Livestock Access	1	1	0	0	0	0
161	16_Commercial and Se	1	1	0	0	0	0
162	16_Cropland	1	1	0	0	0	0
163	16_Farmstead	1	1	0	0	0	0
164	16_Improved Pasture	1	1	0	0	0	0
165	16_Livestock Operati	1	1	0	0	0	0
166	16_Residential	1	1	0	0	0	0
167	16_Unimproved Pastur	1	1	0	0	0	0
169	16_Woodland	1	1	0	0	0	0
170	17_Livestock Access	1	1	0	0	0	0
172	17_Cropland	1	1	0	0	0	0
173	17_Farmstead	1	1	0	0	0	0
174	17_Improved Pasture	1	1	0	0	0	0
176	17_Residential	1	1	0	0	0	0
177	17_Unimproved Pastur	1	1	0	0	0	0
178	17_Water	1	1	0	0	0	0
179	17_Woodland	1	1	0	0	0	0
180	18_Livestock Access	1	1	0	0	0	0
181	18_Commercial and Se	1	1	0	0	0	0
182	18_Cropland	1	1	0	0	0	0
183	18_Farmstead	1	1	0	0	0	0
184	18_Improved Pasture	1	1	0	0	0	0
186	18_Residential	1	1	0	0	0	0
188	18_Water	1	1	0	0	0	0
189	18_Woodland	1	1	0	0	0	0
190	19_Livestock Access	1	1	0	0	0	0
191	19_Commercial and Se	1	1	0	0	0	0
192	19_Cropland	1	1	0	0	0	0
193	19_Farmstead	1	1	0	0	0	0
194	19_Improved Pasture	1	1	0	0	0	0
195	19_Livestock Operati	1	1	0	0	0	0
196	19_Residential	1	1	0	0	0	0
199	19_Woodland	1	1	0	0	0	0
200	20_Livestock Access	1	1	0	0	0	0
201	20_Commercial and Se	1	1	0	0	0	0
203	20_Farmstead	1	1	0	0	0	0
204	20_Improved Pasture	1	1	0	0	0	0
206	20_Residential	1	1	0	0	0	0
209	20_Woodland	1	1	0	0	0	0
210	21_Livestock Access	1	1	0	0	0	0
211	21_Commercial and Se	1	1	0	0	0	0
212	21_Cropland	1	1	0	0	0	0
213	21_Farmstead	1	1	0	0	0	0
214	21_Improved Pasture	1	1	0	0	0	0
216	21_Residential	1	1	0	0	0	0
218	21_Water	1	1	0	0	0	0
219	21_Woodland	1	1	0	0	0	0
220	22_Livestock Access	1	1	0	0	0	0
221	22_Commercial and Se	1	1	0	0	0	0
222	22_Cropland	1	1	0	0	0	0
223	22_Farmstead	1	1	0	0	0	0
224	22_Improved Pasture	1	1	0	0	0	0
226	22_Residential	1	1	0	0	0	0
227	22_Unimproved Pastur	1	1	0	0	0	0
228	22_Water	1	1	0	0	0	0
229	22_Woodland	1	1	0	0	0	0
230	23_Livestock Access	1	1	0	0	0	0
231	23_Commercial and Se	1	1	0	0	0	0
232	23_Cropland	1	1	0	0	0	0
233	23_Farmstead	1	1	0	0	0	0
234	23_Improved Pasture	1	1	0	0	0	0
236	23_Residential	1	1	0	0	0	0

237	23_Unimproved Pastur	1	1	0	0	0	0
238	23_Water	1	1	0	0	0	0
239	23_Woodland	1	1	0	0	0	0
240	24_Livestock Access	1	1	0	0	0	0
241	24_Commercial and Se	1	1	0	0	0	0
242	24_Cropland	1	1	0	0	0	0
243	24_Farmstead	1	1	0	0	0	0
244	24_Improved Pasture	1	1	0	0	0	0
246	24_Residential	1	1	0	0	0	0
248	24_Water	1	1	0	0	0	0
249	24_Woodland	1	1	0	0	0	0
250	25_Livestock Access	1	1	0	0	0	0
251	25_Commercial and Se	1	1	0	0	0	0
252	25_Cropland	1	1	0	0	0	0
253	25_Farmstead	1	1	0	0	0	0
254	25_Improved Pasture	1	1	0	0	0	0
256	25_Residential	1	1	0	0	0	0
258	25_Water	1	1	0	0	0	0
259	25_Woodland	1	1	0	0	0	0
260	26_Livestock Access	1	1	0	0	0	0
261	26_Commercial and Se	1	1	0	0	0	0
262	26_Cropland	1	1	0	0	0	0
263	26_Farmstead	1	1	0	0	0	0
264	26_Improved Pasture	1	1	0	0	0	0
265	26_Livestock Operati	1	1	0	0	0	0
266	26_Residential	1	1	0	0	0	0
267	26_Unimproved Pastur	1	1	0	0	0	0
268	26_Water	1	1	0	0	0	0
269	26_Woodland	1	1	0	0	0	0
270	27_Livestock Access	1	1	0	0	0	0
272	27_Cropland	1	1	0	0	0	0
273	27_Farmstead	1	1	0	0	0	0
274	27_Improved Pasture	1	1	0	0	0	0
275	27_Livestock Operati	1	1	0	0	0	0
276	27_Residential	1	1	0	0	0	0
277	27_Unimproved Pastur	1	1	0	0	0	0
279	27_Woodland	1	1	0	0	0	0
280	28_Livestock Access	1	1	0	0	0	0
282	28_Cropland	1	1	0	0	0	0
283	28_Farmstead	1	1	0	0	0	0
284	28_Improved Pasture	1	1	0	0	0	0
285	28_Livestock Operati	1	1	0	0	0	0
286	28_Residential	1	1	0	0	0	0
287	28_Unimproved Pastur	1	1	0	0	0	0
288	28_Water	1	1	0	0	0	0
289	28_Woodland	1	1	0	0	0	0
290	29_Livestock Access	1	1	0	0	0	0
291	29_Commercial and Se	1	1	0	0	0	0
292	29_Cropland	1	1	0	0	0	0
293	29_Farmstead	1	1	0	0	0	0
294	29_Improved Pasture	1	1	0	0	0	0
295	29_Livestock Operati	1	1	0	0	0	0
296	29_Residential	1	1	0	0	0	0
297	29_Unimproved Pastur	1	1	0	0	0	0
298	29_Water	1	1	0	0	0	0
299	29_Woodland	1	1	0	0	0	0
300	30_Livestock Access	1	1	0	0	0	0
301	30_Commercial and Se	1	1	0	0	0	0
302	30_Cropland	1	1	0	0	0	0
303	30_Farmstead	1	1	0	0	0	0
304	30_Improved Pasture	1	1	0	0	0	0
306	30_Residential	1	1	0	0	0	0
307	30_Unimproved Pastur	1	1	0	0	0	0
308	30_Water	1	1	0	0	0	0
309	30_Woodland	1	1	0	0	0	0
310	31_Livestock Access	1	1	0	0	0	0
312	31_Cropland	1	1	0	0	0	0
313	31_Farmstead	1	1	0	0	0	0
314	31_Improved Pasture	1	1	0	0	0	0
316	31_Residential	1	1	0	0	0	0
319	31_Woodland	1	1	0	0	0	0

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  320     32_Livestock Access             1    1    0    0    0    0
  321     32_Commercial and Se            1    1    0    0    0    0
  322     32_Cropland                     1    1    0    0    0    0
  323     32_Farmstead                    1    1    0    0    0    0
  324     32_Improved Pasture             1    1    0    0    0    0
  325     32_Livestock Operati            1    1    0    0    0    0
  326     32_Residential                  1    1    0    0    0    0
  328     32_Water                        1    1    0    0    0    0
  329     32_Woodland                     1    1    0    0    0    0
  330     33_Livestock Access             1    1    0    0    0    0
  332     33_Cropland                     1    1    0    0    0    0
  333     33_Farmstead                    1    1    0    0    0    0
  334     33_Improved Pasture             1    1    0    0    0    0
  335     33_Livestock Operati            1    1    0    0    0    0
  336     33_Residential                  1    1    0    0    0    0
  337     33_Unimproved Pastur            1    1    0    0    0    0
  338     33_Water                        1    1    0    0    0    0
  339     33_Woodland                     1    1    0    0    0    0
  340     34_Livestock Access             1    1    0    0    0    0
  341     34_Commercial and Se            1    1    0    0    0    0
  342     34_Cropland                     1    1    0    0    0    0
  343     34_Farmstead                    1    1    0    0    0    0
  344     34_Improved Pasture             1    1    0    0    0    0
  346     34_Residential                  1    1    0    0    0    0
  347     34_Unimproved Pastur            1    1    0    0    0    0
  349     34_Woodland                     1    1    0    0    0    0
  350     35_Livestock Access             1    1    0    0    0    0
  351     35_Commercial and Se            1    1    0    0    0    0
  352     35_Cropland                     1    1    0    0    0    0
  353     35_Farmstead                    1    1    0    0    0    0
  354     35_Improved Pasture             1    1    0    0    0    0
  355     35_Livestock Operati            1    1    0    0    0    0
  356     35_Residential                  1    1    0    0    0    0
  357     35_Unimproved Pastur            1    1    0    0    0    0
  359     35_Woodland                     1    1    0    0    0    0
  360     36_Livestock Access             1    1    0    0    0    0
  362     36_Cropland                     1    1    0    0    0    0
  363     36_Farmstead                    1    1    0    0    0    0
  364     36_Improved Pasture             1    1    0    0    0    0
  365     36_Livestock Operati            1    1    0    0    0    0
  366     36_Residential                  1    1    0    0    0    0
  367     36_Unimproved Pastur            1    1    0    0    0    0
  368     36_Water                        1    1    0    0    0    0
  369     36_Woodland                     1    1    0    0    0    0
  370     37_Livestock Access             1    1    0    0    0    0
  371     37_Commercial and Se            1    1    0    0    0    0
  372     37_Cropland                     1    1    0    0    0    0
  373     37_Farmstead                    1    1    0    0    0    0
  374     37_Improved Pasture             1    1    0    0    0    0
  375     37_Livestock Operati            1    1    0    0    0    0
  376     37_Residential                  1    1    0    0    0    0
  377     37_Unimproved Pastur            1    1    0    0    0    0
  378     37_Water                        1    1    0    0    0    0
  379     37_Woodland                     1    1    0    0    0    0
  380     38_Livestock Access             1    1    0    0    0    0
  382     38_Cropland                     1    1    0    0    0    0
  383     38_Farmstead                    1    1    0    0    0    0
  384     38_Improved Pasture             1    1    0    0    0    0
  386     38_Residential                  1    1    0    0    0    0
  389     38_Woodland                     1    1    0    0    0    0
  END GEN-INFO

  PWAT-PARM1
*** <PLS >                   Flags
*** x -  x CSNO RTOP UZFG  VCS  VUZ  VNN VIFW VIRC  VLE IFFC  HWT IRRG
   10  389    0    1    1    0    0    0    0    0    1    1    0    0
  END PWAT-PARM1

  PWAT-PARM2
*** < PLS>    FOREST      LZSN    INFILT      LSUR     SLSUR     KVARY     AGWRC
*** x  - x               (in)   (in/hr)      (ft)              (1/in)   (1/day)
```

10	1	6.5	0.084	110	0.001	0	0.98
11	1	6.5	0.084	369.5751	0.1241	0	0.98
12	1	6.5	0.084	897.072	0.041	0	0.98
13	1	6.5	0.084	218.7578	0.0424	0	0.98
14	1	6.5	0.084	434.6182	0.0472	0	0.98
15	1	6.5	0.084	835.9075	0.0307	0	0.98
16	1	6.5	0.084	262.6979	0.0398	0	0.98
17	1	6.5	0.084	437.1469	0.0985	0	0.98
18	1	6.5	0.084	110	0.0194	0	0.98
19	1	6.5	0.084	497.9778	0.0925	0	0.98
20	1	6.5	0.08	110	0.001	0	0.98
22	1	6.5	0.08	585.4506	0.0342	0	0.98
23	1	6.5	0.08	177.139	0.0469	0	0.98
24	1	6.5	0.08	356.1568	0.0494	0	0.98
26	1	6.5	0.08	222.5423	0.0642	0	0.98
27	1	6.5	0.08	414.5731	0.0797	0	0.98
28	1	6.5	0.08	110	0.016	0	0.98
29	1	6.5	0.08	442.5558	0.1063	0	0.98
30	1	6.5	0.08	110	0.0148	0	0.98
31	1	6.5	0.08	1387.113	0.0694	0	0.98
32	1	6.5	0.08	864.2307	0.0425	0	0.98
33	1	6.5	0.08	593.489	0.0397	0	0.98
34	1	6.5	0.08	527.8329	0.0444	0	0.98
35	1	6.5	0.08	454.2876	0.0295	0	0.98
36	1	6.5	0.08	305.8447	0.0403	0	0.98
37	1	6.5	0.08	504.6789	0.0424	0	0.98
38	1	6.5	0.08	110	0.0201	0	0.98
39	1	6.5	0.08	781.499	0.0614	0	0.98
40	1	6.5	0.08	110	0.001	0	0.98
42	1	6.5	0.08	617.9631	0.031	0	0.98
43	1	6.5	0.08	212.284	0.0447	0	0.98
44	1	6.5	0.08	401.4316	0.042	0	0.98
46	1	6.5	0.08	110	0.0499	0	0.98
47	1	6.5	0.08	2063	0.0426	0	0.98
48	1	6.5	0.08	154.1493	0.0387	0	0.98
49	1	6.5	0.08	1156.151	0.0492	0	0.98
50	1	6.5	0.08	110	0.001	0	0.98
52	1	6.5	0.08	497.4568	0.0458	0	0.98
53	1	6.5	0.08	439.9562	0.0534	0	0.98
54	1	6.5	0.08	476.8768	0.0575	0	0.98
55	1	6.5	0.08	1212.512	0.1043	0	0.98
56	1	6.5	0.08	656.9404	0.0618	0	0.98
57	1	6.5	0.08	257.6447	0.0658	0	0.98
58	1	6.5	0.08	110	0.0338	0	0.98
59	1	6.5	0.08	809.9756	0.0706	0	0.98
60	1	6.5	0.08	110	0.0109	0	0.98
61	1	6.5	0.08	297.3905	0.0771	0	0.98
62	1	6.5	0.08	834.2977	0.0408	0	0.98
63	1	6.5	0.08	344.1709	0.0364	0	0.98
64	1	6.5	0.08	445.535	0.0541	0	0.98
65	1	6.5	0.08	753.5056	0.0377	0	0.98
66	1	6.5	0.08	608.1203	0.0384	0	0.98
67	1	6.5	0.08	219.0378	0.0686	0	0.98
68	1	6.5	0.08	110	0.0197	0	0.98
69	1	6.5	0.08	634.5605	0.0663	0	0.98
70	1	6.5	0.08	100	0.001	0	0.98
71	1	6.5	0.08	1352	0.0606	0	0.98
72	1	6.5	0.08	310.5958	0.0623	0	0.98
73	1	6.5	0.08	1512.857	0.062	0	0.98
74	1	6.5	0.08	510.3814	0.0704	0	0.98
76	1	6.5	0.08	3055.383	0.0527	0	0.98
77	1	6.5	0.08	389.4072	0.124	0	0.98
79	1	6.5	0.08	608.454	0.0757	0	0.98
80	1	6.5	0.08	110	0.001	0	0.98
83	1	6.5	0.08	227.5696	0.0776	0	0.98
84	1	6.5	0.08	266.1922	0.0544	0	0.98
86	1	6.5	0.08	469.0948	0.0242	0	0.98
87	1	6.5	0.08	177.4514	0.0721	0	0.98
89	1	6.5	0.08	296.3304	0.1011	0	0.98
90	1	6.5	0.071	110	0.0129	0	0.98
91	1	6.5	0.071	399.8866	0.0366	0	0.98

92	1	6.5	0.071	1441.979	0.0199	0	0.98
93	1	6.5	0.071	187.4393	0.0339	0	0.98
94	1	6.5	0.071	495.4647	0.0356	0	0.98
95	1	6.5	0.071	353.9532	0.0278	0	0.98
96	1	6.5	0.071	507.1729	0.0181	0	0.98
97	1	6.5	0.071	446.6758	0.0349	0	0.98
98	1	6.5	0.071	110	0.0198	0	0.98
99	1	6.5	0.071	472.1543	0.1519	0	0.98
100	1	6.5	0.08	110	0.012	0	0.98
102	1	6.5	0.08	266.4325	0.0282	0	0.98
103	1	6.5	0.08	383.3581	0.0937	0	0.98
104	1	6.5	0.08	493.7322	0.0627	0	0.98
105	1	6.5	0.08	285.1888	0.0463	0	0.98
106	1	6.5	0.08	157.2929	0.0483	0	0.98
107	1	6.5	0.08	290.1458	0.0376	0	0.98
108	1	6.5	0.08	110	0.0302	0	0.98
109	1	6.5	0.08	337.4944	0.1054	0	0.98
110	1	6.5	0.09	110	0.001	0	0.98
111	1	6.5	0.08	321.5044	0.1579	0	0.98
112	1	6.5	0.08	626.7361	0.032	0	0.98
113	1	6.5	0.08	313.9881	0.0296	0	0.98
114	1	6.5	0.08	376.7512	0.0465	0	0.98
115	1	6.5	0.08	350.927	0.0217	0	0.98
116	1	6.5	0.08	152.8279	0.0352	0	0.98
117	1	6.5	0.08	364.9812	0.0299	0	0.98
118	1	6.5	0.08	110.6305	0.0243	0	0.98
119	1	6.5	0.08	420.1992	0.161	0	0.98
120	1	6.5	0.08	110	0.001	0	0.98
121	1	6.5	0.08	416.5505	0.0194	0	0.98
122	1	6.5	0.08	485.7196	0.0488	0	0.98
123	1	6.5	0.08	233.0143	0.0428	0	0.98
124	1	6.5	0.08	356.9847	0.0582	0	0.98
125	1	6.5	0.08	837.8792	0.0274	0	0.98
126	1	6.5	0.08	467.7743	0.0455	0	0.98
127	1	6.5	0.08	321.4879	0.0466	0	0.98
128	1	6.5	0.08	394.902	0.044	0	0.98
129	1	6.5	0.08	301.4467	0.0997	0	0.98
130	1	6.5	0.093	110	0.001	0	0.98
131	1	6.5	0.093	516.7993	0.021	0	0.98
134	1	6.5	0.093	110	0.0318	0	0.98
136	1	6.5	0.093	117.9817	0.0855	0	0.98
137	1	6.5	0.093	124.4521	0.0239	0	0.98
139	1	6.5	0.093	316.4813	0.1403	0	0.98
140	1	6.5	0.08	110	0.001	0	0.98
142	1	6.5	0.08	282.5151	0.0364	0	0.98
143	1	6.5	0.08	483.1855	0.044	0	0.98
144	1	6.5	0.08	417.4476	0.0551	0	0.98
145	1	6.5	0.08	591.6634	0.0326	0	0.98
146	1	6.5	0.08	368.6974	0.0839	0	0.98
147	1	6.5	0.08	412.5753	0.0813	0	0.98
148	1	6.5	0.08	392.8331	0.059	0	0.98
149	1	6.5	0.08	585.8314	0.0908	0	0.98
150	1	6.5	0.08	100	0.001	0	0.98
152	1	6.5	0.08	518.9684	0.0377	0	0.98
153	1	6.5	0.08	299.7514	0.0596	0	0.98
154	1	6.5	0.08	339.7242	0.0609	0	0.98
155	1	6.5	0.08	451.2147	0.0696	0	0.98
156	1	6.5	0.08	646.927	0.056	0	0.98
157	1	6.5	0.08	339.4743	0.0686	0	0.98
159	1	6.5	0.08	380.2835	0.0895	0	0.98
160	1	6.5	0.08	110	0.001	0	0.98
161	1	6.5	0.08	663.1727	0.0542	0	0.98
162	1	6.5	0.08	569.9617	0.0348	0	0.98
163	1	6.5	0.08	401.3167	0.0514	0	0.98
164	1	6.5	0.08	378.5446	0.0469	0	0.98
165	1	6.5	0.08	956.6623	0.0496	0	0.98
166	1	6.5	0.08	222.4808	0.0554	0	0.98
167	1	6.5	0.08	274.8572	0.0409	0	0.98
169	1	6.5	0.08	440.5875	0.0757	0	0.98
170	1	6.5	0.08	110	0.0112	0	0.98
172	1	6.5	0.08	515.9761	0.0726	0	0.98

173	1	6.5	0.08	469.1213	0.0402	0	0.98
174	1	6.5	0.08	342.7555	0.0646	0	0.98
176	1	6.5	0.08	950.1799	0.0299	0	0.98
177	1	6.5	0.08	323.1391	0.0733	0	0.98
178	1	6.5	0.08	110	0.0166	0	0.98
179	1	6.5	0.08	483.7527	0.0975	0	0.98
180	1	6.5	0.08	110	0.018	0	0.98
181	1	6.5	0.08	126.529	0.0371	0	0.98
182	1	6.5	0.08	617.9092	0.0411	0	0.98
183	1	6.5	0.08	107.8742	0.043	0	0.98
184	1	6.5	0.08	496.7762	0.0544	0	0.98
186	1	6.5	0.08	379.9626	0.0787	0	0.98
188	1	6.5	0.08	109	0.0302	0	0.98
189	1	6.5	0.08	784.2125	0.0698	0	0.98
190	1	6.5	0.08	110	0.001	0	0.98
191	1	6.5	0.08	452.4986	0.06	0	0.98
192	1	6.5	0.08	333.5394	0.0379	0	0.98
193	1	6.5	0.08	578.9221	0.0391	0	0.98
194	1	6.5	0.08	280.0916	0.0488	0	0.98
195	1	6.5	0.08	840.6927	0.0403	0	0.98
196	1	6.5	0.08	482.5249	0.0718	0	0.98
199	1	6.5	0.08	302.1682	0.0694	0	0.98
200	1	6.5	0.08	110	0.0166	0	0.98
201	1	6.5	0.08	617.4696	0.0846	0	0.98
203	1	6.5	0.08	215.3804	0.0339	0	0.98
204	1	6.5	0.08	420.2979	0.0544	0	0.98
206	1	6.5	0.08	463.9998	0.0548	0	0.98
209	1	6.5	0.08	924.5853	0.0748	0	0.98
210	1	6.5	0.08	110	0.001	0	0.98
211	1	6.5	0.08	750.3593	0.0291	0	0.98
212	1	6.5	0.08	3487.001	0.0289	0	0.98
213	1	6.5	0.08	1437.28	0.0331	0	0.98
214	1	6.5	0.08	644.6159	0.0335	0	0.98
216	1	6.5	0.08	811.4683	0.0391	0	0.98
218	1	6.5	0.08	110	0.024	0	0.98
219	1	6.5	0.08	1050.113	0.0542	0	0.98
220	1	6.5	0.052	110	0.001	0	0.98
221	1	6.5	0.052	618.608	0.0406	0	0.98
222	1	6.5	0.052	608.7639	0.0304	0	0.98
223	1	6.5	0.052	110	0.026	0	0.98
224	1	6.5	0.052	422.535	0.0485	0	0.98
226	1	6.5	0.052	1765.735	0.0441	0	0.98
227	1	6.5	0.052	2844.625	0.0226	0	0.98
228	1	6.5	0.052	110	0.0527	0	0.98
229	1	6.5	0.052	1211.86	0.0548	0	0.98
230	1	6.5	0.055	110	0.001	0	0.98
231	1	6.5	0.055	700.3515	0.0273	0	0.98
232	1	6.5	0.055	259.8107	0.0219	0	0.98
233	1	6.5	0.055	219.0117	0.0663	0	0.98
234	1	6.5	0.055	282.5348	0.0517	0	0.98
236	1	6.5	0.055	534.2773	0.0523	0	0.98
237	1	6.5	0.055	249.1398	0.0683	0	0.98
238	1	6.5	0.055	110	0.0303	0	0.98
239	1	6.5	0.055	444.1843	0.0666	0	0.98
240	1	6.5	0.08	110	0.013	0	0.98
241	1	6.5	0.08	573.3135	0.0516	0	0.98
242	1	6.5	0.08	433.4326	0.0281	0	0.98
243	1	6.5	0.08	870.8921	0.0317	0	0.98
244	1	6.5	0.08	454.2236	0.0408	0	0.98
246	1	6.5	0.08	687.333	0.0638	0	0.98
248	1	6.5	0.08	110	0.0253	0	0.98
249	1	6.5	0.08	528.8689	0.073	0	0.98
250	1	6.5	0.1	110	0.001	0	0.98
251	1	6.5	0.1	450.8453	0.0288	0	0.98
252	1	6.5	0.1	529.4776	0.0286	0	0.98
253	1	6.5	0.1	503.7502	0.0718	0	0.98
254	1	6.5	0.1	263.2449	0.0356	0	0.98
256	1	6.5	0.1	446.7256	0.0348	0	0.98
258	1	6.5	0.1	110	0.0147	0	0.98
259	1	6.5	0.1	253.5465	0.0698	0	0.98
260	1	6.5	0.1	110	0.0103	0	0.98

261	1	6.5	0.08	935.0799	0.0382	0	0.98
262	1	6.5	0.08	440.502	0.0268	0	0.98
263	1	6.5	0.08	372.1447	0.0527	0	0.98
264	1	6.5	0.08	461.6713	0.0524	0	0.98
265	1	6.5	0.08	198.452	0.1237	0	0.98
266	1	6.5	0.08	485.2174	0.0577	0	0.98
267	1	6.5	0.08	214.212	0.0698	0	0.98
268	1	6.5	0.08	110	0.0213	0	0.98
269	1	6.5	0.08	469.4624	0.0712	0	0.98
270	1	6.5	0.08	110	0.0168	0	0.98
272	1	6.5	0.08	431.7463	0.043	0	0.98
273	1	6.5	0.08	252.347	0.0451	0	0.98
274	1	6.5	0.08	373.011	0.0498	0	0.98
275	1	6.5	0.08	293.3055	0.0488	0	0.98
276	1	6.5	0.08	549.2024	0.0841	0	0.98
277	1	6.5	0.08	549.746	0.0609	0	0.98
279	1	6.5	0.08	381.3773	0.0741	0	0.98
280	1	6.5	0.08	110	0.011	0	0.98
282	1	6.5	0.08	981.9388	0.0363	0	0.98
283	1	6.5	0.08	826.2197	0.0488	0	0.98
284	1	6.5	0.08	496.496	0.0632	0	0.98
285	1	6.5	0.08	828.9576	0.0866	0	0.98
286	1	6.5	0.08	621.1424	0.0757	0	0.98
287	1	6.5	0.08	746.8707	0.0539	0	0.98
288	1	6.5	0.08	110	0.001	0	0.98
289	1	6.5	0.08	496.0735	0.0828	0	0.98
290	1	6.5	0.08	110	0.0154	0	0.98
291	1	6.5	0.08	924.3329	0.0231	0	0.98
292	1	6.5	0.08	705.2804	0.0353	0	0.98
293	1	6.5	0.08	870.983	0.0334	0	0.98
294	1	6.5	0.08	469.8864	0.0467	0	0.98
295	1	6.5	0.08	528.5553	0.0422	0	0.98
296	1	6.5	0.08	441.5463	0.0534	0	0.98
297	1	6.5	0.08	326.1224	0.0574	0	0.98
298	1	6.5	0.08	544.7945	0.0104	0	0.98
299	1	6.5	0.08	520.9015	0.0837	0	0.98
300	1	6.5	0.06	110	0.0107	0	0.98
301	1	6.5	0.06	648.7498	0.0274	0	0.98
302	1	6.5	0.06	462.6484	0.0277	0	0.98
303	1	6.5	0.06	517.6871	0.0495	0	0.98
304	1	6.5	0.06	339.9978	0.0386	0	0.98
306	1	6.5	0.06	524.8222	0.0443	0	0.98
307	1	6.5	0.06	827.8719	0.0384	0	0.98
308	1	6.5	0.06	110	0.001	0	0.98
309	1	6.5	0.06	428.2845	0.0504	0	0.98
310	1	6.5	0.09	110	0.001	0	0.98
312	1	6.5	0.09	341.1128	0.0336	0	0.98
313	1	6.5	0.09	807.4236	0.0442	0	0.98
314	1	6.5	0.09	356.3012	0.0644	0	0.98
316	1	6.5	0.09	292.1407	0.2849	0	0.98
319	1	6.5	0.09	229.8109	0.0871	0	0.98
320	1	6.5	0.08	110	0.001	0	0.98
321	1	6.5	0.08	977.7128	0.0477	0	0.98
322	1	6.5	0.08	283.9849	0.0299	0	0.98
323	1	6.5	0.08	323.576	0.0376	0	0.98
324	1	6.5	0.08	416.151	0.0528	0	0.98
325	1	6.5	0.08	1100.884	0.0624	0	0.98
326	1	6.5	0.08	304.9806	0.0489	0	0.98
328	1	6.5	0.08	110	0.001	0	0.98
329	1	6.5	0.08	274.9931	0.064	0	0.98
330	1	6.5	0.08	110	0.001	0	0.98
332	1	6.5	0.08	619.9933	0.0266	0	0.98
333	1	6.5	0.08	478.072	0.0445	0	0.98
334	1	6.5	0.08	472.6589	0.0331	0	0.98
335	1	6.5	0.08	1025.951	0.0137	0	0.98
336	1	6.5	0.08	1858.137	0.0651	0	0.98
337	1	6.5	0.08	1643.655	0.0413	0	0.98
338	1	6.5	0.08	110	0.0407	0	0.98
339	1	6.5	0.08	1007.247	0.0501	0	0.98
340	1	6.5	0.09	110	0.0118	0	0.98
341	1	6.5	0.09	1098.586	0.0293	0	0.98

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  350             1       6.5     0.075       110    0.0134         0      0.98
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  352             1       6.5     0.075  478.7029    0.0313         0      0.98
  353             1       6.5     0.075   637.771    0.0392         0      0.98
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  364             1       6.5     0.072  398.8198    0.0267         0      0.98
  365             1       6.5     0.072  780.9731    0.0393         0      0.98
  366             1       6.5     0.072  145.2704    0.0578         0      0.98
  367             1       6.5     0.072  937.1381    0.0625         0      0.98
  368             1       6.5     0.072       110     0.001         0      0.98
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  371             1       6.5     0.072  330.8448    0.0344         0      0.98
  372             1       6.5     0.072  452.8517    0.0361         0      0.98
  373             1       6.5     0.072   450.948    0.0398         0      0.98
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  376             1       6.5     0.072  755.1885    0.0262         0      0.98
  377             1       6.5     0.072  196.8456    0.0336         0      0.98
  378             1       6.5     0.072       110    0.0147         0      0.98
  379             1       6.5     0.072  283.3097    0.0572         0      0.98
  380             1       6.5      0.08       110     0.001         0      0.98
  382             1       6.5      0.08  831.2561    0.0494         0      0.98
  383             1       6.5      0.08  808.3819    0.0748         0      0.98
  384             1       6.5      0.08  365.9771    0.0554         0      0.98
  386             1       6.5      0.08  692.5897    0.0981         0      0.98
  389             1       6.5      0.08  760.5997     0.055         0      0.98
  END PWAT-PARM2

  PWAT-PARM3
*** < PLS>    PETMAX    PETMIN    INFEXP    INFILD    DEEPFR    BASETP    AGWETP
*** x  - x   (deg F)   (deg F)
   10  389       40.       35.        2.        2.       0.1     0.032        0.
  END PWAT-PARM3

  PWAT-PARM4
*** <PLS >     CEPSC      UZSN      NSUR     INTFW       IRC     LZETP
*** x -  x      (in)      (in)                       (1/day)
   10  389       0.1     1.128       0.2      0.75       0.5       0.1
  END PWAT-PARM4

  PWAT-STATE1
*** < PLS>  PWATER state variables (in)
*** x  - x      CEPS      SURS       UZS      IFWS       LZS      AGWS      GWVS
   10  389      0.01      0.01       0.3      0.01       1.5      0.01      0.01
  END PWAT-STATE1

  MON-UZSN
*** <PLS >  Upper zone storage at start of each month  (inches)
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
   10      1.12 1.12 1.12 1.12 1.12   1.   1.  1.1  1.1 1.12 1.12 1.12
   11   12 1.13 1.12 1.12 1.12 1.12   1.   1.  1.1  1.1 1.12 1.12 1.12
   13      1.12 1.12 1.13 1.12 1.12   1.   1.  1.1  1.1 1.12 1.12 1.12
   14      1.12 1.12 1.12 1.13 1.12   1.   1.  1.1  1.1 1.12 1.12 1.12
   15   16 1.12 1.12 1.12 1.12 1.12   1.   1.  1.1  1.1 1.12 1.12 1.12
   17      1.12 1.12 1.12 1.12 1.14   1.   1.  1.1  1.1 1.12 1.12 1.12
   18      1.12 1.12 1.12 1.12 1.12   1.   1.  1.1  1.1 1.12 1.12 1.12
   19      1.12 1.12 1.12 1.15 1.12   1. 1.16  1.1  1.1 1.12 1.12 1.12
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   20   22 1.12 1.12 1.12 1.12 1.12   1.   1.  1.1  1.1 1.12 1.12 1.12
   23      1.12 1.12 1.12 1.12 1.13   1. 1.13  1.1  1.1 1.12 1.12 1.12
   24   27 1.12 1.12 1.12 1.12 1.12   1. 1.13  1.1  1.1 1.12 1.12 1.12
   28      1.12 1.12 1.12 1.12 1.12   1. 1.15  1.1  1.1 1.12 1.12 1.12
   29      1.12 1.12 1.12 1.12 1.12   1. 1.16  1.1  1.1 1.12 1.12 1.12
   30      1.12 1.12 1.12 1.12 1.12   1. 1.17  1.1  1.1 1.12 1.12 1.12
   31      1.12 1.12 1.12 1.12 1.12   1. 1.18  1.1  1.1 1.12 1.12 1.12
   32      1.12 1.12 1.12 1.12 1.12   1.   1.  1.1  1.1 1.12 1.12 1.12
   33      1.18 1.12 1.12 1.12 1.12   1.   1.  1.1  1.1 1.12 1.12 1.12
   34  389 1.12 1.12 1.12 1.12 1.12   1.   1.  1.1  1.1 1.12 1.12 1.12
  END MON-UZSN

  MON-LZETPARM
*** <PLS >  Lower zone evapotransp   parm at start of each month
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
   10  389  0.2  0.2  0.3  0.3  0.4  0.4  0.4  0.4  0.4  0.3  0.2  0.2
  END MON-LZETPARM

  NQUALS
*** <PLS >
*** x -  xNQUAL
   10  389    1
  END NQUALS

  QUAL-PROPS
*** <PLS >  Identifiers and Flags
*** x -  x    QUALID      QTID  QSD VPFW VPFS  QSO  VQO QIFW VIQC QAGW VAQC
   10  389FECAL COLIFO       #    0    0    0    1    1    1    1    0    0
  END QUAL-PROPS

  QUAL-INPUT
***         Storage on surface and nonseasonal parameters
***            SQO   POTFW   POTFS   ACQOP  SQOLIM   WSQOP    IOQC    AOQC
*** <PLS >  qty/ac qty/ton qty/ton    qty/  qty/ac   in/hr qty/ft3 qty/ft3
*** x -  x                          ac.day
   10     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.50001.00E+030.00E+00
   11     7.04E+080.00E+000.00E+001.00E+031.00E+00  0.20001.00E+030.00E+00
   12     1.16E+040.00E+000.00E+001.00E+031.00E+00  0.80001.00E+030.00E+00
   13     1.92E+070.00E+000.00E+001.00E+031.00E+00  0.30001.00E+030.00E+00
   14     7.05E+070.00E+000.00E+001.00E+031.00E+00  0.65001.00E+030.00E+00
   15     7.89E+080.00E+000.00E+001.00E+031.00E+00  0.30001.00E+030.00E+00
   16     2.21E+110.00E+000.00E+001.00E+031.00E+00  0.25001.00E+030.00E+00
   17     1.51E+080.00E+000.00E+001.00E+031.00E+00  0.55001.00E+030.00E+00
   18     4.41E+080.00E+000.00E+001.00E+031.00E+00  0.01001.00E+030.00E+00
   19     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.70001.00E+030.00E+00
   20     2.56E+080.00E+000.00E+001.00E+031.00E+00  0.50001.00E+030.00E+00
   22     8.53E+080.00E+000.00E+001.00E+031.00E+00  0.80001.00E+030.00E+00
   23     8.63E+020.00E+000.00E+001.00E+031.00E+00  0.30001.00E+030.00E+00
   24     6.47E+070.00E+000.00E+001.00E+031.00E+00  0.65001.00E+030.00E+00
   26     1.07E+080.00E+000.00E+001.00E+031.00E+00  0.25001.00E+030.00E+00
   27     3.15E+080.00E+000.00E+001.00E+031.00E+00  0.55001.00E+030.00E+00
   28     7.85E+070.00E+000.00E+001.00E+031.00E+00  0.01001.00E+030.00E+00
   29     2.69E+080.00E+000.00E+001.00E+031.00E+00  0.70001.00E+030.00E+00
   30     2.69E+080.00E+000.00E+001.00E+031.00E+00  0.50001.00E+030.00E+00
   31     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.20001.00E+030.00E+00
   32     2.14E+080.00E+000.00E+001.00E+031.00E+00  0.80001.00E+030.00E+00
   33     7.40E+080.00E+000.00E+001.00E+031.00E+00  0.30001.00E+030.00E+00
   34     6.93E+030.00E+000.00E+001.00E+031.00E+00  0.65001.00E+030.00E+00
   35     8.62E+070.00E+000.00E+001.00E+031.00E+00  0.30001.00E+030.00E+00
   36     6.22E+070.00E+000.00E+001.00E+031.00E+00  0.25001.00E+030.00E+00
   37     2.93E+080.00E+000.00E+001.00E+031.00E+00  0.55001.00E+030.00E+00
   38     9.24E+070.00E+000.00E+001.00E+031.00E+00  0.01001.00E+030.00E+00
   39     2.33E+080.00E+000.00E+001.00E+031.00E+00  0.70001.00E+030.00E+00
   40     1.85E+080.00E+000.00E+001.00E+031.00E+00  0.50001.00E+030.00E+00
   42     0.00E+000.00E+000.00E+001.00E+031.00E+00  0.80001.00E+030.00E+00
   43     2.66E+080.00E+000.00E+001.00E+031.00E+00  0.30001.00E+030.00E+00
   44     9.32E+080.00E+000.00E+001.00E+031.00E+00  0.65001.00E+030.00E+00
   46     3.88E+020.00E+000.00E+001.00E+031.00E+00  0.25001.00E+030.00E+00
   47     6.16E+070.00E+000.00E+001.00E+031.00E+00  0.55001.00E+030.00E+00
   48     1.21E+080.00E+000.00E+001.00E+031.00E+00  0.01001.00E+030.00E+00
   49     2.91E+080.00E+000.00E+001.00E+031.00E+00  0.70001.00E+030.00E+00
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50	1.19E+080.00E+000.00E+001.00E+031.00E+00	1.00001.00E+030.00E+00
52	6.11E+070.00E+000.00E+001.00E+031.00E+00	1.60001.00E+030.00E+00
53	2.61E+080.00E+000.00E+001.00E+031.00E+00	0.60001.00E+030.00E+00
54	0.00E+000.00E+000.00E+001.00E+031.00E+00	1.30001.00E+030.00E+00
55	2.77E+080.00E+000.00E+001.00E+031.00E+00	0.60001.00E+030.00E+00
56	9.60E+080.00E+000.00E+001.00E+031.00E+00	0.50001.00E+030.00E+00
57	6.62E+060.00E+000.00E+001.00E+031.00E+00	1.10001.00E+030.00E+00
58	1.17E+080.00E+000.00E+001.00E+031.00E+00	0.01001.00E+030.00E+00
59	9.95E+070.00E+000.00E+001.00E+031.00E+00	1.40001.00E+030.00E+00
60	1.46E+080.00E+000.00E+001.00E+031.00E+00	0.25001.00E+030.00E+00
61	3.52E+080.00E+000.00E+001.00E+031.00E+00	0.10001.00E+030.00E+00
62	1.42E+080.00E+000.00E+001.00E+031.00E+00	0.40001.00E+030.00E+00
63	1.99E+080.00E+000.00E+001.00E+031.00E+00	0.15001.00E+030.00E+00
64	3.15E+070.00E+000.00E+001.00E+031.00E+00	0.37501.00E+030.00E+00
65	3.10E+080.00E+000.00E+001.00E+031.00E+00	0.15001.00E+030.00E+00
66	1.41E+080.00E+000.00E+001.00E+031.00E+00	0.12501.00E+030.00E+00
67	2.71E+080.00E+000.00E+001.00E+031.00E+00	0.27501.00E+030.00E+00
68	6.91E+060.00E+000.00E+001.00E+031.00E+00	0.01001.00E+030.00E+00
69	8.83E+070.00E+000.00E+001.00E+031.00E+00	0.35001.00E+030.00E+00
70	1.55E+080.00E+000.00E+001.00E+031.00E+00	1.00001.00E+030.00E+00
71	1.82E+080.00E+000.00E+001.00E+031.00E+00	0.40001.00E+030.00E+00
72	3.45E+080.00E+000.00E+001.00E+031.00E+00	1.60001.00E+030.00E+00
73	0.00E+000.00E+000.00E+001.00E+031.00E+00	0.60001.00E+030.00E+00
74	1.56E+090.00E+000.00E+001.00E+031.00E+00	1.30001.00E+030.00E+00
76	1.46E+080.00E+000.00E+001.00E+031.00E+00	0.50001.00E+030.00E+00
77	4.75E+080.00E+000.00E+001.00E+031.00E+00	1.10001.00E+030.00E+00
79	5.27E+080.00E+000.00E+001.00E+031.00E+00	1.40001.00E+030.00E+00
80	5.43E+080.00E+000.00E+001.00E+031.00E+00	0.25001.00E+030.00E+00
83	4.36E+080.00E+000.00E+001.00E+031.00E+00	0.15001.00E+030.00E+00
84	4.62E+080.00E+000.00E+001.00E+031.00E+00	0.32501.00E+030.00E+00
86	2.64E+080.00E+000.00E+001.00E+031.00E+00	0.12501.00E+030.00E+00
87	0.00E+000.00E+000.00E+001.00E+031.00E+00	0.27501.00E+030.00E+00
89	4.08E+080.00E+000.00E+001.00E+031.00E+00	0.35001.00E+030.00E+00
90	7.99E+080.00E+000.00E+001.00E+031.00E+00	0.50001.00E+030.00E+00
91	2.32E+080.00E+000.00E+001.00E+031.00E+00	0.20001.00E+030.00E+00
92	3.73E+080.00E+000.00E+001.00E+031.00E+00	0.80001.00E+030.00E+00
93	5.01E+080.00E+000.00E+001.00E+031.00E+00	0.30001.00E+030.00E+00
94	6.70E+080.00E+000.00E+001.00E+031.00E+00	0.65001.00E+030.00E+00
95	5.04E+080.00E+000.00E+001.00E+031.00E+00	0.30001.00E+030.00E+00
96	5.23E+080.00E+000.00E+001.00E+031.00E+00	0.25001.00E+030.00E+00
97	0.00E+000.00E+000.00E+001.00E+031.00E+00	0.55001.00E+030.00E+00
98	4.98E+080.00E+000.00E+001.00E+031.00E+00	0.01001.00E+030.00E+00
99	1.02E+090.00E+000.00E+001.00E+031.00E+00	0.70001.00E+030.00E+00
100	2.43E+080.00E+000.00E+001.00E+031.00E+00	0.25001.00E+030.00E+00
102	4.59E+080.00E+000.00E+001.00E+031.00E+00	0.40001.00E+030.00E+00
103	5.01E+080.00E+000.00E+001.00E+031.00E+00	0.15001.00E+030.00E+00
104	6.54E+080.00E+000.00E+001.00E+031.00E+00	0.32501.00E+030.00E+00
105	3.77E+080.00E+000.00E+001.00E+031.00E+00	0.15001.00E+030.00E+00
106	5.29E+080.00E+000.00E+001.00E+031.00E+00	0.12501.00E+030.00E+00
107	5.43E+080.00E+000.00E+001.00E+031.00E+00	0.27501.00E+030.00E+00
108	1.20E+090.00E+000.00E+001.00E+031.00E+00	0.01001.00E+030.00E+00
109	2.36E+080.00E+000.00E+001.00E+031.00E+00	0.35001.00E+030.00E+00
110	4.19E+080.00E+000.00E+001.00E+031.00E+00	0.25001.00E+030.00E+00
111	5.24E+080.00E+000.00E+001.00E+031.00E+00	0.10001.00E+030.00E+00
112	4.72E+080.00E+000.00E+001.00E+031.00E+00	0.40001.00E+030.00E+00
113	2.55E+080.00E+000.00E+001.00E+031.00E+00	0.15001.00E+030.00E+00
114	0.00E+000.00E+000.00E+001.00E+031.00E+00	0.32501.00E+030.00E+00
115	7.64E+080.00E+000.00E+001.00E+031.00E+00	0.15001.00E+030.00E+00
116	2.25E+080.00E+000.00E+001.00E+031.00E+00	0.12501.00E+030.00E+00
117	4.29E+080.00E+000.00E+001.00E+031.00E+00	0.27501.00E+030.00E+00
118	4.99E+080.00E+000.00E+001.00E+031.00E+00	0.01001.00E+030.00E+00
119	7.46E+080.00E+000.00E+001.00E+031.00E+00	0.35001.00E+030.00E+00
120	4.41E+080.00E+000.00E+001.00E+031.00E+00	0.50001.00E+030.00E+00
121	6.47E+080.00E+000.00E+001.00E+031.00E+00	0.20001.00E+030.00E+00
122	0.00E+000.00E+000.00E+001.00E+031.00E+00	0.80001.00E+030.00E+00
123	6.78E+080.00E+000.00E+001.00E+031.00E+00	0.30001.00E+030.00E+00
124	2.47E+080.00E+000.00E+001.00E+031.00E+00	0.65001.00E+030.00E+00
125	5.10E+080.00E+000.00E+001.00E+031.00E+00	0.30001.00E+030.00E+00
126	5.07E+080.00E+000.00E+001.00E+031.00E+00	0.25001.00E+030.00E+00
127	8.36E+080.00E+000.00E+001.00E+031.00E+00	0.55001.00E+030.00E+00
128	4.72E+080.00E+000.00E+001.00E+031.00E+00	0.01001.00E+030.00E+00

129	4.86E+080.00E+000.00E+001.00E+031.00E+00	0.70001.00E+030.00E+00
130	6.36E+080.00E+000.00E+001.00E+031.00E+00	0.50001.00E+030.00E+00
131	0.00E+000.00E+000.00E+001.00E+031.00E+00	0.20001.00E+030.00E+00
134	6.57E+080.00E+000.00E+001.00E+031.00E+00	0.65001.00E+030.00E+00
136	1.19E+080.00E+000.00E+001.00E+031.00E+00	0.25001.00E+030.00E+00
137	5.44E+080.00E+000.00E+001.00E+031.00E+00	0.55001.00E+030.00E+00
139	5.36E+080.00E+000.00E+001.00E+031.00E+00	0.70001.00E+030.00E+00
140	8.68E+080.00E+000.00E+001.00E+031.00E+00	0.40001.00E+030.00E+00
142	4.63E+080.00E+000.00E+001.00E+031.00E+00	0.64001.00E+030.00E+00
143	5.85E+080.00E+000.00E+001.00E+031.00E+00	0.24001.00E+030.00E+00
144	0.00E+000.00E+000.00E+001.00E+031.00E+00	0.52001.00E+030.00E+00
145	5.87E+080.00E+000.00E+001.00E+031.00E+00	0.24001.00E+030.00E+00
146	2.22E+080.00E+000.00E+001.00E+031.00E+00	0.20001.00E+030.00E+00
147	5.72E+080.00E+000.00E+001.00E+031.00E+00	0.44001.00E+030.00E+00
148	5.25E+080.00E+000.00E+001.00E+031.00E+00	0.01001.00E+030.00E+00
149	8.63E+080.00E+000.00E+001.00E+031.00E+00	0.56001.00E+030.00E+00
150	5.32E+080.00E+000.00E+001.00E+031.00E+00	0.50001.00E+030.00E+00
152	7.85E+080.00E+000.00E+001.00E+031.00E+00	0.80001.00E+030.00E+00
153	0.00E+000.00E+000.00E+001.00E+031.00E+00	0.30001.00E+030.00E+00
154	5.20E+080.00E+000.00E+001.00E+031.00E+00	0.65001.00E+030.00E+00
155	2.30E+080.00E+000.00E+001.00E+031.00E+00	0.30001.00E+030.00E+00
156	5.23E+080.00E+000.00E+001.00E+031.00E+00	0.25001.00E+030.00E+00
157	7.01E+080.00E+000.00E+001.00E+031.00E+00	0.55001.00E+030.00E+00
159	3.86E+080.00E+000.00E+001.00E+031.00E+00	0.70001.00E+030.00E+00
160	4.13E+080.00E+000.00E+001.00E+031.00E+00	1.00001.00E+030.00E+00
161	6.79E+080.00E+000.00E+001.00E+031.00E+00	0.40001.00E+030.00E+00
162	0.00E+000.00E+000.00E+001.00E+031.00E+00	1.60001.00E+030.00E+00
163	4.75E+080.00E+000.00E+001.00E+031.00E+00	0.60001.00E+030.00E+00
164	1.03E+090.00E+000.00E+001.00E+031.00E+00	1.30001.00E+030.00E+00
165	2.40E+080.00E+000.00E+001.00E+031.00E+00	0.60001.00E+030.00E+00
166	4.70E+080.00E+000.00E+001.00E+031.00E+00	0.50001.00E+030.00E+00
167	4.97E+080.00E+000.00E+001.00E+031.00E+00	1.10001.00E+030.00E+00
169	4.21E+080.00E+000.00E+001.00E+031.00E+00	1.40001.00E+030.00E+00
170	5.66E+080.00E+000.00E+001.00E+031.00E+00	0.50001.00E+030.00E+00
172	5.20E+080.00E+000.00E+001.00E+031.00E+00	0.80001.00E+030.00E+00
173	5.00E+080.00E+000.00E+001.00E+031.00E+00	0.30001.00E+030.00E+00
174	1.05E+090.00E+000.00E+001.00E+031.00E+00	0.65001.00E+030.00E+00
176	2.30E+080.00E+000.00E+001.00E+031.00E+00	0.25001.00E+030.00E+00
177	4.36E+080.00E+000.00E+001.00E+031.00E+00	0.55001.00E+030.00E+00
178	4.68E+080.00E+000.00E+001.00E+031.00E+00	0.01001.00E+030.00E+00
179	4.56E+080.00E+000.00E+001.00E+031.00E+00	0.70001.00E+030.00E+00
180	6.47E+080.00E+000.00E+001.00E+031.00E+00	0.25001.00E+030.00E+00
181	0.00E+000.00E+000.00E+001.00E+031.00E+00	0.10001.00E+030.00E+00
182	6.78E+080.00E+000.00E+001.00E+031.00E+00	0.40001.00E+030.00E+00
183	2.47E+080.00E+000.00E+001.00E+031.00E+00	0.15001.00E+030.00E+00
184	5.10E+080.00E+000.00E+001.00E+031.00E+00	0.37501.00E+030.00E+00
186	5.07E+080.00E+000.00E+001.00E+031.00E+00	0.12501.00E+030.00E+00
188	8.36E+080.00E+000.00E+001.00E+031.00E+00	0.01001.00E+030.00E+00
189	4.72E+080.00E+000.00E+001.00E+031.00E+00	0.35001.00E+030.00E+00
190	4.86E+080.00E+000.00E+001.00E+031.00E+00	0.25001.00E+030.00E+00
191	6.36E+080.00E+000.00E+001.00E+031.00E+00	0.10001.00E+030.00E+00
192	0.00E+000.00E+000.00E+001.00E+031.00E+00	0.40001.00E+030.00E+00
193	6.57E+080.00E+000.00E+001.00E+031.00E+00	0.15001.00E+030.00E+00
194	1.19E+080.00E+000.00E+001.00E+031.00E+00	0.37501.00E+030.00E+00
195	5.44E+080.00E+000.00E+001.00E+031.00E+00	0.15001.00E+030.00E+00
196	5.36E+080.00E+000.00E+001.00E+031.00E+00	0.12501.00E+030.00E+00
199	8.68E+080.00E+000.00E+001.00E+031.00E+00	0.35001.00E+030.00E+00
200	4.63E+080.00E+000.00E+001.00E+031.00E+00	0.25001.00E+030.00E+00
201	5.85E+080.00E+000.00E+001.00E+031.00E+00	0.10001.00E+030.00E+00
203	0.00E+000.00E+000.00E+001.00E+031.00E+00	0.15001.00E+030.00E+00
204	5.87E+080.00E+000.00E+001.00E+031.00E+00	0.37501.00E+030.00E+00
206	2.22E+080.00E+000.00E+001.00E+031.00E+00	0.12501.00E+030.00E+00
209	5.72E+080.00E+000.00E+001.00E+031.00E+00	0.35001.00E+030.00E+00
210	5.25E+080.00E+000.00E+001.00E+031.00E+00	0.25001.00E+030.00E+00
211	8.63E+080.00E+000.00E+001.00E+031.00E+00	0.10001.00E+030.00E+00
212	5.32E+080.00E+000.00E+001.00E+031.00E+00	0.40001.00E+030.00E+00
213	7.85E+080.00E+000.00E+001.00E+031.00E+00	0.15001.00E+030.00E+00
214	0.00E+000.00E+000.00E+001.00E+031.00E+00	0.37501.00E+030.00E+00
216	5.20E+080.00E+000.00E+001.00E+031.00E+00	0.12501.00E+030.00E+00
218	2.30E+080.00E+000.00E+001.00E+031.00E+00	0.01001.00E+030.00E+00
219	5.23E+080.00E+000.00E+001.00E+031.00E+00	0.35001.00E+030.00E+00

220	7.01E+080.00E+000.00E+001.00E+031.00E+00	0.25001.00E+030.00E+00
221	3.86E+080.00E+000.00E+001.00E+031.00E+00	0.10001.00E+030.00E+00
222	4.13E+080.00E+000.00E+001.00E+031.00E+00	0.40001.00E+030.00E+00
223	6.79E+080.00E+000.00E+001.00E+031.00E+00	0.15001.00E+030.00E+00
224	0.00E+000.00E+000.00E+001.00E+031.00E+00	0.37501.00E+030.00E+00
226	4.75E+080.00E+000.00E+001.00E+031.00E+00	0.12501.00E+030.00E+00
227	1.03E+090.00E+000.00E+001.00E+031.00E+00	0.27501.00E+030.00E+00
228	2.40E+080.00E+000.00E+001.00E+031.00E+00	0.01001.00E+030.00E+00
229	4.70E+080.00E+000.00E+001.00E+031.00E+00	0.35001.00E+030.00E+00
230	4.97E+080.00E+000.00E+001.00E+031.00E+00	0.25001.00E+030.00E+00
231	4.21E+080.00E+000.00E+001.00E+031.00E+00	0.10001.00E+030.00E+00
232	5.66E+080.00E+000.00E+001.00E+031.00E+00	0.40001.00E+030.00E+00
233	5.20E+080.00E+000.00E+001.00E+031.00E+00	0.15001.00E+030.00E+00
234	5.00E+080.00E+000.00E+001.00E+031.00E+00	0.37501.00E+030.00E+00
236	1.05E+090.00E+000.00E+001.00E+031.00E+00	0.12501.00E+030.00E+00
237	2.30E+080.00E+000.00E+001.00E+031.00E+00	0.27501.00E+030.00E+00
238	4.36E+080.00E+000.00E+001.00E+031.00E+00	0.01001.00E+030.00E+00
239	4.68E+080.00E+000.00E+001.00E+031.00E+00	0.35001.00E+030.00E+00
240	4.56E+080.00E+000.00E+001.00E+031.00E+00	0.50001.00E+030.00E+00
241	6.47E+080.00E+000.00E+001.00E+031.00E+00	0.20001.00E+030.00E+00
242	0.00E+000.00E+000.00E+001.00E+031.00E+00	0.80001.00E+030.00E+00
243	6.78E+080.00E+000.00E+001.00E+031.00E+00	0.30001.00E+030.00E+00
244	2.47E+080.00E+000.00E+001.00E+031.00E+00	0.65001.00E+030.00E+00
246	5.10E+080.00E+000.00E+001.00E+031.00E+00	0.25001.00E+030.00E+00
248	5.07E+080.00E+000.00E+001.00E+031.00E+00	0.01001.00E+030.00E+00
249	8.36E+080.00E+000.00E+001.00E+031.00E+00	0.70001.00E+030.00E+00
250	4.72E+080.00E+000.00E+001.00E+031.00E+00	0.50001.00E+030.00E+00
251	4.86E+080.00E+000.00E+001.00E+031.00E+00	0.20001.00E+030.00E+00
252	6.36E+080.00E+000.00E+001.00E+031.00E+00	0.80001.00E+030.00E+00
253	0.00E+000.00E+000.00E+001.00E+031.00E+00	0.30001.00E+030.00E+00
254	6.57E+080.00E+000.00E+001.00E+031.00E+00	0.65001.00E+030.00E+00
256	1.19E+080.00E+000.00E+001.00E+031.00E+00	0.25001.00E+030.00E+00
258	5.44E+080.00E+000.00E+001.00E+031.00E+00	0.01001.00E+030.00E+00
259	5.36E+080.00E+000.00E+001.00E+031.00E+00	0.70001.00E+030.00E+00
260	8.68E+080.00E+000.00E+001.00E+031.00E+00	0.50001.00E+030.00E+00
261	4.63E+080.00E+000.00E+001.00E+031.00E+00	0.20001.00E+030.00E+00
262	5.85E+080.00E+000.00E+001.00E+031.00E+00	0.80001.00E+030.00E+00
263	0.00E+000.00E+000.00E+001.00E+031.00E+00	0.30001.00E+030.00E+00
264	5.87E+080.00E+000.00E+001.00E+031.00E+00	0.65001.00E+030.00E+00
265	2.22E+080.00E+000.00E+001.00E+031.00E+00	0.30001.00E+030.00E+00
266	5.72E+080.00E+000.00E+001.00E+031.00E+00	0.25001.00E+030.00E+00
267	5.25E+080.00E+000.00E+001.00E+031.00E+00	0.55001.00E+030.00E+00
268	8.63E+080.00E+000.00E+001.00E+031.00E+00	0.01001.00E+030.00E+00
269	5.32E+080.00E+000.00E+001.00E+031.00E+00	0.70001.00E+030.00E+00
270	7.85E+080.00E+000.00E+001.00E+031.00E+00	1.50001.00E+030.00E+00
272	0.00E+000.00E+000.00E+001.00E+031.00E+00	2.40001.00E+030.00E+00
273	5.20E+080.00E+000.00E+001.00E+031.00E+00	0.90001.00E+030.00E+00
274	2.30E+080.00E+000.00E+001.00E+031.00E+00	1.95001.00E+030.00E+00
275	5.23E+080.00E+000.00E+001.00E+031.00E+00	0.90001.00E+030.00E+00
276	7.01E+080.00E+000.00E+001.00E+031.00E+00	0.75001.00E+030.00E+00
277	3.86E+080.00E+000.00E+001.00E+031.00E+00	1.65001.00E+030.00E+00
279	4.13E+080.00E+000.00E+001.00E+031.00E+00	2.10001.00E+030.00E+00
280	6.79E+080.00E+000.00E+001.00E+031.00E+00	0.50001.00E+030.00E+00
282	0.00E+000.00E+000.00E+001.00E+031.00E+00	0.80001.00E+030.00E+00
283	4.75E+080.00E+000.00E+001.00E+031.00E+00	0.30001.00E+030.00E+00
284	1.03E+090.00E+000.00E+001.00E+031.00E+00	0.65001.00E+030.00E+00
285	2.40E+080.00E+000.00E+001.00E+031.00E+00	0.30001.00E+030.00E+00
286	4.70E+080.00E+000.00E+001.00E+031.00E+00	0.25001.00E+030.00E+00
287	4.97E+080.00E+000.00E+001.00E+031.00E+00	0.55001.00E+030.00E+00
288	4.21E+080.00E+000.00E+001.00E+031.00E+00	0.01001.00E+030.00E+00
289	5.66E+080.00E+000.00E+001.00E+031.00E+00	0.70001.00E+030.00E+00
290	5.20E+080.00E+000.00E+001.00E+031.00E+00	0.50001.00E+030.00E+00
291	5.00E+080.00E+000.00E+001.00E+031.00E+00	0.20001.00E+030.00E+00
292	1.05E+090.00E+000.00E+001.00E+031.00E+00	0.80001.00E+030.00E+00
293	2.30E+080.00E+000.00E+001.00E+031.00E+00	0.30001.00E+030.00E+00
294	4.36E+080.00E+000.00E+001.00E+031.00E+00	0.65001.00E+030.00E+00
295	4.68E+080.00E+000.00E+001.00E+031.00E+00	0.30001.00E+030.00E+00
296	4.56E+080.00E+000.00E+001.00E+031.00E+00	0.25001.00E+030.00E+00
297	4.70E+080.00E+000.00E+001.00E+031.00E+00	0.55001.00E+030.00E+00
298	4.97E+080.00E+000.00E+001.00E+031.00E+00	0.01001.00E+030.00E+00
299	4.21E+080.00E+000.00E+001.00E+031.00E+00	0.70001.00E+030.00E+00

300	5.66E+080.00E+000.00E+001.00E+031.00E+00	0.50001.00E+030.00E+00
301	5.20E+080.00E+000.00E+001.00E+031.00E+00	0.20001.00E+030.00E+00
302	5.00E+080.00E+000.00E+001.00E+031.00E+00	0.80001.00E+030.00E+00
303	1.05E+090.00E+000.00E+001.00E+031.00E+00	0.30001.00E+030.00E+00
304	2.30E+080.00E+000.00E+001.00E+031.00E+00	0.65001.00E+030.00E+00
306	4.36E+080.00E+000.00E+001.00E+031.00E+00	0.25001.00E+030.00E+00
307	4.68E+080.00E+000.00E+001.00E+031.00E+00	0.55001.00E+030.00E+00
308	4.56E+080.00E+000.00E+001.00E+031.00E+00	0.01001.00E+030.00E+00
309	4.70E+080.00E+000.00E+001.00E+031.00E+00	0.70001.00E+030.00E+00
310	4.97E+080.00E+000.00E+001.00E+031.00E+00	0.50001.00E+030.00E+00
312	4.21E+080.00E+000.00E+001.00E+031.00E+00	0.80001.00E+030.00E+00
313	5.66E+080.00E+000.00E+001.00E+031.00E+00	0.30001.00E+030.00E+00
314	5.20E+080.00E+000.00E+001.00E+031.00E+00	0.65001.00E+030.00E+00
316	5.00E+080.00E+000.00E+001.00E+031.00E+00	0.25001.00E+030.00E+00
319	1.05E+090.00E+000.00E+001.00E+031.00E+00	0.70001.00E+030.00E+00
320	2.30E+080.00E+000.00E+001.00E+031.00E+00	0.50001.00E+030.00E+00
321	4.36E+080.00E+000.00E+001.00E+031.00E+00	0.20001.00E+030.00E+00
322	4.68E+080.00E+000.00E+001.00E+031.00E+00	0.80001.00E+030.00E+00
323	4.56E+080.00E+000.00E+001.00E+031.00E+00	0.30001.00E+030.00E+00
324	4.56E+080.00E+000.00E+001.00E+031.00E+00	0.65001.00E+030.00E+00
325	1.03E+090.00E+000.00E+001.00E+031.00E+00	0.30001.00E+030.00E+00
326	2.40E+080.00E+000.00E+001.00E+031.00E+00	0.25001.00E+030.00E+00
328	4.70E+080.00E+000.00E+001.00E+031.00E+00	0.01001.00E+030.00E+00
329	4.97E+080.00E+000.00E+001.00E+031.00E+00	0.70001.00E+030.00E+00
330	4.21E+080.00E+000.00E+001.00E+031.00E+00	0.50001.00E+030.00E+00
332	5.66E+080.00E+000.00E+001.00E+031.00E+00	0.80001.00E+030.00E+00
333	5.20E+080.00E+000.00E+001.00E+031.00E+00	0.30001.00E+030.00E+00
334	5.00E+080.00E+000.00E+001.00E+031.00E+00	0.65001.00E+030.00E+00
335	1.05E+090.00E+000.00E+001.00E+031.00E+00	0.30001.00E+030.00E+00
336	2.30E+080.00E+000.00E+001.00E+031.00E+00	0.25001.00E+030.00E+00
337	4.36E+080.00E+000.00E+001.00E+031.00E+00	0.55001.00E+030.00E+00
338	4.68E+080.00E+000.00E+001.00E+031.00E+00	0.01001.00E+030.00E+00
339	4.56E+080.00E+000.00E+001.00E+031.00E+00	0.70001.00E+030.00E+00
340	4.70E+080.00E+000.00E+001.00E+031.00E+00	0.50001.00E+030.00E+00
341	4.97E+080.00E+000.00E+001.00E+031.00E+00	0.20001.00E+030.00E+00
342	4.21E+080.00E+000.00E+001.00E+031.00E+00	0.80001.00E+030.00E+00
343	5.66E+080.00E+000.00E+001.00E+031.00E+00	0.30001.00E+030.00E+00
344	5.20E+080.00E+000.00E+001.00E+031.00E+00	0.65001.00E+030.00E+00
346	5.00E+080.00E+000.00E+001.00E+031.00E+00	0.25001.00E+030.00E+00
347	1.05E+090.00E+000.00E+001.00E+031.00E+00	0.55001.00E+030.00E+00
349	2.30E+080.00E+000.00E+001.00E+031.00E+00	0.70001.00E+030.00E+00
350	4.36E+080.00E+000.00E+001.00E+031.00E+00	0.50001.00E+030.00E+00
351	4.68E+080.00E+000.00E+001.00E+031.00E+00	0.20001.00E+030.00E+00
352	4.56E+080.00E+000.00E+001.00E+031.00E+00	0.80001.00E+030.00E+00
353	4.70E+080.00E+000.00E+001.00E+031.00E+00	0.30001.00E+030.00E+00
354	4.97E+080.00E+000.00E+001.00E+031.00E+00	0.65001.00E+030.00E+00
355	4.21E+080.00E+000.00E+001.00E+031.00E+00	0.30001.00E+030.00E+00
356	5.66E+080.00E+000.00E+001.00E+031.00E+00	0.25001.00E+030.00E+00
357	5.20E+080.00E+000.00E+001.00E+031.00E+00	0.55001.00E+030.00E+00
359	5.00E+080.00E+000.00E+001.00E+031.00E+00	0.70001.00E+030.00E+00
360	1.05E+090.00E+000.00E+001.00E+031.00E+00	0.50001.00E+030.00E+00
362	2.30E+080.00E+000.00E+001.00E+031.00E+00	0.80001.00E+030.00E+00
363	4.36E+080.00E+000.00E+001.00E+031.00E+00	0.30001.00E+030.00E+00
364	4.68E+080.00E+000.00E+001.00E+031.00E+00	0.65001.00E+030.00E+00
365	4.56E+080.00E+000.00E+001.00E+031.00E+00	0.30001.00E+030.00E+00
366	4.56E+080.00E+000.00E+001.00E+031.00E+00	0.25001.00E+030.00E+00
367	4.68E+080.00E+000.00E+001.00E+031.00E+00	0.55001.00E+030.00E+00
368	4.56E+080.00E+000.00E+001.00E+031.00E+00	0.01001.00E+030.00E+00
369	4.68E+080.00E+000.00E+001.00E+031.00E+00	0.70001.00E+030.00E+00
370	4.68E+080.00E+000.00E+001.00E+031.00E+00	0.50001.00E+030.00E+00
371	4.68E+080.00E+000.00E+001.00E+031.00E+00	0.20001.00E+030.00E+00
372	4.68E+080.00E+000.00E+001.00E+031.00E+00	0.80001.00E+030.00E+00
373	4.56E+080.00E+000.00E+001.00E+031.00E+00	0.30001.00E+030.00E+00
374	4.70E+080.00E+000.00E+001.00E+031.00E+00	0.65001.00E+030.00E+00
375	4.97E+080.00E+000.00E+001.00E+031.00E+00	0.30001.00E+030.00E+00
376	4.21E+080.00E+000.00E+001.00E+031.00E+00	0.25001.00E+030.00E+00
377	5.66E+080.00E+000.00E+001.00E+031.00E+00	0.55001.00E+030.00E+00
378	5.20E+080.00E+000.00E+001.00E+031.00E+00	0.01001.00E+030.00E+00
379	5.00E+080.00E+000.00E+001.00E+031.00E+00	0.70001.00E+030.00E+00
380	1.05E+090.00E+000.00E+001.00E+031.00E+00	0.50001.00E+030.00E+00
382	2.30E+080.00E+000.00E+001.00E+031.00E+00	0.80001.00E+030.00E+00

```
  383     4.36E+080.00E+000.00E+001.00E+031.00E+00  0.30001.00E+030.00E+00
  384     4.68E+080.00E+000.00E+001.00E+031.00E+00  0.65001.00E+030.00E+00
  386     4.56E+080.00E+000.00E+001.00E+031.00E+00  0.25001.00E+030.00E+00
  389     4.56E+080.00E+000.00E+001.00E+031.00E+00  0.70001.00E+030.00E+00
  END QUAL-INPUT


  MON-ACCUM
*** <PLS >  Value at start of each month for accum rate of QUALOF (lb/ac.day)
*** x-  x JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
   10     14E0814E0820E0827E0827E0833E0833E0833E0827E0820E0820E0814E08
   11     50E0650E0650E0650E0650E0650E0650E0650E0650E0650E0650E0650E06
   12     72E0885E0880E0980E0980E0920E0720E0720E0720E0980E0980E0972E08
   13     30E0720E0720E0720E0720E0720E0720E0720E0720E0720E0720E0720E07
   14     27E0829E0832E0831E0829E0835E0835E0835E0830E0831E0829E0828E08
   15     45E0845E0845E0845E0845E0845E0845E0845E0845E0845E0845E0845E08
   16     31E0830E0829E0828E0827E0827E0825E0825E0825E0824E0825E0828E08
   17     26E0828E0831E0831E0828E0828E0828E0828E0829E0830E0829E0827E08
   18     70E0170E0170E0170E0170E0170E0170E0170E0170E0170E0170E0170E01
   19     83E0683E0683E0683E0683E0683E0683E0683E0683E0683E0683E0683E06
   20     80E0790E0710E0812E0812E0813E0813E0813E0812E0810E0890E0780E07
   22     10E0710E0710E0710E0710E0710E0710E0710E0710E0710E0710E0710E07
   23     30E0730E0730E0730E0730E0730E0730E0730E0730E0730E0730E0730E07
   24     90E0711E0810E0810E0810E0810E0810E0810E0810E0810E0880E0790E07
   26     19E0819E0818E0817E0817E0816E0815E0815E0815E0815E0815E0817E08
   27     90E0711E0811E0811E0811E0811E0811E0811E0811E0811E0890E0790E07
   28     20E0120E0120E0120E0120E0120E0120E0120E0120E0120E0120E0120E01
   29     82E0682E0682E0682E0682E0682E0682E0682E0682E0682E0682E0682E06
   30     70E0780E0790E0711E0811E0812E0812E0812E0811E0890E0780E0770E07
   31     13E0613E0613E0613E0613E0613E0613E0613E0613E0613E0613E0613E06
   32     86E0620E0770E0760E0720E0720E0720E0720E0730E0730E0730E0786E06
   33     30E0730E0730E0730E0730E0720E0720E0720E0720E0720E0720E0730E07
   34     70E0710E0814E0813E0890E0790E0790E0790E0711E0811E0890E0770E07
   35     57E0657E0657E0657E0657E0657E0657E0657E0657E0657E0657E0657E06
   36     21E0820E0819E0819E0818E0818E0817E0817E0817E0816E0817E0819E08
   37     70E0710E0815E0813E0890E0790E0790E0790E0711E0811E0890E0770E07
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   39     10E0710E0710E0710E0710E0710E0710E0710E0710E0710E0710E0710E07
   40     31E0833E0849E0867E0867E0883E0883E0883E0867E0849E0847E0831E08
   42     30E0940E0939E1039E1039E1010E0710E0710E0712E1039E1039E1030E09
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   44     54E0859E0864E0873E0878E0820E0920E0920E0985E0884E0875E0866E08
   46     12E0812E0811E0811E0811E0811E0810E0810E0810E0810E0810E0811E08
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   55     30E0530E0530E0530E0530E0530E0530E0530E0530E0530E0530E0530E05
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   66     47E0846E0844E0843E0841E0840E0838E0838E0838E0837E0838E0843E08
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   68     20E0120E0120E0120E0120E0120E0120E0120E0120E0120E0120E0120E01
   69     91E0691E0691E0691E0691E0691E0691E0691E0691E0691E0691E0691E06
   70     12E0812E0813E0815E0815E0816E0816E0816E0815E0813E0813E0812E08
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   74     80E0780E0780E0780E0780E0780E0780E0780E0780E0780E0770E0780E07
   76     20E0819E0818E0818E0817E0817E0816E0816E0816E0815E0816E0818E08
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80	10E0811E0811E0811E0811E0811E0811E0811E0811E0811E0810E0810E08
83	20E0720E0720E0720E0710E0710E0710E0710E0710E0710E0710E0720E07
84	30E0730E0730E0730E0730E0730E0730E0730E0730E0730E0730E0730E07
86	62E0861E0858E0856E0855E0854E0851E0851E0851E0849E0851E0856E08
87	50E0750E0750E0750E0750E0750E0750E0750E0750E0750E0750E0750E07
89	30E0730E0730E0730E0730E0730E0730E0730E0730E0730E0730E0730E07
90	60E0760E0770E0770E0770E0770E0770E0770E0770E0770E0760E0760E07
91	11E0611E0611E0611E0611E0611E0611E0611E0611E0611E0611E0611E06
92	53E0620E0760E0750E0720E0720E0720E0720E0730E0730E0730E0753E06
93	40E0740E0740E0740E0740E0740E0740E0740E0740E0730E0740E0740E07
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95	40E0540E0540E0540E0540E0540E0540E0540E0540E0540E0540E0540E05
96	13E0813E0812E0812E0812E0811E0811E0811E0811E0810E0811E0812E08
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98	12E0212E0212E0212E0212E0212E0212E0212E0212E0212E0212E0212E02
99	10E0710E0710E0710E0710E0710E0710E0710E0710E0710E0710E0710E07
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167	17E0823E0844E0840E0824E0824E0825E0825E0831E0830E0830E0818E08
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188	00.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.00
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221	11E0611E0611E0611E0611E0611E0611E0611E0611E0611E0611E0611E06
222	70E0980E0976E1076E1076E1053E0653E0653E0622E1076E1076E1070E09
223	10E0710E0710E0710E0710E0710E0710E0710E0710E0710E0710E0710E07
224	12E0812E0813E0814E0814E0826E0826E0826E0815E0815E0814E0814E08
226	11E0811E0811E0811E0811E0811E0811E0811E0811E0811E0811E0811E08
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229	85E0685E0685E0685E0685E0685E0685E0685E0685E0685E0685E0685E06
230	80E0780E0710E0812E0812E0814E0814E0814E0812E0810E0810E0880E07
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232	40E0950E0944E1044E1044E1030E0730E0730E0713E1044E1044E1040E09
233	88E0687E0685E0684E0683E0682E0680E0680E0680E0678E0680E0684E06
234	11E0811E0811E0812E0812E0821E0822E0822E0813E0813E0812E0812E08
236	50E0750E0750E0750E0750E0750E0750E0750E0750E0750E0750E0750E07
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  386     50E0740E0740E0740E0740E0740E0740E0740E0740E0740E0740E0740E07
  389     20E0720E0720E0720E0720E0720E0720E0720E0720E0720E0720E0720E07
  END MON-ACCUM

  MON-SQOLIM
*** <PLS >  Value at start of month for limiting storage of QUALOF (lb/ac)
*** x-  x JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
   10     56E0856E0812E0921E0921E0939E0939E0939E0921E0912E0980E0856E08
   11     20E0720E0720E0740E0740E0740E0740E0740E0740E0720E0720E0720E07
   12     14E0934E0948E1080E1080E1020E0820E0820E0824E1048E1032E1014E09
   13     12E0812E0816E0824E0824E0824E0820E0820E0820E0812E0880E0712E08
   14     10E0911E0919E0937E0917E0942E0942E0942E0942E0918E0911E0911E09
   15     18E0918E0918E0936E0936E0936E0936E0936E0936E0918E0918E0918E09
   16     12E0912E0917E0922E0921E0921E0920E0920E0920E0914E0910E0911E09
   17     10E0911E0918E0937E0922E0922E0922E0922E0917E0918E0911E0910E09
   18     28E0228E0242E0270E0270E0270E0270E0270E0270E0242E0228E0228E02
   19     33E0733E0733E0783E0783E0783E0783E0783E0783E0733E0733E0733E07
   20     32E0836E0860E0812E0912E0913E0913E0913E0912E0960E0836E0832E08
   22     60E0760E0780E0712E0812E0812E0812E0812E0812E0880E0760E0760E07
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   24     36E0844E0860E0810E0910E0910E0910E0910E0910E0960E0832E0836E08
   26     11E0911E0914E0920E0920E0919E0921E0921E0921E0912E0990E0810E09
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  389     40E0740E0760E0710E0810E0810E0810E0810E0810E0860E0740E0740E07
  END MON-SQOLIM

  MON-IFLW-CONC
*** <PLS >  Conc of QUAL in interflow outflow for each month (qty/ft3)
*** x-   x JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
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    12    16E0439E0484E0484E0484E0423E0323E0323E0384E0484E0484E0416E04
    13    14E0314E0318E0328E0328E0328E0323E0323E0323E0314E0393E0214E03
    14    12E0413E0422E0443E0420E0449E0449E0449E0449E0421E0413E0413E04
    15    21E0421E0421E0442E0442E0442E0442E0442E0442E0421E0421E0421E04
    16    14E0414E0420E0426E0425E0425E0423E0423E0423E0416E0411E0413E04
    17    12E0413E0421E0443E0426E0426E0426E0426E0420E0421E0413E0412E04
    18    00.0300.0300.0500.0800.0800.0800.0800.0800.0800.0500.0300.03
    19    38E0238E0238E0296E0296E0296E0296E0296E0296E0238E0238E0238E02
    20    37E0342E0370E0314E0414E0415E0415E0415E0414E0470E0342E0337E03
    22    70E0270E0293E0214E0314E0314E0314E0314E0314E0393E0270E0270E02
    23    14E0314E0321E0335E0335E0335E0335E0335E0335E0321E0314E0314E03
    24    42E0351E0370E0311E0411E0411E0411E0411E0411E0470E0337E0342E03
    26    13E0413E0416E0423E0423E0422E0424E0424E0424E0414E0410E0411E04
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    43    70E0270E0210E0317E0317E0317E0317E0317E0317E0310E0370E0270E02
    44    12E0413E0422E0442E0445E0484E0484E0484E0449E0439E0487E0315E04
    46    42E0342E0351E0389E0389E0389E0381E0381E0381E0346E0335E0338E03
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   61     6_Commercial and Ser        1    1    0    0    0    0
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  IWAT-PARM1
*** <ILS >        Flags
*** x -  x CSNO RTOP  VRS  VNN RTLI
   11  386    0    0    0    0    0
  END IWAT-PARM1

  IWAT-PARM2
*** <ILS >      LSUR     SLSUR      NSUR     RETSC
*** x -  x      (ft)                          (in)
   11   16      150.    0.1651      0.05       0.1
   36           200.    0.1024      0.05       0.1
   61   66      200.    0.1093      0.05       0.1
   91   96      150.    0.2531      0.05       0.1
  111  116      150.    0.2684      0.05       0.1
  121  126      200.    0.1324      0.05       0.1
  156           200.    0.1308      0.05       0.1
  161  166      200.    0.1074      0.05       0.1
  176           200.     0.127      0.05       0.1
  181  186      200.    0.1038      0.05       0.1
  191  196      200.    0.1007      0.05       0.1
  201  206      200.    0.1002      0.05       0.1
  211  216      200.    0.1157      0.05       0.1
  221  226      200.    0.1166      0.05       0.1
  231  236      200.    0.1061      0.05       0.1
  241  246      200.    0.1087      0.05       0.1
  251  256      250.    0.0877      0.05       0.1
  261  266      200.    0.1135      0.05       0.1
  276           200.    0.1121      0.05       0.1
  286           200.    0.1207      0.05       0.1
  291  296      200.    0.1187      0.05       0.1
  301  306      250.    0.0802      0.05       0.1
  316           200.    0.1032      0.05       0.1
  321  326      250.    0.0983      0.05       0.1
  341  346      250.    0.0804      0.05       0.1
  351  356      250.    0.0794      0.05       0.1
  366           300.     0.057      0.05       0.1
  371  376      300.    0.0694      0.05       0.1
  386           300.    0.0617      0.05       0.1
  END IWAT-PARM2

  IWAT-PARM3
*** <ILS >    PETMAX    PETMIN
*** x -  x   (deg F)   (deg F)
   11  386       40.       35.
  END IWAT-PARM3

  IWAT-STATE1
*** <ILS >  IWATER state variables (inches)
*** x -  x      RETS      SURS
   11  386      0.01      0.01
  END IWAT-STATE1

  NQUALS
*** <ILS >
*** x -  xNQUAL
   11  386    1
  END NQUALS

  QUAL-PROPS
*** <ILS >    Identifiers and Flags
*** x -  x      QUALID    QTID  QSD VPFW  QSO  VQO
   11  386FECAL COLIFO       #    0    0    1    1
  END QUAL-PROPS

  QUAL-INPUT
***          Storage on surface and nonseasonal parameters
***             SQO   POTFW   ACQOP  SQOLIM   WSQOP
*** <ILS >  qty/ac qty/ton    qty/  qty/ac   in/hr
*** x -  x                  ac.day
   11     0.00E+000.00E+000.00E+000.00E+00  0.2000
   16     1.02E+080.00E+000.00E+000.00E+00  0.2500
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   36     5.17E+060.00E+000.00E+000.00E+00  0.2500
   61     1.26E+080.00E+000.00E+000.00E+00  0.1000
   66     4.28E+060.00E+000.00E+000.00E+00  0.1250
   91     1.08E+080.00E+000.00E+000.00E+00  0.2000
   96     4.63E+060.00E+000.00E+000.00E+00  0.2500
  111     6.61E+070.00E+000.00E+000.00E+00  0.2000
  116     4.92E+060.00E+000.00E+000.00E+00  0.2500
  121     7.58E+070.00E+000.00E+000.00E+00  0.2000
  126     2.79E+070.00E+000.00E+000.00E+00  0.2500
  156     2.70E+080.00E+000.00E+000.00E+00  0.2500
  161     1.50E+080.00E+000.00E+000.00E+00  0.2000
  166     2.34E+060.00E+000.00E+000.00E+00  0.2500
  176     1.60E+080.00E+000.00E+000.00E+00  0.2500
  181     1.10E+080.00E+000.00E+000.00E+00  0.2000
  186     1.17E+080.00E+000.00E+000.00E+00  0.2500
  191     1.19E+080.00E+000.00E+000.00E+00  0.2000
  196     1.54E+080.00E+000.00E+000.00E+00  0.2500
  201     1.87E+070.00E+000.00E+000.00E+00  0.2000
  206     1.11E+080.00E+000.00E+000.00E+00  0.2500
  211     2.33E+060.00E+000.00E+000.00E+00  0.2000
  216     1.08E+080.00E+000.00E+000.00E+00  0.2500
  221     2.34E+060.00E+000.00E+000.00E+00  0.2000
  226     1.13E+080.00E+000.00E+000.00E+00  0.2500
  231     3.51E+070.00E+000.00E+000.00E+00  0.2000
  236     1.86E+080.00E+000.00E+000.00E+00  0.2500
  241     0.00E+000.00E+000.00E+000.00E+00  0.2000
  246     1.02E+080.00E+000.00E+000.00E+00  0.2500
  251     5.17E+060.00E+000.00E+000.00E+00  0.2000
  256     1.26E+080.00E+000.00E+000.00E+00  0.2500
  261     4.28E+060.00E+000.00E+000.00E+00  0.2000
  266     1.08E+080.00E+000.00E+000.00E+00  0.2500
  276     4.63E+060.00E+000.00E+000.00E+00  0.7500
  286     6.61E+070.00E+000.00E+000.00E+00  0.2500
  291     4.92E+060.00E+000.00E+000.00E+00  0.2000
  296     7.58E+070.00E+000.00E+000.00E+00  0.2500
  301     2.79E+070.00E+000.00E+000.00E+00  0.2000
  306     2.70E+080.00E+000.00E+000.00E+00  0.2500
  316     1.50E+080.00E+000.00E+000.00E+00  0.2500
  321     2.34E+060.00E+000.00E+000.00E+00  0.2000
  326     1.60E+080.00E+000.00E+000.00E+00  0.2500
  341     1.10E+080.00E+000.00E+000.00E+00  0.2000
  346     1.17E+080.00E+000.00E+000.00E+00  0.2500
  351     1.19E+080.00E+000.00E+000.00E+00  0.2000
  356     1.60E+080.00E+000.00E+000.00E+00  0.2500
  366     1.10E+080.00E+000.00E+000.00E+00  0.2500
  371     1.17E+080.00E+000.00E+000.00E+00  0.2000
  376     1.19E+080.00E+000.00E+000.00E+00  0.2500
  386     1.19E+080.00E+000.00E+000.00E+00  0.2500
  END QUAL-INPUT

  MON-ACCUM
*** <ILS >  Value at start of each month for accum rate of QUALOF (lb/ac.day)
*** x-  x JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
   11     30E0530E0530E0530E0530E0530E0530E0530E0530E0530E0530E0530E05
   16     20E0720E0720E0720E0720E0720E0720E0720E0720E0720E0720E0720E07
   36     10E0710E0710E0710E0710E0710E0710E0710E0710E0710E0710E0710E07
   61     70E0570E0570E0570E0570E0570E0570E0570E0570E0570E0570E0570E05
   66     30E0730E0730E0730E0730E0730E0730E0730E0730E0730E0730E0730E07
   91     68E0468E0468E0468E0468E0468E0468E0468E0468E0468E0468E0468E04
   96     94E0691E0687E0685E0683E0681E0677E0677E0677E0675E0677E0685E06
  111     70E0570E0570E0570E0570E0570E0570E0570E0570E0570E0570E0570E05
  116     10E0710E0710E0710E0710E0710E0710E0710E0710E0710E0710E0710E07
  121     10E0510E0510E0510E0510E0510E0510E0510E0510E0510E0510E0510E05
  126     10E0710E0710E0710E0710E0710E0710E0710E0710E0710E0710E0710E07
  156     71E0669E0666E0664E0662E0661E0657E0657E0657E0656E0657E0664E06
  161     95E0495E0495E0495E0495E0495E0495E0495E0495E0495E0495E0495E04
  166     20E0720E0710E0710E0710E0710E0710E0710E0710E0710E0710E0710E07
  176     40E0740E0740E0730E0730E0730E0730E0730E0730E0730E0730E0730E07
  181     70E0570E0570E0570E0570E0570E0570E0570E0570E0570E0570E0570E05
  186     20E0720E0720E0720E0720E0720E0720E0720E0720E0720E0720E0720E07
  191     85E0485E0485E0485E0485E0485E0485E0485E0485E0485E0485E0485E04
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  196      30E0730E0730E0730E0730E0730E0730E0730E0730E0730E0730E0730E07
  201      30E0530E0530E0530E0530E0530E0530E0530E0530E0530E0530E0530E05
  206      80E0679E0678E0677E0676E0675E0673E0673E0673E0673E0673E0677E06
  211      30E0530E0530E0530E0530E0530E0530E0530E0530E0530E0530E0530E05
  216      54E0654E0654E0654E0654E0654E0654E0654E0654E0654E0654E0654E06
  221      68E0468E0468E0468E0468E0468E0468E0468E0468E0468E0468E0468E04
  226      82E0681E0681E0680E0680E0680E0679E0679E0679E0679E0679E0680E06
  231      78E0478E0478E0478E0478E0478E0478E0478E0478E0478E0478E0478E04
  236      37E0637E0637E0636E0636E0636E0635E0635E0635E0635E0635E0636E06
  241      92E0492E0492E0492E0492E0492E0492E0492E0492E0492E0492E0492E04
  246      76E0676E0675E0674E0674E0673E0672E0672E0672E0671E0672E0674E06
  251      50E0550E0550E0550E0550E0550E0550E0550E0550E0550E0550E0550E05
  256      48E0647E0647E0646E0646E0645E0645E0645E0645E0644E0645E0646E06
  261      63E0463E0463E0463E0463E0463E0463E0463E0463E0463E0463E0463E04
  266      20E0720E0720E0720E0720E0720E0720E0720E0720E0720E0720E0720E07
  276      60E0750E0750E0750E0750E0750E0740E0740E0740E0740E0740E0750E07
  286      30E0730E0730E0730E0720E0720E0720E0720E0720E0720E0720E0730E07
  291      78E0478E0478E0478E0478E0478E0478E0478E0478E0478E0478E0478E04
  296      93E0692E0690E0688E0687E0686E0683E0683E0683E0682E0683E0688E06
  301      45E0445E0445E0445E0445E0445E0445E0445E0445E0445E0445E0445E04
  306      44E0644E0644E0644E0643E0643E0643E0643E0643E0643E0643E0644E06
  316      40E0740E0740E0740E0740E0740E0730E0730E0730E0730E0730E0740E07
  321      17E0417E0417E0417E0417E0417E0417E0417E0417E0417E0417E0417E04
  326      58E0657E0655E0654E0653E0652E0650E0650E0650E0649E0650E0654E06
  341      73E0473E0473E0473E0473E0473E0473E0473E0473E0473E0473E0473E04
  346      84E0682E0679E0677E0675E0673E0670E0670E0670E0668E0670E0677E06
  351      30E0530E0530E0530E0530E0530E0530E0530E0530E0530E0530E0530E05
  356      10E0710E0710E0710E0798E0696E0692E0692E0692E0690E0692E0610E07
  366      10E0710E0710E0710E0710E0710E0796E0696E0696E0693E0696E0610E07
  371      40E0540E0540E0540E0540E0540E0540E0540E0540E0540E0540E0540E05
  376      38E0638E0637E0636E0635E0635E0633E0633E0633E0633E0633E0636E06
  386      33E0632E0631E0630E0630E0629E0628E0628E0628E0628E0628E0630E06
  END MON-ACCUM

  MON-SQOLIM
*** <ILS >  Value at start of month for limiting storage of QUALOF (lb/ac)
*** x-  x JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
   11      12E0612E0618E0630E0630E0630E0630E0630E0630E0618E0612E0612E06
   16      80E0780E0712E0820E0820E0820E0820E0820E0820E0812E0880E0780E07
   36      20E0720E0730E0750E0750E0750E0750E0750E0750E0730E0720E0720E07
   61      42E0642E0663E0610E0710E0710E0710E0710E0710E0763E0642E0642E06
   66      18E0818E0827E0845E0845E0845E0845E0845E0845E0827E0818E0818E08
   91      27E0527E0540E0568E0568E0568E0568E0568E0568E0540E0527E0527E05
   96      37E0736E0752E0785E0783E0781E0777E0777E0777E0745E0730E0734E07
  111      42E0642E0663E0610E0710E0710E0710E0710E0710E0763E0642E0642E06
  116      60E0760E0790E0715E0815E0815E0815E0815E0815E0890E0760E0760E07
  121      20E0520E0530E0550E0550E0550E0550E0550E0550E0530E0520E0520E05
  126      20E0720E0730E0750E0750E0750E0750E0750E0750E0730E0720E0720E07
  156      14E0713E0719E0732E0731E0730E0728E0728E0728E0716E0711E0712E07
  161      19E0519E0528E0547E0547E0547E0547E0547E0547E0528E0519E0519E05
  166      40E0740E0730E0750E0750E0750E0750E0750E0750E0730E0720E0720E07
  176      80E0780E0712E0815E0815E0815E0815E0815E0815E0890E0760E0760E07
  181      56E0656E0684E0614E0714E0714E0714E0714E0714E0784E0656E0656E06
  186      16E0816E0824E0840E0840E0840E0840E0840E0840E0824E0816E0816E08
  191      68E0568E0510E0617E0617E0617E0617E0617E0617E0610E0668E0568E05
  196      24E0824E0836E0860E0860E0860E0860E0860E0860E0836E0824E0824E08
  201      24E0624E0636E0660E0660E0660E0660E0660E0660E0636E0624E0624E06
  206      64E0763E0793E0715E0815E0815E0814E0814E0814E0887E0758E0761E07
  211      24E0624E0636E0660E0660E0660E0660E0660E0660E0636E0624E0624E06
  216      43E0743E0764E0710E0810E0810E0810E0810E0810E0864E0743E0743E07
  221      54E0554E0581E0513E0613E0613E0613E0613E0613E0681E0554E0554E05
  226      65E0764E0797E0716E0816E0816E0815E0815E0815E0894E0763E0764E07
  231      62E0562E0593E0515E0615E0615E0615E0615E0615E0693E0562E0562E05
  236      29E0729E0744E0772E0772E0772E0770E0770E0770E0742E0728E0728E07
  241      18E0518E0527E0546E0546E0546E0546E0546E0546E0527E0518E0518E05
  246      15E0715E0722E0737E0737E0736E0736E0736E0736E0721E0714E0714E07
  251      10E0610E0615E0625E0625E0625E0625E0625E0625E0615E0610E0610E06
  256      96E0694E0614E0723E0723E0722E0722E0722E0722E0713E0790E0692E06
  261      12E0512E0518E0531E0531E0531E0531E0531E0531E0518E0512E0512E05
  266      40E0740E0760E0710E0810E0810E0810E0810E0810E0860E0740E0740E07
  276      12E0810E0815E0825E0825E0825E0820E0820E0820E0812E0880E0710E08
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  286     60E0760E0790E0715E0810E0810E0810E0810E0810E0860E0740E0760E07
  291     15E0515E0523E0539E0539E0539E0539E0539E0539E0523E0515E0515E05
  296     18E0718E0727E0744E0743E0743E0741E0741E0741E0724E0716E0717E07
  301     90E0490E0413E0522E0522E0522E0522E0522E0522E0513E0590E0490E04
  306     88E0688E0613E0722E0721E0721E0721E0721E0721E0712E0786E0688E06
  316     80E0780E0712E0820E0820E0820E0815E0815E0815E0890E0760E0780E07
  321     34E0434E0451E0485E0485E0485E0485E0485E0485E0451E0434E0434E04
  326     11E0711E0716E0727E0726E0726E0725E0725E0725E0714E0710E0710E07
  341     14E0514E0521E0536E0536E0536E0536E0536E0536E0521E0514E0514E05
  346     16E0716E0723E0738E0737E0736E0735E0735E0735E0720E0714E0715E07
  351     60E0560E0590E0515E0615E0615E0615E0615E0615E0690E0560E0560E05
  356     20E0720E0730E0750E0749E0748E0746E0746E0746E0727E0718E0720E07
  366     20E0720E0730E0750E0750E0750E0748E0748E0748E0727E0719E0720E07
  371     80E0580E0512E0620E0620E0620E0620E0620E0620E0612E0680E0580E05
  376     76E0676E0611E0718E0717E0717E0716E0716E0716E0799E0666E0672E06
  386     66E0664E0693E0615E0715E0714E0714E0714E0714E0784E0656E0660E06
  END MON-SQOLIM

END IMPLND
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UCI FILE USED FOR MODELING SOUTH RIVER

```
PERLND
  ACTIVITY
*** <PLS >               Active Sections                               ***
*** x -  x ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC ***
  390  489    0    0    1    0    0    0    1    0    0    0    0    0
  END ACTIVITY

  PRINT-INFO
*** < PLS>                       Print-flags                           PIVL  PYR
*** x  - x ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC
  390  489    4    4    4    4    4    4    4    4    4    4    4    4    1    9
  END PRINT-INFO

  GEN-INFO
***            Name                  Unit-systems   Printer BinaryOut
*** <PLS >                               t-series Engl Metr Engl Metr
*** x -  x                                 in  out
  390     39_Livestock Access               1    1    0    0    0    0
  391     39_Commercial and Se              1    1    0    0    0    0
  392     39_Cropland                       1    1    0    0    0    0
  393     39_Farmstead                      1    1    0    0    0    0
  394     39_Improved Pasture               1    1    0    0    0    0
  395     39_Livestock Operati              1    1    0    0    0    0
  396     39_Residential                    1    1    0    0    0    0
  397     39_Unimproved Pastur              1    1    0    0    0    0
  398     39_Water                          1    1    0    0    0    0
  399     39_Woodland                       1    1    0    0    0    0
  400     40_Livestock Access               1    1    0    0    0    0
  401     40_Commercial and Se              1    1    0    0    0    0
  402     40_Cropland                       1    1    0    0    0    0
  403     40_Farmstead                      1    1    0    0    0    0
  404     40_Improved Pasture               1    1    0    0    0    0
  405     40_Livestock Operati              1    1    0    0    0    0
  406     40_Residential                    1    1    0    0    0    0
  407     40_Unimproved Pastur              1    1    0    0    0    0
  408     40_Water                          1    1    0    0    0    0
  409     40_Woodland                       1    1    0    0    0    0
  410     41_Livestock Access               1    1    0    0    0    0
  411     41_Commercial and Se              1    1    0    0    0    0
  412     41_Cropland                       1    1    0    0    0    0
  413     41_Farmstead                      1    1    0    0    0    0
  414     41_Improved Pasture               1    1    0    0    0    0
  415     41_Livestock Operati              1    1    0    0    0    0
  416     41_Residential                    1    1    0    0    0    0
  417     41_Unimproved Pastur              1    1    0    0    0    0
  418     41_Water                          1    1    0    0    0    0
  419     41_Woodland                       1    1    0    0    0    0
  420     42_Livestock Access               1    1    0    0    0    0
  421     42_Commercial and Se              1    1    0    0    0    0
  422     42_Cropland                       1    1    0    0    0    0
  423     42_Farmstead                      1    1    0    0    0    0
  424     42_Improved Pasture               1    1    0    0    0    0
  425     42_Livestock Operati              1    1    0    0    0    0
  426     42_Residential                    1    1    0    0    0    0
  427     42_Unimproved Pastur              1    1    0    0    0    0
  428     42_Water                          1    1    0    0    0    0
  429     42_Woodland                       1    1    0    0    0    0
  430     43_Livestock Access               1    1    0    0    0    0
  431     43_Commercial and Se              1    1    0    0    0    0
  432     43_Cropland                       1    1    0    0    0    0
  433     43_Farmstead                      1    1    0    0    0    0
  434     43_Improved Pasture               1    1    0    0    0    0
  435     43_Livestock Operati              1    1    0    0    0    0
  436     43_Residential                    1    1    0    0    0    0
  437     43_Unimproved Pastur              1    1    0    0    0    0
  438     43_Water                          1    1    0    0    0    0
  439     43_Woodland                       1    1    0    0    0    0
  440     44_Livestock Access               1    1    0    0    0    0
  441     44_Commercial an                  1    1    0    0    0    0
  442     44_Cropland                       1    1    0    0    0    0
  443     44_Farmstead                      1    1    0    0    0    0
```

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  444     44_Improved Past                  1    1    0    0    0    0
  445     44_Livestock Operati              1    1    0    0    0    0
  446     44_Residential                    1    1    0    0    0    0
  447     44_Unimproved Pastur              1    1    0    0    0    0
  448     44_Water                          1    1    0    0    0    0
  449     44_Woodland                       1    1    0    0    0    0
  451     45_Commercial an                  1    1    0    0    0    0
  452     45_Cropland                       1    1    0    0    0    0
  453     45_Farmstead                      1    1    0    0    0    0
  454     45_Improved Past                  1    1    0    0    0    0
  455     45_Livestock Operati              1    1    0    0    0    0
  456     45_Residential                    1    1    0    0    0    0
  458     45_Water                          1    1    0    0    0    0
  459     45_Woodland                       1    1    0    0    0    0
  461     46_Commercial an                  1    1    0    0    0    0
  462     46_Cropland                       1    1    0    0    0    0
  464     46_Improved Past                  1    1    0    0    0    0
  466     46_Residential                    1    1    0    0    0    0
  468     46_Water                          1    1    0    0    0    0
  469     46_Woodland                       1    1    0    0    0    0
  471     47_Commercial an                  1    1    0    0    0    0
  472     47_Cropland                       1    1    0    0    0    0
  474     47_Improved Past                  1    1    0    0    0    0
  476     47_Residential                    1    1    0    0    0    0
  478     47_Water                          1    1    0    0    0    0
  479     47_Woodland                       1    1    0    0    0    0
  480     48_Livestock Access               1    1    0    0    0    0
  481     48_Commercial an                  1    1    0    0    0    0
  482     48_Cropland                       1    1    0    0    0    0
  484     48_Improved Past                  1    1    0    0    0    0
  486     48_Residential                    1    1    0    0    0    0
  488     48_Water                          1    1    0    0    0    0
  489     48_Woodland                       1    1    0    0    0    0
  END GEN-INFO

  PWAT-PARM1
*** <PLS >                   Flags
*** x -  x CSNO RTOP UZFG  VCS  VUZ  VNN VIFW VIRC  VLE IFFC  HWT IRRG
  390  489    0    1    1    1    0    0    0    0    1    1    0    0
  END PWAT-PARM1

  PWAT-PARM2
*** < PLS>    FOREST      LZSN    INFILT      LSUR     SLSUR     KVARY     AGWRC
*** x  - x                (in)   (in/hr)      (ft)               (1/in)   (1/day)
  390             1.        5.      0.08    1.5986    0.0115        0.      0.99
  391             1.        5.      0.08  377.6964    0.0441        0.      0.99
  392             1.        5.      0.08  732.7711    0.0479        0.      0.99
  393             1.        5.      0.08  360.6173    0.0529        0.      0.99
  394             1.        5.      0.08  468.2639     0.057        0.      0.99
  395             1.        5.      0.08  331.2572    0.0779        0.      0.99
  396             1.        5.      0.08  572.9046    0.0527        0.      0.99
  397             1.        5.      0.08  260.4909    0.0742        0.      0.99
  398             1.        5.      0.08   66.8398    0.0336        0.      0.99
  399             1.        5.      0.08  757.3568    0.0782        0.      0.99
  400             1.        5.      0.08        1.    0.0001        0.      0.99
  401             1.        5.      0.08  613.2917    0.0612        0.      0.99
  402             1.        5.      0.08  658.3878    0.0366        0.      0.99
  403             1.        5.      0.08  426.5683     0.052        0.      0.99
  404             1.        5.      0.08  439.3994    0.0453        0.      0.99
  405             1.        5.      0.08  1127.925    0.0434        0.      0.99
  406             1.        5.      0.08  592.4231    0.0433        0.      0.99
  407             1.        5.      0.08  437.5953    0.0625        0.      0.99
  408             1.        5.      0.08    7.4023    0.0201        0.      0.99
  409             1.        5.      0.08  585.0551    0.0697        0.      0.99
  410             1.        5.      0.08   10.4403    0.0302        0.      0.99
  411             1.        5.      0.08  293.2618    0.0409        0.      0.99
  412             1.        5.      0.08  353.6551     0.043        0.      0.99
  413             1.        5.      0.08  444.9258    0.0583        0.      0.99
  414             1.        5.      0.08  372.3126    0.0347        0.      0.99
  415             1.        5.      0.08  891.0225    0.0647        0.      0.99
  416             1.        5.      0.08   467.172    0.0374        0.      0.99
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  417             1.         5.      0.08  304.7604    0.0435         0.      0.99
  418             1.         5.      0.08    2.8587    0.0124         0.      0.99
  419             1.         5.      0.08   348.704    0.0564         0.      0.99
  420             1.         5.      0.08        1.    0.0001         0.      0.99
  421             1.         5.      0.08  503.5948    0.0402         0.      0.99
  422             1.         5.      0.08   546.834    0.0372         0.      0.99
  423             1.         5.      0.08  338.4655    0.0307         0.      0.99
  424             1.         5.      0.08  333.1287    0.0363         0.      0.99
  425             1.         5.      0.08   466.742    0.0001         0.      0.99
  426             1.         5.      0.08  320.2951    0.0309         0.      0.99
  427             1.         5.      0.08   309.452    0.0348         0.      0.99
  428             1.         5.      0.08    6.2824    0.0169         0.      0.99
  429             1.         5.      0.08   288.753    0.0291         0.      0.99
  430             1.         5.      0.08        1.    0.0001         0.      0.99
  431             1.         5.      0.08    261.99    0.0195         0.      0.99
  432             1.         5.      0.08   240.157    0.0198         0.      0.99
  433             1.         5.      0.08  464.0013     0.023         0.      0.99
  434             1.         5.      0.08  338.7959    0.0295         0.      0.99
  435             1.         5.      0.08    3.2312    0.0001         0.      0.99
  436             1.         5.      0.08  532.9067    0.0222         0.      0.99
  437             1.         5.      0.08   245.954    0.0262         0.      0.99
  438             1.         5.      0.08   70.4617    0.0198         0.      0.99
  439             1.         5.      0.08  351.5038    0.0916         0.      0.99
  440             1.         5.      0.08        1.    0.0001         0.      0.99
  441             1.         5.      0.08  119.6541    0.0301         0.      0.99
  442             1.         5.      0.08  480.2531    0.0274         0.      0.99
  443             1.         5.      0.08  714.2587    0.0175         0.      0.99
  444             1.         5.      0.08  529.2068    0.0288         0.      0.99
  445             1.         5.      0.08  479.0751     0.024         0.      0.99
  446             1.         5.      0.08  631.9734    0.0257         0.      0.99
  447             1.         5.      0.08  140.1579    0.0171         0.      0.99
  448             1.         5.      0.08   13.9732     0.015         0.      0.99
  449             1.         5.      0.08  426.6989    0.0755         0.      0.99
  451             1.         5.      0.08  855.4063    0.0147         0.      0.99
  452             1.         5.      0.08  417.3132    0.0133         0.      0.99
  453             1.         5.      0.08  1924.729    0.0183         0.      0.99
  454             1.         5.      0.08  695.6812    0.0213         0.      0.99
  455             1.         5.      0.08  488.9999    0.0531         0.      0.99
  456             1.         5.      0.08   925.817    0.0139         0.      0.99
  458             1.         5.      0.08  283.7986    0.0167         0.      0.99
  459             1.         5.      0.08  463.9038    0.0702         0.      0.99
  461             1.         5.      0.08  769.8262    0.0211         0.      0.99
  462             1.         5.      0.08   690.025     0.017         0.      0.99
  464             1.         5.      0.08  610.4457    0.0206         0.      0.99
  466             1.         5.      0.08  695.2671    0.0173         0.      0.99
  468             1.         5.      0.08  212.4312    0.0157         0.      0.99
  469             1.         5.      0.08  639.2217     0.052         0.      0.99
  471             1.         5.      0.08  422.7086    0.0195         0.      0.99
  472             1.         5.      0.08  588.3601    0.0113         0.      0.99
  474             1.         5.      0.08  439.8508    0.0191         0.      0.99
  476             1.         5.      0.08  621.8974    0.0143         0.      0.99
  478             1.         5.      0.08   154.032     0.017         0.      0.99
  479             1.         5.      0.08  600.7949    0.1243         0.      0.99
  480             1.         5.      0.08  1454.522    0.0358         0.      0.99
  481             1.         5.      0.08  392.1724    0.0495         0.      0.99
  482             1.         5.      0.08  384.1265    0.0174         0.      0.99
  484             1.         5.      0.08  466.6526    0.0265         0.      0.99
  486             1.         5.      0.08  777.1786    0.0344         0.      0.99
  488             1.         5.      0.08  120.5172     0.017         0.      0.99
  489             1.         5.      0.08  662.0605    0.0632         0.      0.99
  END PWAT-PARM2

  PWAT-PARM3
*** < PLS>     PETMAX    PETMIN    INFEXP    INFILD    DEEPFR    BASETP    AGWETP
*** x  - x   (deg F)   (deg F)
  390  489        40.       35.        2.        2.      0.01     0.048        0.
  END PWAT-PARM3

  PWAT-PARM4
*** <PLS >      CEPSC      UZSN      NSUR     INTFW       IRC     LZETP
*** x -  x       (in)      (in)                       (1/day)
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  390  489       0.1       0.9       0.2        1.       0.7        0.
  END PWAT-PARM4

  PWAT-STATE1
*** < PLS>  PWATER state variables (in)
*** x  - x      CEPS      SURS       UZS      IFWS       LZS      AGWS      GWVS
  390  489      0.01      0.01       0.3      0.01       1.5      0.01      0.01
  END PWAT-STATE1

  MON-INTERCEP
*** <PLS >  Interception storage capacity at start of each month (in)
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  390  489  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1  0.1
  END MON-INTERCEP

  MON-UZSN
*** <PLS >  Upper zone storage at start of each month  (inches)
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  390  489  0.1  0.1  0.1  0.2  0.2  0.2  0.3  0.3  0.3  0.1  0.1  0.1
  END MON-UZSN

  MON-LZETPARM
*** <PLS >  Lower zone evapotransp   parm at start of each month
*** x -  x  JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  390  489  0.1  0.1  0.1  0.1  0.1  0.1  0.2  0.2  0.2  0.1  0.1  0.1
  END MON-LZETPARM

  NQUALS
*** <PLS >
*** x -  xNQUAL
  390         1
  391         1
  392         1
  393         1
  394         1
  395         1
  396         1
  397         1
  398         1
  399         1
  400         1
  401         1
  402         1
  403         1
  404         1
  405         1
  406         1
  407         1
  408         1
  409         1
  410         1
  411         1
  412         1
  413         1
  414         1
  415         1
  416         1
  417         1
  418         1
  419         1
  420         1
  421         1
  422         1
  423         1
  424         1
  425         1
  426         1
  427         1
  428         1
  429         1
  430         1
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  431         1
  432         1
  433         1
  434         1
  435         1
  436         1
  437         1
  438         1
  439         1
  440         1
  441         1
  442         1
  443         1
  444         1
  445         1
  446         1
  447         1
  448         1
  449         1
  451         1
  452         1
  453         1
  454         1
  455         1
  456         1
  458         1
  459         1
  461         1
  462         1
  464         1
  466         1
  468         1
  469         1
  471         1
  472         1
  474         1
  476         1
  478         1
  479         1
  480         1
  481         1
  482         1
  484         1
  486         1
  488         1
  489         1
  END NQUALS

  QUAL-PROPS
*** <PLS >  Identifiers and Flags
*** x -  x    QUALID      QTID  QSD VPFW VPFS  QSO  VQO QIFW VIQC QAGW VAQC
  390  489FECAL COLIFO       #    0    0    0    1    1    1    1    0    0
  END QUAL-PROPS

  QUAL-INPUT
***         Storage on surface and nonseasonal parameters
***            SQO   POTFW   POTFS   ACQOP  SQOLIM   WSQOP    IOQC    AOQC
*** <PLS >  qty/ac qty/ton qty/ton    qty/  qty/ac   in/hr qty/ft3 qty/ft3
*** x -  x                          ac.day
  390           0.      0.      0.      0.0.000001   0.167      0.      0.
  391           0.      0.      0.      0.0.000001   0.067      0.      0.
  392           0.      0.      0.      0.0.000001   0.267      0.      0.
  393           0.      0.      0.      0.0.000001   0.100      0.      0.
  394           0.      0.      0.      0.0.000001   0.217      0.      0.
  395           0.      0.      0.      0.0.000001   0.100      0.      0.
  396           0.      0.      0.      0.0.000001   0.083      0.      0.
  397           0.      0.      0.      0.0.000001   0.183      0.      0.
  398           0.      0.      0.      0.0.000001   0.010      0.      0.
  399           0.      0.      0.      0.0.000001   0.233      0.      0.
  400           0.      0.      0.      0.0.000001   0.167      0.      0.
  401           0.      0.      0.      0.0.000001   0.067      0.      0.
```

402	0.	0.	0.	0.0.000001	0.267	0.	0.
403	0.	0.	0.	0.0.000001	0.100	0.	0.
404	0.	0.	0.	0.0.000001	0.217	0.	0.
405	0.	0.	0.	0.0.000001	0.100	0.	0.
406	0.	0.	0.	0.0.000001	0.083	0.	0.
407	0.	0.	0.	0.0.000001	0.183	0.	0.
408	0.	0.	0.	0.0.000001	0.010	0.	0.
409	0.	0.	0.	0.0.000001	0.233	0.	0.
410	0.	0.	0.	0.0.000001	0.167	0.	0.
411	0.	0.	0.	0.0.000001	0.067	0.	0.
412	0.	0.	0.	0.0.000001	0.267	0.	0.
413	0.	0.	0.	0.0.000001	0.100	0.	0.
414	0.	0.	0.	0.0.000001	0.217	0.	0.
415	0.	0.	0.	0.0.000001	0.100	0.	0.
416	0.	0.	0.	0.0.000001	0.083	0.	0.
417	0.	0.	0.	0.0.000001	0.183	0.	0.
418	0.	0.	0.	0.0.000001	0.010	0.	0.
419	0.	0.	0.	0.0.000001	0.233	0.	0.
420	0.	0.	0.	0.0.000001	0.167	0.	0.
421	0.	0.	0.	0.0.000001	0.067	0.	0.
422	0.	0.	0.	0.0.000001	0.267	0.	0.
423	0.	0.	0.	0.0.000001	0.100	0.	0.
424	0.	0.	0.	0.0.000001	0.217	0.	0.
425	0.	0.	0.	0.0.000001	0.100	0.	0.
426	0.	0.	0.	0.0.000001	0.083	0.	0.
427	0.	0.	0.	0.0.000001	0.183	0.	0.
428	0.	0.	0.	0.0.000001	0.010	0.	0.
429	0.	0.	0.	0.0.000001	0.233	0.	0.
430	0.	0.	0.	0.0.000001	0.167	0.	0.
431	0.	0.	0.	0.0.000001	0.067	0.	0.
432	0.	0.	0.	0.0.000001	0.267	0.	0.
433	0.	0.	0.	0.0.000001	0.100	0.	0.
434	0.	0.	0.	0.0.000001	0.217	0.	0.
435	0.	0.	0.	0.0.000001	0.100	0.	0.
436	0.	0.	0.	0.0.000001	0.083	0.	0.
437	0.	0.	0.	0.0.000001	0.183	0.	0.
438	0.	0.	0.	0.0.000001	0.010	0.	0.
439	0.	0.	0.	0.0.000001	0.233	0.	0.
440	0.	0.	0.	0.0.000001	0.167	0.	0.
441	0.	0.	0.	0.0.000001	0.067	0.	0.
442	0.	0.	0.	0.0.000001	0.267	0.	0.
443	0.	0.	0.	0.0.000001	0.100	0.	0.
444	0.	0.	0.	0.0.000001	0.217	0.	0.
445	0.	0.	0.	0.0.000001	0.100	0.	0.
446	0.	0.	0.	0.0.000001	0.083	0.	0.
447	0.	0.	0.	0.0.000001	0.183	0.	0.
448	0.	0.	0.	0.0.000001	0.010	0.	0.
449	0.	0.	0.	0.0.000001	0.233	0.	0.
451	0.	0.	0.	0.0.000001	0.067	0.	0.
452	0.	0.	0.	0.0.000001	0.267	0.	0.
453	0.	0.	0.	0.0.000001	0.100	0.	0.
454	0.	0.	0.	0.0.000001	0.217	0.	0.
455	0.	0.	0.	0.0.000001	0.100	0.	0.
456	0.	0.	0.	0.0.000001	0.083	0.	0.
458	0.	0.	0.	0.0.000001	0.010	0.	0.
459	0.	0.	0.	0.0.000001	0.233	0.	0.
461	0.	0.	0.	0.0.000001	0.067	0.	0.
462	0.	0.	0.	0.0.000001	0.267	0.	0.
464	0.	0.	0.	0.0.000001	0.217	0.	0.
466	0.	0.	0.	0.0.000001	0.083	0.	0.
468	0.	0.	0.	0.0.000001	0.010	0.	0.
469	0.	0.	0.	0.0.000001	0.233	0.	0.
471	0.	0.	0.	0.0.000001	0.067	0.	0.
472	0.	0.	0.	0.0.000001	0.267	0.	0.
474	0.	0.	0.	0.0.000001	0.217	0.	0.
476	0.	0.	0.	0.0.000001	0.083	0.	0.
478	0.	0.	0.	0.0.000001	0.010	0.	0.
479	0.	0.	0.	0.0.000001	0.233	0.	0.
480	0.	0.	0.	0.0.000001	0.167	0.	0.
481	0.	0.	0.	0.0.000001	0.067	0.	0.
482	0.	0.	0.	0.0.000001	0.267	0.	0.

```
  484           0.      0.      0.      0.0.000001   0.217      0.      0.
  486           0.      0.      0.      0.0.000001   0.083      0.      0.
  488           0.      0.      0.      0.0.000001   0.010      0.      0.
  489           0.      0.      0.      0.0.000001   0.233      0.      0.
  END QUAL-INPUT

  MON-ACCUM
*** <PLS >  Value at start of each month for accum rate of QUALOF (lb/ac.day)
*** x-   x JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  390      90E0710E0812E0815E0815E0817E0817E0817E0815E0812E0811E0890E07
  391      32E0632E0632E0632E0632E0632E0632E0632E0632E0632E0632E0632E06
  392      70E0610E0740E0740E0710E0710E0710E0710E0720E0720E0720E0770E06
  393      20E0720E0720E0720E0720E0720E0720E0720E0720E0720E0720E0720E07
  394      10E0813E0816E0815E0813E0812E0812E0812E0813E0813E0812E0810E08
  395      12E0612E0612E0612E0612E0612E0612E0612E0612E0612E0612E0612E06
  396      10E0890E0790E0790E0790E0780E0780E0780E0780E0780E0780E0790E07
  397      10E0813E0816E0815E0813E0812E0812E0812E0813E0813E0812E0810E08
  398      40E0140E0140E0140E0140E0140E0140E0140E0140E0140E0140E0140E01
  399      10E0710E0710E0710E0710E0710E0710E0710E0710E0710E0710E0710E07
  400      10E0811E0812E0813E0813E0814E0814E0814E0813E0812E0811E0810E08
  401      35E0635E0635E0635E0635E0635E0635E0635E0635E0635E0635E0635E06
  402      10E0720E0760E0750E0720E0720E0720E0720E0730E0730E0730E0710E07
  403      30E0730E0730E0730E0720E0720E0720E0720E0720E0720E0720E0730E07
  404      80E0711E0814E0813E0810E0810E0810E0810E0811E0811E0810E0880E07
  405      00.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.00
  406      10E0810E0810E0890E0790E0790E0780E0780E0780E0780E0780E0790E07
  407      10E0812E0816E0815E0812E0812E0812E0812E0813E0813E0812E0810E08
  408      20E0120E0120E0120E0120E0120E0120E0120E0120E0120E0120E0120E01
  409      20E0720E0720E0720E0720E0720E0720E0720E0720E0720E0720E0720E07
  410      70E0780E0780E0780E0780E0780E0780E0780E0780E0780E0780E0770E07
  411      64E0664E0664E0664E0664E0664E0664E0664E0664E0664E0664E0664E06
  412      30E0730E0730E0730E0730E0730E0730E0730E0730E0730E0730E0730E07
  413      40E0740E0730E0730E0730E0730E0730E0730E0730E0730E0730E0730E07
  414      40E0750E0750E0750E0750E0750E0750E0750E0750E0750E0740E0740E07
  415      60E0560E0560E0560E0560E0560E0560E0560E0560E0560E0560E0560E05
  416      70E0770E0770E0770E0760E0760E0760E0760E0760E0760E0760E0770E07
  417      40E0740E0740E0740E0740E0740E0740E0740E0740E0740E0740E0740E07
  418      80E0180E0180E0180E0180E0180E0180E0180E0180E0180E0180E0180E01
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  421      10E0710E0710E0710E0710E0710E0710E0710E0710E0710E0710E0710E07
  422      10E0740E0716E0813E0840E0740E0740E0740E0770E0770E0770E0710E07
  423      30E0730E0730E0730E0730E0730E0730E0730E0730E0730E0730E0730E07
  424      11E0815E0826E0824E0815E0815E0815E0815E0818E0818E0816E0811E08
  425      31E0631E0631E0631E0631E0631E0631E0631E0631E0631E0631E0631E06
  426      11E0810E0810E0810E0890E0790E0790E0790E0790E0790E0790E0710E08
  427      90E0714E0825E0822E0813E0813E0813E0813E0816E0816E0815E0890E07
  428      90E0190E0190E0190E0190E0190E0190E0190E0190E0190E0190E0190E01
  429      20E0720E0720E0720E0720E0720E0720E0720E0720E0720E0720E0720E07
  430      11E0811E0816E0820E0820E0825E0825E0825E0820E0816E0816E0811E08
  431      20E0720E0720E0720E0720E0720E0720E0720E0720E0720E0720E0720E07
  432      10E0910E0913.0013.0013.0020E0720E0720E0740E0913.0013.0013E10
  433      20E0720E0720E0720E0720E0720E0720E0720E0720E0710E0720E0720E07
  434      24E0825E0826E0827E0828E0851E0851E0851E0830E0830E0828E0827E08
  435      80E0680E0680E0680E0680E0680E0680E0680E0680E0680E0680E0680E06
  436      17E0817E0816E0816E0815E0815E0815E0815E0815E0814E0815E0816E08
  437      25E0826E0827E0828E0829E0829E0830E0830E0831E0831E0829E0828E08
  438      30E0130E0130E0130E0130E0130E0130E0130E0130E0130E0130E0130E01
  439      20E0720E0720E0720E0720E0720E0720E0720E0720E0720E0720E0720E07
  440      60E0760E0760E0760E0760E0760E0760E0760E0760E0760E0760E0760E07
  441      20E0720E0720E0720E0720E0720E0720E0720E0720E0720E0720E0720E07
  442      20E0720E0720E0720E0720E0720E0720E0720E0720E0720E0720E0720E07
  443      10E0710E0710E0710E0710E0710E0710E0710E0710E0710E0710E0710E07
  444      20E0720E0720E0720E0720E0720E0720E0720E0720E0720E0720E0720E07
  445      63E0663E0663E0663E0663E0663E0663E0663E0663E0663E0663E0663E06
  446      11E0811E0811E0811E0810E0810E0810E0810E0810E0810E0810E0811E08
  447      30E0730E0730E0730E0730E0730E0730E0730E0730E0730E0730E0730E07
  448      40E0140E0140E0140E0140E0140E0140E0140E0140E0140E0140E0140E01
  449      20E0720E0720E0720E0720E0720E0720E0720E0720E0720E0720E0720E07
  451   48900.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.00
  END MON-ACCUM
```

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  MON-SQOLIM
*** <PLS >  Value at start of month for limiting storage of QUALOF (lb/ac)
*** x-  x JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  390     54E0860E0810E0918E0918E0930E0930E0930E0918E0910E0966E0854E08
  391     19E0719E0719E0738E0738E0738E0738E0738E0738E0719E0719E0719E07
  392     21E0760E0736E0860E0815E0815E0815E0815E0836E0818E0812E0821E07
  393     12E0818E0824E0836E0836E0836E0830E0830E0830E0818E0812E0818E08
  394     60E0878E0814E0927E0911E0921E0921E0921E0927E0911E0972E0860E08
  395     72E0672E0672E0614E0714E0714E0714E0714E0714E0772E0672E0672E06
  396     60E0854E0881E0810E0910E0996E0896E0896E0896E0872E0848E0854E08
  397     60E0878E0814E0927E0915E0914E0914E0914E0911E0911E0972E0860E08
  398     24E0224E0236E0260E0260E0260E0260E0260E0260E0236E0224E0224E02
  399     60E0760E0760E0715E0815E0815E0815E0815E0815E0860E0760E0760E07
  400     60E0866E0810E0915E0915E0925E0925E0925E0915E0910E0966E0860E08
  401     21E0721E0721E0742E0742E0742E0742E0742E0742E0721E0721E0721E07
  402     30E0712E0854E0875E0830E0830E0830E0830E0854E0827E0818E0830E07
  403     18E0827E0836E0854E0836E0836E0830E0830E0830E0818E0812E0827E08
  404     48E0866E0812E0923E0990E0818E0918E0918E0923E0999E0860E0848E08
  405     00.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.00
  406     60E0860E0890E0810E0910E0910E0996E0896E0896E0872E0848E0854E08
  407     60E0872E0814E0927E0914E0914E0914E0914E0911E0911E0972E0860E08
  408     12E0212E0218E0230E0230E0230E0230E0230E0230E0218E0212E0212E02
  409     12E0812E0812E0830E0830E0830E0830E0830E0830E0812E0812E0812E08
  410     42E0848E0872E0896E0896E0814E0914E0914E0996E0872E0848E0842E08
  411     38E0738E0738E0776E0776E0776E0776E0776E0776E0738E0738E0738E07
  412     90E0718E0827E0845E0845E0845E0845E0845E0854E0827E0818E0890E07
  413     24E0836E0836E0854E0854E0854E0845E0845E0845E0827E0818E0827E08
  414     24E0830E0845E0890E0845E0890E0890E0890E0810E0945E0824E0824E08
  415     36E0636E0636E0672E0672E0672E0672E0672E0672E0636E0636E0636E06
  416     42E0842E0863E0884E0872E0872E0872E0872E0872E0854E0836E0842E08
  417     24E0824E0836E0872E0848E0848E0848E0848E0836E0836E0824E0824E08
  418     48E0248E0272E0212E0312E0312E0312E0312E0312E0372E0248E0248E02
  419     12E0812E0812E0830E0830E0830E0830E0830E0830E0812E0812E0812E08
  420     10E0911E0918E0928E0928E0945E0945E0945E0928E0918E0911E0910E09
  421     10E0810E0810E0820E0820E0820E0820E0820E0820E0810E0810E0810E08
  422     50E0740E0824E0932E0910E0910E0910E0910E0921E0910E0970E0850E07
  423     30E0845E0860E0890E0890E0890E0875E0875E0875E0845E0830E0845E08
  424     11E0915E0939E0972E0922E0945E0945E0945E0963E0927E0916E0911E09
  425     31E0731E0731E0762E0762E0762E0762E0762E0762E0731E0731E0731E07
  426     11E0910E0915E0920E0918E0918E0918E0918E0918E0913E0990E0810E09
  427     90E0814E0937E0966E0926E0926E0926E0926E0924E0924E0915E0990E08
  428     90E0290E0213E0322E0322E0322E0322E0322E0322E0313E0390E0290E02
  429     20E0820E0820E0850E0850E0850E0850E0850E0850E0820E0820E0820E08
  430     11E0911E0924E0940E0940E0975E0975E0975E0940E0924E0916E0911E09
  431     20E0820E0820E0840E0840E0840E0840E0840E0840E0820E0820E0820E08
  432     50E0910E1019E0132E0132E0150E0850E0850E0812E1119E0113E0165E10
  433     20E0830E0840E0860E0860E0860E0850E0850E0850E0815E0820E0830E08
  434     24E0925E0939E0981E0942E0915E1015E1015E1010E1045E0928E0927E09
  435     80E0780E0780E0716E0816E0816E0816E0816E0816E0880E0780E0780E07
  436     17E0917E0924E0932E0930E0930E0930E0930E0930E0921E0915E0916E09
  437     25E0926E0940E0984E0958E0958E0960E0960E0946E0946E0929E0928E09
  438     30E0230E0245E0275E0275E0275E0275E0275E0275E0245E0230E0230E02
  439     20E0820E0820E0850E0850E0850E0850E0850E0850E0820E0820E0820E08
  440     60E0860E0890E0812E0912E0918E0918E0918E0912E0990E0860E0860E08
  441     20E0820E0820E0840E0840E0840E0840E0840E0840E0820E0820E0820E08
  442     10E0820E0830E0850E0850E0850E0850E0850E0860E0830E0820E0810E08
  443     10E0815E0820E0830E0830E0830E0825E0825E0825E0815E0810E0815E08
  444     20E0820E0830E0860E0830E0860E0860E0860E0870E0830E0820E0820E08
  445     63E0763E0763E0712E0812E0812E0812E0812E0812E0863E0763E0763E07
  446     11E0911E0916E0922E0920E0920E0920E0920E0920E0915E0910E0911E09
  447     30E0830E0845E0890E0860E0860E0860E0860E0845E0845E0830E0830E08
  448     40E0240E0260E0210E0310E0310E0310E0310E0310E0360E0240E0240E02
  449     20E0820E0820E0850E0850E0850E0850E0850E0850E0820E0820E0820E08
  451  48900.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.00
  END MON-SQOLIM

  MON-IFLW-CONC
*** <PLS >  Conc of QUAL in interflow outflow for each month (qty/ft3)
*** x-  x JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  390     63E0470E0484E0484E0484E0484E0484E0484E0484E0484E0477E0463E04
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  391     22E0322E0322E0344E0344E0344E0344E0344E0344E0322E0322E0322E03
  392     24E0370E0342E0470E0417E0417E0417E0417E0442E0421E0414E0424E03
  393     14E0421E0428E0442E0442E0442E0435E0435E0435E0421E0414E0421E04
  394     70E0484E0484E0484E0484E0484E0484E0484E0484E0484E0484E0470E04
  395     84E0284E0284E0216E0316E0316E0316E0316E0316E0384E0284E0284E02
  396     70E0463E0484E0484E0484E0484E0484E0484E0484E0484E0456E0463E04
  397     70E0484E0484E0484E0484E0484E0484E0484E0484E0484E0484E0470E04
  398     00.2800.2800.4200.7000.7000.7000.7000.7000.7000.4200.2800.28
  399     70E0370E0370E0317E0417E0417E0417E0417E0417E0470E0370E0370E03
  400     70E0477E0484E0484E0484E0484E0484E0484E0484E0484E0477E0470E04
  401     24E0324E0324E0349E0349E0349E0349E0349E0349E0324E0324E0324E03
  402     35E0314E0463E0484E0435E0435E0435E0435E0463E0431E0421E0435E03
  403     21E0431E0442E0463E0442E0442E0435E0435E0435E0421E0414E0431E04
  404     56E0477E0484E0484E0484E0484E0484E0484E0484E0484E0470E0456E04
  405     00.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.00
  406     70E0470E0484E0484E0484E0484E0484E0484E0484E0484E0456E0463E04
  407     70E0484E0484E0484E0484E0484E0484E0484E0484E0484E0484E0470E04
  408     00.1400.1400.2100.3500.3500.3500.3500.3500.3500.2100.1400.14
  409     14E0414E0414E0435E0435E0435E0435E0435E0435E0414E0414E0414E04
  410     49E0456E0484E0484E0484E0484E0484E0484E0484E0484E0456E0449E04
  411     44E0344E0344E0389E0389E0389E0389E0389E0389E0344E0344E0344E03
  412     10E0421E0431E0452E0452E0452E0452E0452E0463E0431E0421E0410E04
  413     28E0442E0442E0463E0463E0463E0452E0452E0452E0431E0421E0431E04
  414     28E0435E0452E0484E0452E0484E0484E0484E0484E0452E0428E0428E04
  415     42E0242E0242E0284E0284E0284E0284E0284E0284E0242E0242E0242E02
  416     49E0449E0473E0484E0484E0484E0484E0484E0484E0463E0442E0449E04
  417     28E0428E0442E0484E0456E0456E0456E0456E0442E0442E0428E0428E04
  418     00.5600.5600.8401.4001.4001.4001.4001.4001.4000.8400.5600.56
  419     14E0414E0414E0435E0435E0435E0435E0435E0435E0414E0414E0414E04
  420     84E0484E0484E0484E0484E0484E0484E0484E0484E0484E0484E0484E04
  421     11E0411E0411E0423E0423E0423E0423E0423E0423E0411E0411E0411E04
  422     58E0346E0484E0484E0484E0484E0484E0484E0484E0484E0481E0458E03
  423     35E0452E0470E0484E0484E0484E0484E0484E0484E0452E0435E0452E04
  424     84E0484E0484E0484E0484E0484E0484E0484E0484E0484E0484E0484E04
  425     36E0336E0336E0372E0372E0372E0372E0372E0372E0336E0336E0336E03
  426     84E0484E0484E0484E0484E0484E0484E0484E0484E0484E0484E0484E04
  427     84E0484E0484E0484E0484E0484E0484E0484E0484E0484E0484E0484E04
  428     01.0501.0501.5802.6302.6302.6302.6302.6302.6301.5801.0501.05
  429     23E0423E0423E0458E0458E0458E0458E0458E0458E0423E0423E0423E04
  430     84E0484E0484E0484E0484E0484E0484E0484E0484E0484E0484E0484E04
  431     23E0423E0423E0446E0446E0446E0446E0446E0446E0423E0423E0423E04
  432     84E0484E0400.0200.0400.0458E0458E0458E0484E0400.0200.0284E04
  433     23E0435E0446E0470E0470E0470E0458E0458E0458E0417E0423E0435E04
  434     84E0484E0484E0484E0484E0484E0484E0484E0484E0484E0484E0484E04
  435     93E0393E0393E0318E0418E0418E0418E0418E0418E0493E0393E0393E03
  436     84E0484E0484E0484E0484E0484E0484E0484E0484E0484E0484E0484E04
  437     84E0484E0484E0484E0484E0484E0484E0484E0484E0484E0484E0484E04
  438     00.3500.3500.5300.8800.8800.8800.8800.8800.8800.5300.3500.35
  439     23E0423E0423E0458E0458E0458E0458E0458E0458E0423E0423E0423E04
  440     70E0470E0484E0484E0484E0484E0484E0484E0484E0484E0470E0470E04
  441     23E0423E0423E0446E0446E0446E0446E0446E0446E0423E0423E0423E04
  442     11E0423E0435E0458E0458E0458E0458E0458E0470E0435E0423E0411E04
  443     11E0417E0423E0435E0435E0435E0429E0429E0429E0417E0411E0417E04
  444     23E0423E0435E0470E0435E0470E0470E0470E0481E0435E0423E0423E04
  445     73E0373E0373E0314E0414E0414E0414E0414E0414E0473E0373E0373E03
  446     84E0484E0484E0484E0484E0484E0484E0484E0484E0484E0484E0484E04
  447     35E0435E0452E0484E0470E0470E0470E0470E0452E0452E0435E0435E04
  448     00.4700.4700.7001.1701.1701.1701.1701.1701.1700.7000.4700.47
  449     23E0423E0423E0458E0458E0458E0458E0458E0458E0423E0423E0423E04
  451  48900.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.00
  END MON-IFLW-CONC

END PERLND

IMPLND
  ACTIVITY
*** <ILS >               Active Sections
*** x -  x ATMP SNOW IWAT  SLD  IWG IQAL
  391  486    0    0    1    0    0    1
  END ACTIVITY
```

```
  PRINT-INFO
*** <ILS > ******** Print-flags ******** PIVL  PYR
*** x -  x ATMP SNOW IWAT  SLD  IWG IQAL *********
  391  486    4    4    4    4    4    4    1    9
  END PRINT-INFO

  GEN-INFO
***             Name             Unit-systems   Printer BinaryOut
*** <ILS >                           t-series Engl Metr Engl Metr
*** x -  x                            in  out
  391     39_Commercial and Se         1    1    0    0    0    0
  396     39_Residential               1    1    0    0    0    0
  401     40_Commercial and Se         1    1    0    0    0    0
  406     40_Residential               1    1    0    0    0    0
  411     41_Commercial and Se         1    1    0    0    0    0
  416     41_Residential               1    1    0    0    0    0
  421     42_Commercial and Se         1    1    0    0    0    0
  426     42_Residential               1    1    0    0    0    0
  431     43_Commercial and Se         1    1    0    0    0    0
  436     43_Residential               1    1    0    0    0    0
  441     44_Commercial an             1    1    0    0    0    0
  446     44_Residential               1    1    0    0    0    0
  451     45_Commercial an             1    1    0    0    0    0
  456     45_Residential               1    1    0    0    0    0
  461     46_Commercial an             1    1    0    0    0    0
  466     46_Residential               1    1    0    0    0    0
  471     47_Commercial an             1    1    0    0    0    0
  476     47_Residential               1    1    0    0    0    0
  481     48_Commercial an             1    1    0    0    0    0
  486     48_Residential               1    1    0    0    0    0
  END GEN-INFO

  IWAT-PARM1
*** <ILS >       Flags
*** x -  x CSNO RTOP  VRS  VNN RTLI
  391  486    0    0    0    0    0
  END IWAT-PARM1

  IWAT-PARM2
*** <ILS >      LSUR     SLSUR      NSUR     RETSC
*** x -  x      (ft)                          (in)
  391           200.    0.1162      0.05       0.1
  396           200.    0.1161      0.05       0.1
  401           250.    0.0847      0.05       0.1
  406           250.    0.0845      0.05       0.1
  411           200.    0.1384      0.05       0.1
  416           200.    0.1383      0.05       0.1
  421           300.    0.0627      0.05       0.1
  426           300.    0.0628      0.05       0.1
  431           150.    0.1736      0.05       0.1
  436           150.    0.1735      0.05       0.1
  441           200.    0.1282      0.05       0.1
  446           200.    0.1281      0.05       0.1
  451           200.    0.1163      0.05       0.1
  456           200.    0.1164      0.05       0.1
  461           250.    0.0986      0.05       0.1
  466           250.    0.0987      0.05       0.1
  471           150.    0.2381      0.05       0.1
  476           150.    0.2383      0.05       0.1
  481           200.    0.1357      0.05       0.1
  486           200.    0.1356      0.05       0.1
  END IWAT-PARM2

  IWAT-PARM3
*** <ILS >    PETMAX    PETMIN
*** x -  x   (deg F)   (deg F)
  391  486       40.       35.
  END IWAT-PARM3

  IWAT-STATE1
*** <ILS >  IWATER state variables (inches)
```

```
*** x -  x       RETS      SURS
  391  486      0.01      0.01
  END IWAT-STATE1

  NQUALS
*** <ILS >
*** x -  xNQUAL
  391         1
  396         1
  401         1
  406         1
  411         1
  416         1
  421         1
  426         1
  431         1
  436         1
  441         1
  446         1
  451         1
  456         1
  461         1
  466         1
  471         1
  476         1
  481         1
  486         1
  END NQUALS

  QUAL-PROPS
*** <ILS >    Identifiers and Flags
*** x -  x      QUALID    QTID  QSD VPFW  QSO  VQO
  391  486FECAL COLIFO       #    0    0    1    1
  END QUAL-PROPS

  QUAL-INPUT
***         Storage on surface and nonseasonal parameters
***            SQO   POTFW   ACQOP  SQOLIM   WSQOP
*** <ILS >  qty/ac qty/ton    qty/  qty/ac   in/hr
*** x -  x                  ac.day
  391           0.      0.      0.0.000001     0.8
  396           0.      0.      0.0.000001       1
  401           0.      0.      0.0.000001     0.8
  406           0.      0.      0.0.000001       1
  411           0.      0.      0.0.000001     0.8
  416           0.      0.      0.0.000001       1
  421           0.      0.      0.0.000001     0.8
  426           0.      0.      0.0.000001       1
  431           0.      0.      0.0.000001     0.8
  436           0.      0.      0.0.000001       1
  441           0.      0.      0.0.000001     0.8
  446           0.      0.      0.0.000001       1
  451           0.      0.      0.0.000001     0.8
  456           0.      0.      0.0.000001       1
  461           0.      0.      0.0.000001     0.8
  466           0.      0.      0.0.000001       1
  471           0.      0.      0.0.000001     0.8
  476           0.      0.      0.0.000001       1
  481           0.      0.      0.0.000001     0.8
  486           0.      0.      0.0.000001       1
  END QUAL-INPUT

  MON-ACCUM
*** <ILS >  Value at start of each month for accum rate of QUALOF (lb/ac.day)
*** x-  x JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  391     20E0520E0520E0520E0520E0520E0520E0520E0520E0520E0520E0520E05
  396     69E0668E0665E0664E0662E0661E0658E0658E0658E0657E0658E0664E06
  401     20E0520E0520E0520E0520E0520E0520E0520E0520E0520E0520E0520E05
  406     74E0672E0669E0667E0665E0663E0659E0659E0659E0657E0659E0667E06
  411     40E0540E0540E0540E0540E0540E0540E0540E0540E0540E0540E0540E05
  416     51E0650E0648E0647E0646E0645E0643E0643E0643E0642E0643E0647E06
```

```
  421     70E0570E0570E0570E0570E0570E0570E0570E0570E0570E0570E0570E05
  426     76E0675E0671E0670E0668E0667E0663E0663E0663E0662E0663E0670E06
  431     11E0611E0611E0611E0611E0611E0611E0611E0611E0611E0611E0611E06
  436     10E0710E0710E0710E0710E0710E0710E0710E0710E0710E0710E0710E07
  441     11E0611E0611E0611E0611E0611E0611E0611E0611E0611E0611E0611E06
  446     82E0681E0678E0676E0675E0673E0670E0670E0670E0669E0670E0676E06
  451  48648E0100.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.00
  END MON-ACCUM

  MON-SQOLIM
*** <ILS >  Value at start of month for limiting storage of QUALOF (lb/ac)
*** x-  x JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
  391     12E0612E0612E0612E0612E0612E0612E0612E0612E0612E0612E0612E06
  396     41E0740E0739E0738E0737E0736E0734E0734E0734E0734E0734E0738E07
  401     12E0612E0612E0612E0612E0612E0612E0612E0612E0612E0612E0612E06
  406     44E0743E0741E0740E0739E0737E0735E0735E0735E0734E0735E0740E07
  411     24E0624E0624E0624E0624E0624E0624E0624E0624E0624E0624E0624E06
  416     30E0730E0728E0728E0727E0727E0725E0725E0725E0725E0725E0728E07
  421     70E0670E0670E0670E0670E0670E0670E0670E0670E0670E0670E0670E06
  426     76E0775E0771E0770E0768E0767E0763E0763E0763E0762E0763E0770E07
  431     11E0711E0711E0711E0711E0711E0711E0711E0711E0711E0711E0711E07
  436     10E0810E0810E0810E0810E0810E0810E0810E0810E0810E0810E0810E08
  441     11E0711E0711E0711E0711E0711E0711E0711E0711E0711E0711E0711E07
  446     82E0781E0778E0776E0775E0773E0770E0770E0770E0769E0770E0776E07
  451  48600.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.0000.00
  END MON-SQOLIM


END IMPLND
```

APPENDIX G

FUTURE HUMAN POPULATION GROWTH TMDL

Table G.1 Average annual loads (cfu/year) modeled after TMDL allocation in the Upper Middle River, Moffett Creek, Lewis Creek, Polecat Draft, and Lower Middle River watersheds with permitted point source loads increased five times.

Impairment		WLA (cfu/year)	LA (cfu/year)	MOS	TMDL (cfu/year)
Upper Middle River		4.27E+10	3.33E+13		3.34E+13
	VA0060917	*2.52E+10*			
	VAG401064	*8.70E+09*			
	VAG401359	*8.70E+09*			
Moffett Creek		0.0	5.39E+12		5.39E+12
		0.0			
Lewis Creek		1.74E+10	6.91E+12		6.93E+12
	VAG401072	*8.70E+09*			
	VAG401882	*8.70E+09*			
Polecat Draft		0.0	2.56E+12		2.56E+12
		0.0			
Lower Middle River		6.11E+13	6.53E+13	Implicit	1.26E+14
	VA0002194	*1.65E+11*			
	VA0022322	*1.31E+12*			
	VA0062481	*3.05E+11*			
	VA0064793	*5.92E+13*			
	VA0084212	*2.61E+10*			
	VA0089419	*3.05E+10*			
	VAG401312	*8.70E+09*			
	VAG401498	*8.70E+09*			
	VAG401664	*8.70E+09*			
	VAG401915	*8.70E+09*			
South River		5.31E+11	2.04E+13		2.09E+13
	VA0023400	*5.22E+11*			
	VAG401981	*8.70E+09*			